Hu-m-an™

Human Movement Analysis

A computer environment for 2D and 3D, interactive, video-based analysis of human motion, and a platform for teaching or learning movement biomechanics.

HU-M-AN GUIDE
TO
PRACTICE EXERCISES
AND
EXAMPLE LABAORATORIES

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Preface to Hu-m-an Guide to Practice Exercises and Example Laboratories

The **Hu-m-an Environment** includes **Demonstrations**, **Practice Exercises**, and **Example Laboratories**. For both **Practice Exercises** and **Example Laboratories**, it is often more efficient to work from a printed copy rather than the on-screen instruction panels. Due to the complex nature of interactive human movement analysis, computer video display space is at a premium and convenient on-screen instructions can interfere with important program components.

The **Hu-m-an Guide to Practice Exercises and Example Laboratories** includes exact replicas of the on-screen instruction panels. When using the printed copy of instructions, simply close the on-screen panels. If necessary, the on-screen panels can be re-displayed using the **[Help][Exercise Help]** main menu option.

NOTE THAT YOU ARE FREE TO REPRODUCE AND DISTRIBUTE COPIES OF THE PRACTICE EXERCISES AND EXAMPLE LABORATORIES TO STUDENTS AS NECESSARY.

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Introduction

The **Example Laboratories** are intended to present a sample of the possible form that undergraduate laboratories might take. The **Demonstrations**, and **Practice exercises** can also be structured as laboratory assignments for both introductory and advance classes.

The main goal of the **Hu-m-an** software is to provide a platform for the creation of original laboratories. In its simplest form written instructions can provide the specific direction for virtually any type of laboratory experience.

Example of Laboratory Structure for an Introductory Course

The following 3 pages are an illustration of how the laboratory portion of a course might be structured. It is provided only as an example. It is recommended that at scheduled times, a laboratory instructor should be available for help.

LABORATORIES IN BIOMECHANICS

The laboratories for **Introduction to the Biomechanics of Human Movement** are presented entirely in computer format. Requirements include completing **Demonstrations**, **Laboratories** and a **Practice Exercise**. **Demonstrations** illustrate how the **Hu-m-an** program functions, the **Practice Exercise** reviews basic operations while the **Laboratories** cover applied biomechanics theory relevant to the course.

The laboratory portion of the biomechanics course consists of completing seven **Demonstrations**, one **Practice Exercise** and ten **Laboratories** (two groups of five).

SPECIFIC LABORATORY REQUIREMENTS

Laboratory Notebook

Each laboratory lists specific output (following a 'Notebook:' heading), which is to be completed, collated and stapled to form a **Laboratory Notebook**. A cover page and front page for each laboratory should be included as provided.

The completed **Laboratory Notebook** will be evaluated out of XX marks. The marks will be based on presentation, accuracy and completeness. Note that for laboratories including a "Quiz" (Centre of Gravity, Kinematic and Kinetic labs) accuracy is NOT based on correctly answering the questions on the first attempt! The completed notebook with all ten laboratories will be submitted at the second class laboratory exam.

LABORATORY SCHEDULE

The ten laboratories are divided into two groups of five (**PART I** and **PART II**). After the completion of each group of five laboratories, there is both a "hands on" laboratory computer based exam, and a classroom laboratory theory exam.

PART I Teaching week 1 to week 6 - First Five Laboratories

An **Orientation** to successfully executing the laboratories will be provided during the first week of class lectures. A suggested completion date is indicated for each laboratory although they can be completed on a faster schedule.

Complete (in order);

1. Introduction to Demonstrations (Demonstration)
   - shows how to use Demonstrations
2. Hu-m-an Overview Part I (Demonstration)
   - an initial look at what the 'Hu-m-an' program does (covers more than required for the course.)
3. Introduction to List Exercises
   - describes how Practice Exercises and Laboratories are different from Demonstrations.
4. **Projectile Analysis (Laboratory - week 1)**

5. Instant Calculation (Demonstration)
6. **Instant Calculation (Laboratory - week 2)**

7. **Centre of Gravity (Laboratory - week 3)**

8 Viewing Analyzed Data (Demonstration)
9. Just Starting (Practice Exercise)
10. **Kinematic Quiz (Laboratory - week 4)**

11. Frame by Frame Digitizing (Demonstration)
12. Analysis Using Macros (Demonstration)
13. **Gait Analysis (Laboratory - week 5)**

Teaching week 6

laboratory theory test

PART II Teaching week 7 to week 12 - Second Five Laboratories

Complete:

1. **Vertical Jump Analysis (Laboratory - week 7)**

2. **Kinetic Quiz (Laboratory - week 8)**

3. Conservation of Angular Momentum (Laboratory - week 9)

4. Analysis of Lifting (Laboratory - week 10)

5. Starting Original Calculations (Demonstration)
6. Original Kinematic Analysis (Laboratory - week 11)

Teaching week 12

laboratory test

To activate the Demonstration, Practice Exercise and Laboratory entry window:
Double click the “Allstart” or “Ehuman” icon on the desktop. (Desktop icon will need to be manually installed by the laboratory directory if it is not present.)

Starting Suggestions:
1. When executing the **Laboratories** you can either follow the on-screen instruction panels or read from the hard copy laboratory manual. Both are identical. If you wish to read from the provided printed copy, simply '**close**' the on-screen instruction panel at the beginning of the laboratory.

2. It is important to be reasonably efficient at moving, down sizing and recovering windows. This is particularly the case if you have lower resolution screen display (e.g. 640 x 480 pixels). It is necessary for the **Hu-m-an** program to simultaneously display many windows and this works far more effectively on higher resolution screens.

3. Always try to understand how and why the information is presented in a particular fashion. The **Hu-m-an** program is simply a tool for biomechanically analyzing motion. For knowledgeable users much of the **Hu-m-an** program operation is intuitive.

TABLE OF CONTENTS

PRACTICE EXERCISES

CONTENTS **Page**

PRACTICE EXERCISES

NOTE: 12-19 have been reserved for expansion of the **Practice Exercise** section

EXAMPLE LABORATORIES

The printed copies of the **Practice Exercises** included in this manual are exact copies of the on-screen instruction panels. Solid bar horizontal lines separate the individual instruction panels. The **Forward** and **Back** underlined words are hypertext, accessed only when used on-screen.

1 . INTRODUCTION TO PRACTICE EXERCISES

HU-M-AN

Forward

Introduction to Practice Exercises

Practice Exercises are significantly different from **Demonstrations,** in that they provide instructions **only**, and program execution is left entirely to the user.

(Note that the right side scroll bars can be used to display parts of this instruction panel, if they are not shown.)

To execute a **Practice Exercise** simply click on the desired exercise and then follow the instruction panels presented. Many help screens require that the scroll bars be used in order that all the information can be read. It is often helpful to maximize the window for easier reading, or to move or minimize the window for better viewing.

In some cases it may be easier to work from a printed copy of the instructions and close the **Instruction Window.** A 'PDF' format file of the Laboratories and Practice Exercises is available from the web-page http://www.hma-tech.com/???

There are two additional menu items under the **[Help]** main menu item of the **Hu-m-an** program. The **[Exercise Help]** item re-displays the current exercise instruction window, if it has been closed, and the **[Options]** item allows for changes in the **Instruction Window** font size.

When using the Practice Exercise instruction panels, occasionally palette sharing will cause problems with the coloring of the video window. An easy correction is made by clicking the left hand mouse button, while the mouse arrow is over the video window.

For a brief review on elements related to manipulating windows see **REVIEW OF `WINDOWS` FUNCTIONS**

Click **[Forward]** for next panel. **Forward**

HU-M-AN

Return

REVIEW OF SELECTED WINDOW FUNCTIONS (Accessed through hypertext)

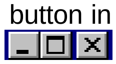
The instruction window can be manipulated in a number of ways:

Forward **Back** (These are not active.)

[Forward] and **[Back]** hypertext are placed at the beginning and at the end of each page and control the display of the next or previous instruction panel, respectively.

It is particularly important to know how to maximize, minimize and normalize the instruction window, while executing exercises and laboratories. This is very helpful to enable the user to better view the entire screen, as necessary.

Starting with a Normal Sized Instruction Window.

If the instruction window is of normal size, then it can be maximized (full screen) by using the center **square page** button in the top right corner, or minimized by using the **single bar** button in the top right corner.  The window can also be re-sized by placing the cursor over the wide window borders and by clicking and dragging, as with normal window procedures.

Starting with a Maximized Instruction Window.

If the instruction window is maximized (full screen), then it can be reduced to normal size by using the center `**overlapping square**` button in the top right corner, or minimized by using the `**single bar**` button in the top right corner. 

Starting with a Minimized Instruction Window.

If the Instruction Window has been minimized, then it can be returned to the current size by clicking the appropriate **bar button OR** clicking the **<Help><Exercise Help>** menu item.

Continue **[Forward]** for more information.

Return

HU-M-AN

Back

Exiting a Practice Exercise

At the end of a **Practice Exercise**, the user must activate the normal **Hu-m-an** program exiting procedures.

The **[File]** item is selected from the main menu bar and then followed by clicking the listed **[Exit]** menu item.

Note that, in order to access the **Hu-m-an** main menu bar items, when the help/instruction window is maximized, the window will need to be down-sized by using the top right window buttons.

THE INTRODUCTION TO PRACTICE EXERCISES IS NOW COMPLETE. AS DESCRIBED ABOVE, IN ORDER TO EXIT THE HU-M-AN PROGRAM, CLICK THE [FILE] MENU ITEM FROM THE MAIN MENU BAR AND THEN SELECT THE [EXIT] MENU ITEM.

Back

2 . JUST STARTING

HU-M-AN
Forward
Just Starting

Before starting, the following **Demonstrations** should have been completed:

- **Introduction to Demonstrations**
- **Hu-m-an Overview Part I**
- **Viewing Analyzed Data**

This **Practice Exercise** will illustrate some of the control functions important to successful use of the **Hu-m-an** program.

> Use the scroll bar on the side of this instruction panel, if all of the text is not visible.

Note: If the instruction panel is lost:

1. click **[Help][Exercise Help]** in the main menu bar, or
2. click the **[File][Exit]** in the main menu bar and then start again.

Click **[Forward]** for the next panel.

Forward

HU-M-AN
Forward **Back**

Read these entire instructions before proceeding.

If working from a printed copy of the instructions move directly to '2. Loading video data'.

1. Minimizing and then restoring the instruction panel.

> At times it is convenient to minimize the instruction panel for better viewing. For **Windows '95** this is done by single clicking on the small **[_]** box in the top right corner of this instruction panel (not the one in the corner of the whole screen), and for **Windows 3.1x** by clicking the single down arrow in the top right corner of the instruction panel.

> The instruction panel can be restored in **Windows '95** by clicking the **[Just Starting]** button found in the **Task Bar** (the same bar in which the Windows Start button is located), and for **Windows 3.1x** by double clicking the **Just Starting** icon at the bottom left of the screen (or by single clicking and choosing **[Restore]**).

> Try minimizing and then restoring this instruction panel at this time.

> The size of the instruction panel window can be changed by placing the mouse arrow over a side, top or bottom border (double arrows will appear), pressing and holding the mouse button and then "dragging" the window edge to a new size.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Now proceed with instructions as they are given.

2. Loading video data.

> Select and click the **[File][Load Trial]** item from the main menu bar. If the LOAD TRIAL window is partially hidden, place the arrow tip over the LOAD TRIAL title bar, then click and hold the left mouse button and "drag" the window to a new location.

> Use a single click to mark (highlight) the **jumpa.avi** file and then click the **[OK]** button. **Hu-m-an** will now load this video file.

> Click the **[>]** button in the **Video Model Control** (**VMC**) window to "play" the video.

> Click the **[R1]** button in the **VMC**. This "re-sets" the video to the beginning using values obtained at loading.

> Try the other VCR style controls **[>] [<] [|>][<|]**. When finished, click **[R1]**.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

3. Loading collected data.

> Select and click the **[File][Load Trial]** item from the main menu bar. Use a single click to mark (highlight) the **jumpa.ht1** file and then click the **[OK]** button. **Hu-m-an** will now load this collected data file. If this file has a record of a video, it will load that file at the same time, if not, it will look for a video with the same main name.

> Note that in the **VMC** window there are now three check boxes (**[Model]**, **[Video]** and **[+ Model]**) with the **[Video]** box checked. This means that only the video is ready to play.

> Click the **[Model]** check box. The model stick figure should appear. If it does not, or is not centered, click the **[C]** button in the **VMC** window. If it was not in the middle, this means that it was saved in that fashion. Since **Hu-m-an** must accommodate many screen sizes and resolutions, this is very likely. The **[R1]** and **[C]** button are often used to re-set and center the model.

> Try the VCR style controls **[>] [<] [|>][<|]** with various combinations of **[Model]**, **[Video]** and **[+ Model]**.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

4. Viewing different model displays.

> Click **[R1] and [C]** to reset video and model. Remove the check (if present) in the **[Video]** check box in the **VMC** window. Only **[Model]** should be checked.

> Play **[>]** the model. Now click **[R2.]**. **[R2]** simply re-sets the model to frame "zero" without changing other settings.

> Click the **[Cumulative]** check box in the **VMC** window and then play **[>].**

> Increase the "**Sep**" value from "0" to "2" in the **VMC** window by twice single clicking the small up arrow. Now play **[>]**. This "separates" each figure by two screen pixels.

> Increase the "**Inc**" value from "1" to "3" in the **VMC** window by twice clicking the small up arrow. Now play **[>].**

> Click **[R1]** and **[C]**. **[R1]** was used here to re-set all the changed values.

> Click **[S]** in the **VMC** window. This "stretches" cumulative figures maximally in the window.

> Increase the "**Inc**" value to "4" and click **[S]** again.

> Click **[R1]** and **[C]**.

> Display and choose "**Wrist**" from the **Overtrace** list in the **VMC** window. Click **[S]**.

> Click **[R1]** and **[C]**.

> The **[P]** button "picks" specified frames for drawing and will be covered at a later time.
Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

5. Viewing different graph displays.

Calculated or Graph Data were already prepared and loaded with the **jumpa.ht1** data file.

> If using on-screen instructions, click the mouse arrow over the title bar of this instruction panel (**Just Starting**) and while holding "drag" the instruction panel to the top left corner of the screen for a clear view of the **Graph** window.

> Click the **[Clear/Reset]** button in the **Graph Data Control** (**GDC**) window. This is to ensure a clean starting position.

> Click on the **C of G Y** entry in the **GDC** list. This displays the vertical motion of the center of gravity.

> Click under the maximum crouch portion of the graph. A 0.70 (using same graph color) appears at the top right of the window. This is the center of gravity position at this time. It is not necessary to click directly on the line. Note also that the Graph title bar lists the **C of G Y** name. Click the **[Clear/Reset]** button.

> Click the **Hip angle** entry from the **GDC** list. Click the **[Narrow]** "radio" button and then the **Knee angle** entry. Click the **[Dash**] "radio" button and then the **Ankle angle** entry.

> Re-click the **Hip angle** entry. Note that the title bar name changes. Now click under the

maximum flexion portion of this red plot. A red 65 or 66 should appear at the top right of the window. This is the hip angle at this instant.

> Re-click the **Knee angle** entry. Note that the title bar name changes. Now click under the maximum flexion portion of this green plot. A green 84 or 85 should appear at the top right of the window.

> Click the **[Clear/Reset]** button and the **[Wide]** "radio" button.

> Click the **[Two Vars.]** check box in the bottom right corner of the **GDC** window. Click the **Hip angle** and then the **Knee angle** entries. This is an "angle-angle" plot of the hip and knee. Re-click the **[Two Vars.]** check box (to clear) and then click the **[Clear/Reset]** button.

> Click the **Hip**, **Knee** and **Ankle angle** entries. Click the **[Run-time Graphs]** check box in the **GDC** window and the **[Model]** check box in the **VMC** window. If using on-screen instructions, move (click title bar and "drag") the instruction panel to the side, even partially off the screen, if necessary, so that the Model window is visible. Now click the play **[>]** button in the VMC window to see the model and graphs operate together.

> Re-click the **[Run-time Graphs]** check box and the **[Clear/Reset]** button.

> Experiment with other model, video and graph displays.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Back

6. Exiting the program.

Choose the **[File]** and then the **[Exit]** menu item.

Back

3 . EXPLORING THE VIDEO LIBRARY

HU-M-AN

Forward

Exploring the Video Library

The **Hu-m-an** program comes with a number of video and pre-collected and analyzed files. This practice exercise will look at a number of these files.

1. Selecting the first file.

> Click the **[File][Load Trial]** menu item. In this particular instance there are no files listed. The **Hu-m-an** program has a master video and data storage area on the CD or Server. Click the **[CD/Server Data Area]** button in the **Load Trial** window to move to this location.

> This main area lists sub-directories for the main categories available. Click and, therefore, mark (highlight) the **[jumps]** sub-directory and then click **[Change Path].** This moves the user into the jumps area. Listed now are all the subject data sub-directories.

> Now click to mark the **[jumpa]** sub-directory and re-click **[Change Path].** This now shows the video and data available for this subject. Select **jumpa.avi** and click **[OK]** to load this file. "Play" the video. The video will be recognized, as it is used in a number of demonstrations and practice exercises.

> Again click the **[File][Load Trial]** menu item. This time mark and load (with **[OK]**) the **jumpa.ht1** file. Note that there is also a **jump.ht0** file. Using **Hu-m-an** protocol, this is the original digitized data and is not further used for calculations. This means that if something happens to the other working data sets, the original digitizing is always available.

> Click **[R1]** and **[C]** to display the model. View and investigate the data if you wish.
> Click **[Forward]** for the next panel.

Forward

HU-M-AN

Forward Back

2. The Video List.

Hu-m-an provides a summary list of the videos available.

> Click the **[View][Video List]** menu item. The categories (**Dir.**) are listed, followed by the subjects and trials available for each category. Also a brief summary is provided, giving pertinent information for each subject and trial. Note that it also indicates that the scaling rod length for all video scaling pictures is 1.8 meters unless otherwise stated.

> Scroll down to the **lifts** category and view the **liftb** entry. This entry indicates that **liftb** is a female subject, that there are 35 frames, that the file size is 2.69 megabytes and that the skill is a simple lift with poor technique.

> To view this video, click **[Exit]** in the **[Video List]** window and then execute the following commands. Click **[File][Load Trial]**, then click **[CD/Server Data Area]**. Now mark the **[lifts]** sub-directory and then click **[Change Path]**. Do the same for the **[liftb]** sub-directory. Now mark **liftb.avi** and click **[OK]**. In the future, when asked to "load" a certain file, a similar

sequence should be followed.
Play **[>]** this video to display the simple lift.

Forward **Back**

HU-M-AN

Forward **Back**

3. More Videos.

> Click the **[View][Video List]** menu item. This time, scroll down to the **run** category and note the **runa** entry. This entry indicates that **runa** is a female subject, that there are 85 frames, that the file size is 6.53 megabytes and that the skill is treadmill running.

> To view this trial click **[Exit]** in the **[Video List]** and then follow previously described procedures to load the **runa.avi** trial. Remember that this file is located in the **[CD/Server Data Area]** and the **run/runa** sub-directory. If problems are encountered here, go **[Back]** and repeat **2. The Video List**.

> Play **[>]** the video to observe the entire running video.

> Re-click the **[View][Video List]** menu item. Scroll down to the **runa** entry. The **.ht0** and **.ht1** listings directly beneath this are data files taken from the **runa.avi** video. Note that they are both 30 frames long, with one being the source file and the other being a file that includes a panning/movement correction.

> Click **[Exit]** in the **[Video List]** window and then "load" the **runa.ht0** file.

> Click **[R1]** and **[C]** to display the model. **This model is of a single leg only.** View and investigate the data if you wish. Note that the model figure duplicates the treadmill style running. Note also that this trial is 30 frames even though the original video was 85 frames. For collection a **sub-sequence** was defined. This information is stored with the file and automatically activated, when loaded.

> Now "load" the **runa.ht1** file. Click **[R1]** and **[C]** to display the model. Play **[>]** the video and model. Note that the model has been corrected for treadmill running and now simulates normal ground running. The knee and ankle angle displacement patterns, that have been calculated, can also be viewed.

> Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

4. And even more Videos.

> Click the **[View][Video List]** menu item. This time, scroll down to the **run** category and note the **runreara** entry. This is a lower leg shot on the treadmill at 60 fps.

> To view this trial click **[Exit]** in the **[Video List]** and then follow previously described procedures to load the **runreara.avi** trial. If problems are encountered here, go **[Back]** and repeat **2. The Video List**.

> Play **[>]** the video to observe the entire running video.

> Click the **[Edit][Trial Set Up]** menu listing and then the **[Subject-Trial Data]** button. Note that in the bottom left corner of this window the time interval is correctly indicated as 0.016667 seconds. When original videos are captured, the sampling time interval should be checked since this provides the time base for all future calculations. If it is necessary to change the current sampling time displayed, before the first digitized data set is saved, the correct time interval should be entered and registered by clicking the **[Set time interval to:]** button. This will be saved with the data set and any future modification and, therefore, the time interval re-set does not need to be repeated.

> **[Exit]** both the **[Subject-Trial Data]** window and **[Trial Set Up]** window.
> Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

5. The Local Data Area.

The **CD/Server Data Area** is read only (unless the user has write authority on a server system) and, therefore, any new data cannot be saved in these directories and additions cannot be made to the **.avi** video files. **Hu-m-an** provides a "**Local Data Area**" for saving new files.

> Use the normal procedures and "load" the **jumpa.ht1** data from the **CD/Server Data Area**.

> Now click the **[File][Save as]** menu item and then click the **[Local Data Area]** button. The **Files** listing will now show a series of sub-directories **[user01]**, **[user02]**, etc.. These are empty directories and can be used for saving any data. They can also be re-named or new names can be added, using the **File Manager** in **Windows 3.1x** or the **Explorer** in **Windows 95.**

> Mark the **[user01]** sub-directory and then click **[Change Path]**. The "Path" listing near the top of the **Save As** window should read **?:\hu-m-an\data\user01** where ? refers to the letter of the local drive. If it does not, the steps will need to be retraced.

> If successful, then proceed. The **File Name** near the top of the **Save As** window should read **jumpa.ht1,** as this was the file loaded. If the original file load was an **.avi** file, then it would be a "generic" **jumpa.ht** name. Although this file could be saved under this name, for practice purposes, the name extension will be altered. Click the cursor over the "1" in **.ht1** and change it to a "2". Now click the **[Save]** button. If successful, then a "Save Successful" note will appear at the bottom of the window. If not successful, ensure that the path is **?:\hu-m-an\data\user01** and that the **File Name** is **jumpa.ht2.**

> Since this file is not needed, delete it. Mark the **jumpa.ht2** file in the **Files** list, and then click the **[Delete File]** button in the bottom left corner of the **[Save As]** window. When the **Caution** query window is displayed, click **[Yes].** Now **[Exit]** the **Save As** window.
> Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Back

6. Exploring the Video Library

This is the end of the **Exploring the Video Library** practice exercise. You can continue to view all of the available videos and data files. Of course the main objective of the **Hu-m-an** program is to capture and analyze one's own video!

Use normal procedures, **[File][Exit]** when leaving the program.

Back

4 . REVIEWING THE TRIAL SET UP

HU-M-AN

Forward

Reviewing the Trial Set Up

If subject digitizing is to be the base for biomechanical analysis, then a framework for processing must be established. The minimum requirement is to define the points to be collected. If it is preferred to view a superimposed line model during digitizing, then a display model must also be defined. Depending on the requirements for analysis, a more extensive framework may be necessary, although this can be provided post collection and can be modified at any time. In **Hu-m-an** the following components are included as part of the **Trial Set Up** framework.

1. **Collection Model**. Defines the points for collection.
2. **Display Models**. Identifies appropriate line figures.
3. **Relative Angle Table**. Defines relative angles needed for analysis. Optional, but provides convenient list for future relative angle calculations.
4. **Segment Data and Absolute Angle Table**. Defines the user provided segment anthropometric data and defines absolute angles.
5. **System Models**. These are defined collections of segments. For example, for some analyses one may need to calculate the center of gravity of an entire body or just one limb. These can be defined as separate "systems".
6. **Subject-Trial Data**. Special events, such as the take-off in jumping or the heel contact in walking, are called **critical points** in **Hu-m-an**. These are established as **Subject Trial Data**. Additional to include a line to represent the ground or re-define the time interval for sampling are also available through this window. Finally, personal subject or performance information can be recorded here.

These 6 components make up a **Trial Set Up** framework. A single established framework in **Hu-m-an** is known as a **Trial Set Up Title** and can be saved as a separate item, in order that it can be recalled for future use. Multiple **Trial Set Up Titles** are saved in a **Trial Set Up Template File** and there can be more than one **Trial Set Up Template File.** When collected data are saved, the **Trial Set Up** framework becomes part of the file. It can still be modified, as necessary, during future analysis.
Click **[Forward]** for the next panel.

Forward

HU-M-AN

Forward **Back**

1. Trial Set Up starting point.

> Click the **[Edit][Trial Set Up]** menu item. The **Trial Set Up** window is the access point for all components. Notice that there is a list of available pre-constructed **Trial Set Up Titles** (each containing the 6 components) taken from the current **Trial Set Up File,** and the title for this file listed at the bottom of the window. **Trial Set Up Template Files** have the extension .hg? (**Hu-m-an** global).

> Click the **[Collection Model Build/Edit]** button. This is typically a list of the points to be collected. As expected, there are no points listed. Click the **[Cancel - Exit]** button in this window.

> Click the **[Segment Data - Abs. Angle Table]** button. This table is also blank at this point. Click the **[Cancel - Exit]** button in this window.

> Scroll down to the bottom of the **List Trial of Set Up Titles**. Mark (highlight) the **3 Pt. Lower Limb** title and then click **[Load]**. A caution will indicate that on loading this title, the current framework will be replaced. Respond **[Yes]** to continue with loading.

> When an **.avi** file is loaded, **Hu-m-an** automatically loads an initial "default**" Trial Set Up Title**. This can be replaced entirely or modified by the user. Remember that all **.ht?** files already contain a **Trial Set Up** framework, which then replaces the existing listed framework, when loaded. It is to be noted that each title represents a separate framework.

When completed, click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

2. Looking at the 3 Pt. Lower Limb Trial Set Up Title.

> Click the **[Collection Model Build/Edit]** button. This is a 3 Point lower limb model with the three points being listed. Notice the *Mid Point" column of check boxes. It is possible to define a listed point as the "mid point" of two other listed points. For example, the top of the trunk could be defined as the middle of the left and right shoulder. This becomes a "virtual" point and, although listed, is not actually collected during the digitizing process. Click the **[Cancel - Exit]** button to exit this window.

> Click the **[Display Model Build/Edit]** button. "Drag" the window to a new location, if it is not visible. This window presents a table for constructing a stick figure using "connect the dot" lines. Up to ten separate "pieces" can be used to build the display model.

> Notice that this model has just one piece connecting points 1, 2 and 3. From the **Coordinate Points** list, it is seen that this piece connects the hip to the knee and then to the ankle. Place the mouse arrowhead over the "1" in the top left box and click the left mouse button. A straight line text cursor will appear in this box. Select and click a coordinate point from the list. The corresponding number will replace the present number and the cursor will then automatically move on to the next box. For practice click on the hip, then the knee, then the ankle, and then again, the knee and the hip. The list of numbers should now be 1 - 2 - 3 - 2 - 1. The **[Test]** button permits checking the model using collected points. It will not work at this point, as no data have been collected. More than one "display" model can be constructed and then activated, as required, through the **Video Model Control** window. Click the **[Cancel - Exit]** button to exit this window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

3. More Trial Set Up Title components.

> Click the **[Relative Angle Build/Edit]** button. One relative angle, the knee, has been defined in this table. Angles are, of course, defined from the previously defined collection points.

Program conventions for relative angles are discussed in detail in the **Reference Manual**. Basically, the angle is visualized counter-clockwise and then the two lines are identified starting with the angle vertex. In this case, that would be the knee, hip, knee and ankle.

> For practice click the **[Add at End]** button. Click over the "2' with the cursor and then replace the "2" with the name, "knee". Now click on the "Not Defined" listing under the **Segment-1 Vertex** column, changing it to "Select Coordinate". Now click on "Knee" from the **Coordinates** list. The focus then automatically changes to the next column. Click on "Hip" from the **Coordinates** list followed by "Knee" and "Ankle" to complete the table. This list of relative angles will appear in a "Pre-defined" angles list, when the **Relative Angle** window is accessed. Click the **[Cancel - Exit]** button to exit this window. A caution window indicating that changes have been made will appear. Respond **[Yes]** to exiting.

> Click the **[Segment Data - Abs. Angle Table]** button. This table defines the segment to be used in future analyses. At this point a thigh and shank segment have been entered.

> For practice, click the **[Add Segment at End]** button. Replace the "3" with the name "Shank". Click on the "Not Defined" in the "Proximal(Vertex)" column changing it to "Select Coordinate". Now click on "Knee" from the **Coordinates** list and then click on "Ankle". The knee has been defined as proximal, which is anatomically correct. The standardized data being entered are for this orientation.

> "Wi" refers to weight ratio, Rpi is the "ratio of segment length from the proximal end" and "Kg" is the radius of gyration with respect to the center of gravity. It is assumed that readers are familiar with these concepts based on their knowledge of biomechanics. Replace the 1.0 default values in these columns with 0.0465, 0.433 and 0.302 respectively. These values are taken from tables of standardized anthropometric data. Click the **[Cancel - Exit]** button to exit this window. A caution window indicating that changes have been made will appear. Respond **[Yes]** to exiting.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

4. Completing the Trial Set Up Title components.

> Click the **[System Models]** button. **The System Models** window shows that, at this point, no "systems" have been defined. If, as part of the analyses, the center of gravity of the thigh and shank combined (looking at the movement of the leg) are to be calculated, this "system" would be constructed at this time.

> For practice, click the **[Build New System Model]** button. Replace the **System No. 1** "default" title under **Current System Name** with the words "Lower Leg".

> To build the system, mark (highlight) **Thigh** in the **Segment Table** list and then click the **[Add to System Segments]** button. Do the same for the **Shank**. Remember that the **Thigh** and **Shank** listings come directly from the previously constructed **Segment Data,** which, in turn, were based on the defined **Collection Model**.

> Now click the **[Keep Changes and Exit]** button.

> Finally click the **[Subject - Trial Data]** button. "Drag" the window to a new location, if it is not visible. The only parts of the **Subject - Trial Data** that are saved as part of the **Trial Set Up Title** are the **Critical Points** and the subject weight. Remember that the **Trial Set Up** is saved with each data collection and, in that instance, all other **Subject - Trial Data** are also included. Review the information included in this window and, for additional information, refer to the **Hu-m-an Manual**.

> Click the **[Exit]** button in the **Subject - Trial Data** window..
Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

5. Using Trial Set Up Title and Template Files

When an original **.avi** file is loaded, **Hu-m-an** automatically loads an initial "default" **Trial Set Up Title**. A more suitable **Title** can be loaded at this point. Also any changes or modifications can also be incorporated. Modification can also be made at a later time. Deleting some entries can be cumbersome. For example, in our previous example, if for some reason a decision was made to delete the "ankle" as a collection point, then it would be necessary to first delete parts, related to the ankle collection point, in **the System Models, Segment Table, Relative Angle Table and Display Models** components!

A number of pre-constructed **Trial Set Up Titles** are available for use. If a modified or new title is constructed, then it can also be saved to the **Trial Set Up Title** list for use with future collections.

Up to this point virtually all of the **Demonstrations**, **Practice Exercises** and **Laboratories** have made use of **Trial Set Up Titles,** but mostly by "default" and in the background. They are, however, very important and are the engine for most analyses. Knowledge of the **Trial Set Up Titles** will guard against incorrect or inappropriate analysis.

It is good practice to investigate **Trial Set Up Titles** after loading an **.avi** video file. Since no **Trial Set Up** has been established, a “default” **Trial Set Up Title** is loaded with the video. Note that **.ht?** files already incorporate established **Trial Set Up** Components and, therefore, when investigating and reviewing **Trial Set Up Titles,** do not use a **.ht** file as a starting point.

At this point or at any time in the future, load any **.avi** file and then:

> investigate all components of the "default" **Trial Set Up.**

> load and investigate components of other available **Trial Set Up Titles.**

> read further about **Trial Set Up** in the **Hu-m-an Manual.**

After practicing with a file and then proceeding to load a second, a caution may appear warning that data have been changed and will question whether or not changes should be saved before proceeding. Because the changes are temporary and do not need to be saved to disk, the user would normally load or exit **without saving**.
Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Back

6. Concluding the Trial Set Up Title and Template File Review.

This concludes the review. To exit the program, first **[Exit]** the **Trial Set Up** window and then, as usual, click **[File][Exit]** menu item. If questioned, exit without saving changes.

Back

5 . DIGITIZING A NEW AVI FILE

HU-M-AN

Forward

Digitizing a New AVI File

(Note that if the instruction panel is ever lost, it can be re-displayed by clicking the [Help][Exercise Help] menu item).

The **Hu-m-an** program has many objectives:

1. To display video sequences for careful review.
2. To permit "Instant Calculation" for measures of interest.
   This is covered in both the **Instant Calculation Demonstration** and **the Instant Calculation Example Laboratory** in **List-2.**
3. As a basis for providing guided exercises and laboratories in biomechanics.
4. As a platform for original biomechanical analysis of human movement.

This **Practice Exercise** will guide the user through the process of beginning a simple original biomechanical analysis by creating a digitized data base from a source **.avi** file. **Since this is the essence of effective biomechanical analysis, the exercise will be presented in some detail.** If using on-screen instructions, it will also be useful to maximize this instruction panel for easier display and reading of some sections.

Before starting, the following **Demonstrations** should have been completed.

Introduction to Demonstrations
Hu-m-an Overview Part I
Viewing Analyzed Data
Instant Calculation
Frame by Frame Digitizing

In addition, the following **Practice Exercises** should have been completed.

Just Starting
Exploring the Video Library
Reviewing the Trial Set Up

Joint Center Marking.

It is good clinical practice to carefully mark joint centers to improve consistency and accuracy in digitizing. Skilled data collectors recognize, however, that for two dimensional analysis, surface markers only aid in identifying the true underlying joint center. The center of surface markers often do not fall directly over the true joint center, as a result of incorrect placement, shifting of clothing or surface tissue, and rotation of the limb or segment under investigation. Beginners can introduce error by incorrectly assuming that the markers are always accurate. The absence of joint centers in many of the videos provided in Hu-m-an is intentional, with the objective of providing practice in identifying joint centers as a basis for accurate portrayal of the underlying segment. During the digitizing process, the line drawn between collected points should accurately represent the segment in question. Videos with joint markings are also provided for other practice sessions. Biomechanical analysis is used for gaining insight into human movement and skill performance and, at this stage, each instructor and student will need to determine the importance and practicality of using joint center markings depending on the situation. For research purposes, joint center marking becomes a far more important issue.

Click **[Forward]** for the next panel.

Forward

HU-M-AN

Forward **Back**

1. Planning the Analysis.

Before starting, a clear idea of the desired end results of the analysis needs to be established. Modifications can be made at a later date but better planning makes for an efficient data collection. For this exercise the right leg during a single step in walking will be analyzed, similar to that illustrated in the Frame by Frame Digitizing Demonstrations. This time, however, the hip angle, as well as the knee and ankle angles will be included. In addition the center of gravity of the whole lower limb, in particular tracking its swing phase, will be analyzed.

To accomplish this eight points on the leg will be collected, using an **adaptation** of the markings identified by Vaughan, Davis and O'Connor in **Dynamics of Human Gait** (Champaign, Illinois: Human Kinetics Publishers, 1992).

1. mid-superior iliac spine (MSIS, located directly above and in line with the hip joint center in erect standing)
2. hip (greater trochanter)
3. knee (femoral epicondyle)
4. ankle lateral malleolus
5. toe (metatarsal head V)
6. tip toe at the bottom of the foot
7. under ball of the foot (under the toe marking at the bottom of the foot)
8. heel (at the back of the heel at the bottom of the foot)

With these markings the hip angle (points 1, 2 and 3), knee angle (points 2, 3 and 4) and ankle (between lines defined by points 3-4 and 8-7) can be determined. The points necessary to calculate the lower limb center of gravity are present and a good stick representation of the leg and foot can be drawn. See the **Selected Topics Manual** section on **Joint Centers** and study the figures below.

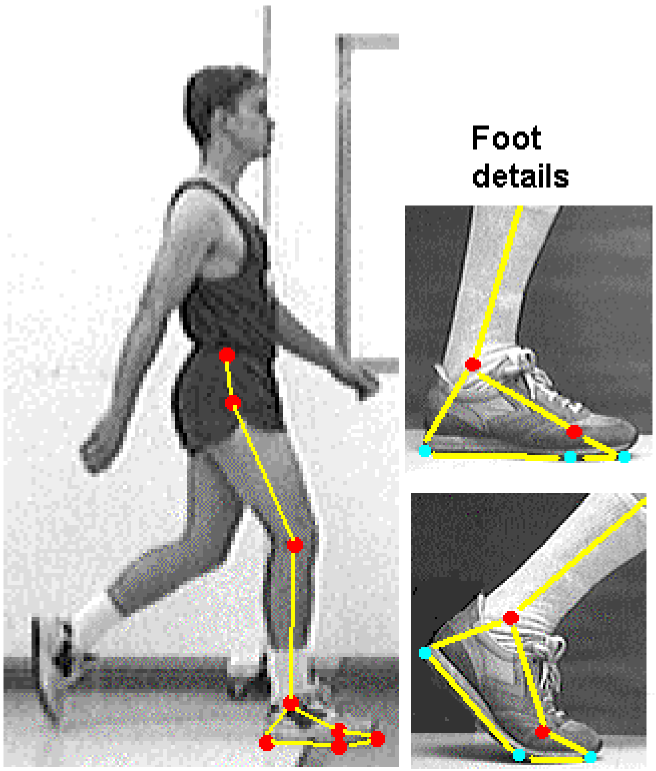


Figure 1
Collection Points

The video will need to be a sagittal view of a complete right leg walking cycle. The video capture system (the one used for the sample source video in this exercise) has been found to result in no distortion and, therefore, the aspect ratio is 1.00. A scaling rod in the plane of the walk must be captured in a separate **.avi** file and renamed with a **.sca** extension. For this particular trial, the video files will be named **walk.avi** and **walk.sca**.. The **.sca** file does not show up as a listing during the file loading procedure, but is accessed as needed, when digitizing. Read further about creating videos for analysis in **Hu-m-an Manual**.

With the objectives of the proposed study now defined and the specific approach for analysis outlined, the actual collection process can be started.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

2. Establishing an appropriate sub-sequence.

> Click the **[File][Load Trial]** menu item. In the Load Trial window mark the **walk.avi** file and click **[OK]**. "Play" **[>]** the video and then click **[R1]** to re-set to the start.

> An interest interval from three frames before the first right heel contact to three frames after the second right heel contact will be isolated. Use the single frame advance and reverse buttons (**[|>] [<|]**) to identify the first right heel contact. An effective key is to look for the point when the heel no longer moves forward at the moment of ground contact. Careful scrutiny will show that frame 7 is the best choice for heel contact and, therefore, the interval should start at frame 4. Set the **Start** number in the **Video Model Control** window to "4".

> Follow the same procedure and find the second right heel contact. The selection should be frame 38. Set the **End** number in the Video Model control to 41 (right heel contact +3). Now click the **[Utilities][Set a New Trial Sub-Sequence]** menu item and respond **[Yes]** to the caution query. Since data have not yet been collected, there is nothing to be replaced.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

3. Establishing and modifying the Trial Set Up components.

> Click the **[Edit][Trial Set Up]** menu item and then click the **[Collection Model]** button. Notice that the current **Trial Set Up** is for an 11 point symmetric full body collection. Rather than modify the current files, it is more efficient to find a more suitable template. It is far easier to make additions, as opposed to deletions, in current files. Click **[Cancel - Exit]** to return to the **Trial Set Up** window.

> Survey the **List of Trial Set Up Titles**. The **7 Pt. Lower Limb** model appears closest to the requirements. Mark the **7 Pt. Lower Limb** item and click **[Load],** responding **[Yes]** to the caution query. Details of **Template Titles** can be found under **Collection Models** in the **Hu-m-an Manual**.

> Click the **[Collection Model]** button. Notice that 7 of our required points are listed. The only missing point is the mid superior iliac spine (MSIS). This is a point directly above the hip joint in erect standing, located on the superior iliac spine and is used to calculate the hip joint angle. To add this point click over the first "hip" point to locate the cursor in that box. Now click the **[Insert Pair]** button and then replace the "1" with "MSIS". As this completes the list, click **[Keep Changes and Exit]** and respond **[Yes]** to the caution query.

> Click the **[Display Models]** button. Notice that the current model connects all the listed points in order and finally returns to the ankle to complete the foot drawing. To add MSIS to the drawing, first click over the "2" in the first box to place the cursor. Now in the **Coordinate Points** list click on MSIS and continue through to the heel. Now click on the ankle again to complete the foot. Since piece one is now full, if an additional line is required, a second line can be started as piece two. Click the **[Keep Changes and Exit]** button and respond **[Yes]** to the caution query.

> Click the **[Relative Angle Table]** button. The knee and ankle angles are already listed but the hip angle needs to be added. Click over the "knee" to locate the cursor in this box. Click the **[Insert]** button and replace the "1" with "hip". Now click over the "Not Defined" in the "Segment-1 Vertex" column changing it to "Select Coordinate". From the **Coordinates** list click on Hip, followed by Knee, Hip and the MSIS to complete the table. This follows angle conventions as described in the **Hu-m-an Manual**. Click **[Keep Changes and Exit]** and respond **[Yes]** to the caution query.

> The current **Segment Data - Abs. Angle Table**, **System Models** and **Subject-Trial Data**

components are already complete, as they stand. View them for information and exit using the **[Cancel - Exit]** or **[Exit]** button, where appropriate.

The **Trial Set Up** for the collection is now complete and the digitizing process can now be started.

Click **[Exit]** in the **TRIAL SET UP** window.

Click [Forward] **for the next panel.** **Forward** **Back**

HU-M-AN

Forward **Back**

4. Establishing a scaling factor.

> Click the **[Options][Digitize]** menu item to display the **Digitizing Screen** and the **Digitize** window. **When the Digitizing Screen is active, if the palette (color) changes, the video can be restored by clicking the [Re-Display] button in the Digitize window, Aspect Ratio window or Scaling Factor window. Do not click over the screen (normally used to correct the palette) since that action is part of the digitizing process.** The palette color change is due to switching between two color applications, in this case, **Hu-m-an** and **Windows Help**. For some practice exercises this may happen quite often and some users may prefer to work from printed copies. The **Practice Exercises** are included in the **Appendix** of the printed **Hu-m-an Manual,** or can be printed individually by the user, following procedures described under "**Printing Exercises and Demonstrations**" in the **Hu-m-an Manual**.

> Click the **[Fit to Size]** button in the Digitize window.

> Since it is known that the aspect ratio is 1.0, the user can proceed directly to the scaling process. Click the **[Scale]** button and respond **[OK]** accepting 1.0 as the aspect ratio. If the **Scaling Factor** window is accessed a second time, the caution notice will not appear, since an aspect ratio of 1.0 has already been accepted.

> Following correct scaling procedures, enter 1.8 as the **Real Length**, select **meters** from the **Length Units** list, and then click on the top and then the bottom marker edge of the scaling rod (see **Figure 2** below).

Figure 2
Scaling Rod Marker Edges

> The **New Scale** entry for the scale should be approximately 0.002450 - 0.002490. If your result is acceptable, click **[Apply New Scale]** or click **[Re-Display]** and re-digitize the top and bottom markers on the scaling rod.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

5. Frame by frame digitizing.

> Notice that the **Collection Model** points are listed in a drop down menu in the **Digitize** window and can be viewed using the down arrow. The top entry indicates the next point that is to be digitized. The current entry is "MSIS".

> Now begin the actual digitizing by clicking the mouse arrow carefully over the MSIS location on the subject walking in the video screen and continue through the **Collection Model** points in the following order:

(Review **Figure 1 - Collection Points** in the previous instruction panel **1. Planning the Analysis**, if necessary.)

1. MSIS
2. Hip
3. Knee
4. Ankle
5. Toe
6. Tip toe/bottom
7. Ball of foot/bottom
8. Heel/bottom

> After collecting points 1-8 listed above, by clicking again over the **Digitizing Screen,** the frame will automatically advance. There are procedures for re-collecting a frame or a single point also, as previously illustrated in the **Demonstration: Frame by Frame Digitizing**. In any case, it is always possible to correct errors at the end of a digitizing session.

> Now continue through and collect the 38 frames of data. After the last frame, the video will automatically jump back to the first frame. Note that 'best guesses' will need to be made when the arms cover the MSIS and hip points.

> The digitizing process can be interrupted and the data saved at any point. See **Saving Interim Digitizing** for the specific procedures.

> When the digitizing is complete, **[Exit]** the **Digitize** window.

Click **[Forward]** for the next panel.
Forward **Back**

HU-M-AN

Forward **Back**

6. Completing the data file.

To view the digitized data click the **[R1]** and **[C]** button in the **Video Model Control** window and then "play" **[>]** the model and video.

To finish the data file critical points need to be identified and the **Subject - Trial Data** information completed.

Click the **[Edit][Trial Set Up]** menu item and then click the **[Subject - Trial Data]** button.

For this movement the important events or "critical points" would be the two right heel contacts and the toe off. Click the **[Add]** button and replace the "1" with "Right heel contact". Replace the zero in the Frame column with a "3". Notice that the VCR controls are still active, so that the video can be reviewed at this time, if necessary. Now click the check box in the **Activate** column. This means that a vertical line will be drawn at this frame in the **Graph** window during future plotting. It can be de-activated at any time.

Again click the **[Add]** button and replace the "2" with "Toe off". Use the VCR controls to identify the last frame that the right toe is in contact with the ground. In this case it is frame 22. Replace the zero with 22 and click the **Activate** check box.

Again click the **[Add]** button and replace the "3" with "Right heel contact", the zero with "34" and click the **Activate** check box.

If a line representing the ground is to be included in the **Model** screen, it is done at this time. Click the **Ground Line … Show** check box and then click on the model screen, identifying the level at which the ground line should be positioned. Re-click until a suitable line is displayed.

Notice that the weight is set at 700 followed by "no units". SIU units are to be used, therefore, select N (Newtons) from this list. Enter 713 for the subject's weight. If the subject's height is known, it would be entered at this time. The entry must be in meters, since this was the length unit defined during the original scaling procedure. The height should be left at 0.0, since this measurement is not needed. If other subject data are known, they can be entered at this time.

Finally, select the "right" from the **Subject Facing** list.

The time interval is correct for 30fps. The data are updated automatically on exiting.

Click **[Exit]** to leave the **Subject - Trial Data** window and again click **[Exit]** to leave the Trial Set Up window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

7. Saving the new data file.

To date the digitized data have been saved within the **Hu-m-an** program, but now need to be saved permanently to disk. The next **Practice Exercise,** "**Calculations with Digitized Data**", will continue from this point.

- Click the **[File][Save As]** menu item. The current assigned **File Name** is **walk.ht**. The **.avi** extension is reserved for video files only. Add a zero to the end of the name completing it as **walk.ht0**. This follows the **Hu-m-an** recommended protocol of naming original source data as **.ht0**.

- The current path is the practice exercise disk area on the CD or Server. Since these are typically read only disks, the path needs to be changed to a different area. It is recommended that the **Local Data Area** be used for this purpose. Click the **[Local Data Area]** button in the **Save As** window. Sub-directories, normally **[user01]**, **[user02],** etc., will now be listed. Select one of these, mark it and click the **[Change Path]** button. Now click the **[Save]** button looking at the message area at the bottom for the **"Save Successful"** confirmation.

- The data can also be saved to a floppy disk. Simply insert the floppy into the appropriate drive, mark the drive letter and click **[Change Path]** and then click the **[Save]** button.

If the "Save Successful" confirmation message does not appear, do not make a final exit from the **Hu-m-an** program or the data may be lost. Re-trace the save procedures or obtain help from an experienced user.

Click **[Exit]** in the **Save As** window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Back

8. Completing the digitizing session.

The digitizing is now complete and ready for processing.

Use the normal procedures for leaving the **Hu-m-an** program. Click the **[File][Exit]** menu item.

Back

6 . CALCULATIONS WITH DIGITIZED DATA

HU-M-AN

Forward
Calculations with Digitized Data

This **Practice Exercise** will begin, assuming that data have been collected as described in the **Digitizing a New AVI File** exercise.

> Click the **[File][Load Trial]** menu item. A data file titled **walk.ht0** is listed, which is a data set collected as a result of completing the previous exercise. If the user has also saved data, then the exercise can be repeated with that data later, with the results being compared to **walk.ht0.** Mark the **walk.ht0** file and click **[OK]** to load the data.

> Click the **[R1]** and **[C]** buttons in the **Video Model Control** and play the data to familiarize yourself with the collection.

We are now ready to proceed with calculation and analysis.

Click **[Forward]** for the next panel.

Forward

HU-M-AN

Forward **Back**
1. Calculations and data analysis.
During the planning process the stated goals were to calculate the hip, knee, and ankle angles, and then track the motion of the limb. "Tracking the motion" of the limb is now specifically defined to mean, determine the movement of the center of gravity.

The following parameters will, therefore, be calculated.

1 Hip angle
2 Knee angle
3 Ankle angle
4 Limb center of gravity 'x'
5 Limb center of gravity 'y'

> Click the **[Calculate][Relative Angle]** menu item to display the **Relative Angle** window. The **Destination** list on the left mirrors the **Graph Data Control** list. On opening the window, **Hu-m-an,** by default, assumes that the first **Pre-defined Angle** (from the **Relative Angle Table**) is to be calculated, and locates this title in the first empty position. The text entry box at the top duplicates the marked selection from the list and permits editing of the title.

In addition to using **Pre-defined Angles**, relative angles can also be specified manually from the **Relative Angle** window. The **Discontinuity Check** box permits automatic correction of angles when lines defining a relative angle cross (for example when the arm crosses the trunk during a shoulder angle calculation).

> Since the default "Hip angle" is correct for the current analysis, simply click the **[Calculate]** button.

> Now click the **Hip angle** entry in the **Graph Data Control** list to display the angle just calculated. Notice that the data are somewhat "noisy" at this point, but this will be dealt with later.

> Again click the **[Calculate][Relative Angle]** menu item. Since the first position already holds the initial **Hip angle**, the default selection takes the second position. Click on the **Knee angle** in the **Pre-defined Angles** list, to identify the second selection, and then click **[Calculate]**.

> Again click the **[Calculate][Relative Angle]** menu item, select the **Ankle angle** and click **[Calculate]**.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

2. Processing the joint angle results.

> Click on the **Hip angle**, **Knee angle** and **Ankle angle** entries in the **Graph Data Control** list. Notice that the "scale" for the Hip angle is displayed on the left axis, the **Knee angle** is scaled on the right axis, while for the ankle angle an "All Axis Values Not Shown" message appears at the bottom of the graph. It would make sense to have a common axis for all angles to enable better visual comparison of their patterns.

> Click on the **[Edit][Calculated or Graph]** data menu item. The last plotted variable is selected for default display. Click on each of the hip, knee and ankle angles and make note of their range. For the common display a scale range from 50 degrees to 200 degrees seems suitable.

> Click on the **Hip angle** entry and then click on the **[Scale-Decimals-Units]** button. Enter 200 in the **Maximum** entry box and 50 in the **Minimum** entry box. Although not to be used at this time, notice that the displayed unit and the number of decimals can be changed within this window. Click the **[OK]** button.

> Repeat the process, selecting the **Knee angle** and then the **Ankle angle,** and use the same 200 and 50 values.

> Again click on the **Hip angle** entry in the **Calculated Graph Data** window. As noted earlier, the data appear to be somewhat "noisy".

The theory and application of data smoothing will not be introduced at this time. However, a very basic three point moving average, to attenuate the most obvious error, will be used. **Hu-m-an** does make available Butterworth digital filtering for more powerful data processing.

> Click on the **[Immediate 3 Pt. MA]** button to smooth the **Hip angle**. Now mark and smooth the **Knee** and **Ankle** angles. Click the **[Exit]** button in the **Calculated Graph Data** window.

> For a final check. click on the **Hip**, **Knee** and **Ankle** angles in the **Graph Data Control** window to display the results. Notice that the vertical lines on the graph represent the first heel contact, the toe off and the second heel contact as entered, following the digitizing process.

> Click on the **[Clear/Reset]** button to clear the **Graph** screen.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

3. More calculations and data analysis.

The next task is to calculate the center of gravity of the digitized limb.

> Click on the **[Calculate]** menu item and then move down to the **System C. of G**. item and then click on the displayed **3 Segment Leg** entry. The **3 Segment Leg** system was incorporated as part of the **Trial Set Up,** for this particular data set. The **System Center of Gravity** window is now displayed.

> For reference purposes the **3 Segment Leg** system is displayed on the left. The two **Destination** lists mirror the **Graph Data Control** list. There are two lists since the calculation of the center of gravity produces both 'X' and 'Y' results. Initial default titles and locations are automatically provided. Changes in the titles, if necessary, can be made in the edit boxes at the top of the lists.

> The **[Save as Coordinate Pair …]** check box provides an alternative of saving the center of gravity within the coordinate data set, which can then be displayed as an **Overtrace**. That option will not be used at this time.

> Since the default selections meet the requirements, click the **[Calculate]** button.

> If the **Graph** window is not clear, click the **[Clear/Reset]** button. Now display the data just calculated by marking both **C of G** listings in the **Graph Data Control** window. Notice that the 'Y' plot appears quite noisy, but this is due in part to the fact that the scale is quite magnified with the full range representing only about 10 cm.. As well as re-defining the range, there is a need for more decimals to be displayed.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

4. Processing the center of gravity results.

> Click the **[Edit][Calculated or Graph Data]** menu item and then select and display the **C of G X** item. Notice that the initial value for **C of G X** is about 0.7 meters. This is a result of

the arbitrary origin for the original digitizing. The baseline of virtually all linear displacement variables should be adjusted to more meaningful values. In this case, it makes sense to simply start at "0".

> Click the **[Normalize Data]** button. Click the first listing **[Set Frame '0' Value to '0']** and then click **[Process and Exit].** The result shows the same **C of G X** pattern with the adjusted baseline. An **[Undo]** button also appears, which means that the previous operation can be reversed before another variable selection is made.

> Now click the **C of G Y** listing. It would seem to make sense that the **C of G Y** value should represent the height of the limb above the ground. Click the **[Normalize Data]** button, select the **[Set Ground Line as Vertical Base]** check box and then click **[Process and Exit].**

> It is likely that basic smoothing should be applied to both data sets. In turn select each of the C of G coordinates and click **[Immediate 3 Pt. MA]**.

> Finally, to more effectively present the data, the scale should be altered. Mark the **C of G X** item and click the **[Scale-Decimals-Units]** button. Set the **Maximum** to 3.0 and the **Minimum** to 0.0 and then click **[OK]**. Now mark the **C of G Y** item and click the **[Scale-Decimals-Units]** button. Set the **Maximum** to 0.60, the **Minimum** to 0.50, set the decimals to 2 (the third decimal would always be zero, and, therefore, is not necessary), and then click **[OK]**. Depending on the eventual use of this data, other valid ranges could also be selected.

> **[Exit]** from the **Calculated Graph Data** window.

Click **[Forward]** for the next panel.

Forward Back

HU-M-AN

Forward Back

5. Analysis of the results.

A comprehensive analysis will not be done at this time, except for a simple review of the completed results.

> Select the **Hip**, **Knee** and **Ankle** angles from the **Graph Data Control** list. These results show expected patterns of motion during walking.

> Click the **[Clear/Reset]** button and then mark the two **C of G** coordinates. Notice that the **C of G X** results reflect a decreased velocity (by virtue of the line slope) during stance and an increased velocity during recovery, which again is an expected result.

Although **Hu-m-an** has the capacity to apply a far more comprehensive analysis, the objective of this exercise is to provide an introduction to calculation and data processing.

Click **[Forward]** for the next panel.

Forward Back

HU-M-AN

Forward **Back**

6. Saving the results.

The new results should now be saved permanently to disk.

> Click the **[File][Save Trial As]** menu item. The original **walk.ht0** is listed as the **File Name**. Recommended **Hu-m-an** protocol is to leave the source data unaltered, so change the **walk.ht0** to **walk.ht1**.

> The current path is the practice exercise disk area on the CD or Server. Since these are typically read only disks, the path needs to be changed to a different area. It is recommended that the **Local Data Area** be used for this purpose. Click the **[Local Data Area]** button in the **Save Trial As** window. Sub-directories, normally **[user01]**, **[user02],** etc., will now be listed. Select one of these, mark it and click the **[Change Path]** button. Now click the **[Save]** button looking at the message area at the bottom for the "Save Successful" confirmation.

> Data can also be saved to a floppy disk. Simply insert a floppy into the appropriate drive, mark the drive letter and click **[Change Path]** and then click the **[Save]** button.

Click **[Exit]** from the **Save Trial As** window.

If the "Save Successful" confirmation message does not appear, do not make a final exit from the **Hu-m-an** program or the data may be lost. Re-trace the save procedures or obtain help from an experienced user.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

7. Repeating this Practice Exercise.

If this exercise using the **Hu-m-an** provided source data has just been completed, it is recommended that the entire exercise be repeated, and this time, during the load sequence locate the user digitized data which were saved either in the **Local Data Area** or on disk.

Proceed exactly as instructed for the current exercise. The results may reflect more noise. This is normal and simply reflects the fact that digitizing is a learned skill that improves with practice. It may also be an argument for using joint center markings.

The user may find that the ranges used during processing of the data may need to be altered. Good luck!

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Back

8. Completing the session.

The **Calculations with Digitized Data** exercise are now complete.

Use the normal procedures for leaving the **Hu-m-an** program. (Click the **[File][Exit]** menu item.)

Back

7 . PRINTING GRAPHS AND BASIC REPORTS

HU-M-AN

Forward

Printing Graphs and Basic Reports

After calculating the necessary variables for analyzing a skill or movement, and then processing the data, the next step is printing a hard copy or preparing an electronic version of the results.

The most direct way of preparing results is to "copy" **Hu-m-an** prepared video pictures, models, and graphs on to one's preferred word processor, image editor or other desk top publishing software, and then completing the reports using these applications.

> **Copying results to other printing and publishing applications**. (Not included in this **Practice Exercise** but described here briefly.) Following the preparation of the model or graph to be incorporated into a report, click the **[Utilities]** menu item, select the **[Copy]** item, and then click on **[Model Window]**, **[Video Window]**, **[Graph Window]**, or **[DeskTop],** as appropriate. With the publishing software activated, "paste" the image into the document. Professional quality results can be produced following these procedures.

This exercise will concentrate on printing results directly from the **Hu-m-an** program. **Hu-m-an** incorporates basic word processing functions, but does not offer the range or power of options available on most specialized publishing applications.

> The processed results from the previous **Calculations with Digitized Data** exercise will be used for this practice session. Click the **[File][Load Trial]** menu item, mark the **walk.ht1** listing and click **[OK]**.

Click **[Forward]** for the next panel.

Forward

HU-M-AN

Forward **Back**

1. Preparing the graph for printing.

> The first target for printing will be a graph of the hip, knee and ankle angles during the walk. From a dear graph window click on the **Hip angle**, **Knee angle** and **Ankle angle** items in the **Graph Data Control** list.

> To display the graph more effectively, labels will be added. Click the **[Label]** button in the **Graph Data Control** window to display the **Label Graph** window. Enter the word "Hip" in the label text box and then click **[Display Label]**. The **Hip** label will appear on the graph screen. Click (and hold), and then while holding the mouse arrow over the **Hip** label, "drag" it to an appropriate location to identify the **Hip angle** graph (the red line). Now click the **[Update Label]** button in the **Label Graph** window.

> Repeat the procedure, entering **Knee** in the text box, clicking **[Display Label]**, dragging it to the appropriate location and clicking the **[Update Label]** button. Repeat this a third time for

the **Ankle** angle.

The three vertical lines represent the first heel contact, the toe off and the second heel contact. If desired, label these lines (using perhaps the words, Heel contact and Toe off) following the same procedures.

> With the **Label Graph** window visible and the **[Display Label]** button active, the user can again re-click and drag any of the current labels to a new location. When finished, click the **[Exit]** button in the **Label Graph** window. The **Label Graph** window can be re-displayed and labels added, edited or moved at any time unless the **[Clear/Reset]** button has been clicked.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

2. Printing a graph.

> Click the **[File][Print Model and/or Graphs]** menu item to display the **Print Models/Graphs** window.

There are three options available for printing:

1. Print the model (stick figure) window.
2. Print the graph window.
3. Print the model and graph together with the model positioned directly above the graph window.

To print the graph window:

> Click the **[Graph]** radio button at the top of the **Print Models/Graphs** window.

> Enter the title in the **Title** text box, for example, "The Hip, Knee and Ankle Motion During Walking".

The default entries specify that the graph will be approximately 10 cm. wide and positioned 5 cm from the left edge and 8 cm from the top edge of the page. The "Auto" height entry means that general height-width ratio of the display will automatically be maintained. The size of the current font is considered to be 100%, but can be changed, if necessary, for a second printing. For this first printing retain the default values.

> Click the **[Print]** button and the **Print Options** window is displayed. If an entry is to be made in the **Optional Header,** or the **[Include File Code]** check box is activated, this information is placed within the top margin area. If a printer is currently available for the computer, click the **[Proceed with Printing]** button, otherwise click the **[Cancel Current Printing]** button.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward Back

3. Printing Models and Combined Graphs.

> Click the **[File][Print Model and/or Graphs]** menu item to display the **Print Models/Graphs** window.

Printing a model:

> Click the **[Model]** radio button at the top of the window. Notice that the entries are virtually the same as for the graph, except for the addition of the **[Border]** check box. This places a border around the printed model. Although not proceeding with a print command at this time, any model created by the user in the **Model** window can be reproduced.

Printing a combined model and graph:

> Click the **[Combined]** button. The displayed options indicate that the **Model** figure becomes the master and determines the combined figure width and page location. It is good practice to make the **Model** window the same width as the **Graph** window, while constructing the figures, so that the printed combined figure will retain correct proportions. Make a note of the options available, although a specific combined graph will not be printed at this time.

> Click the **[Exit]** button in the **Print Models/Graphs** window.

Click **[Forward]** for the next panel.

Forward Back

HU-M-AN

Forward Back

4. Preparation of figures for printing in a trial report.

Specially prepared and "saved" **Models** and **Graphs** can also be mixed with text on a printed page using the **Trial Report** facility.

To "save" a Model or Graph:

The following pertains to graphs but the process for models is identical. If the previously prepared graph with labels is still present, continue, if not, then prepare another graph with labels.

> Click the **[Options][Figure List]** menu item. This window is identical to the previous **Print Models/Graphs** window except for the addition of the **Figure List** and related functions at the bottom of the window. Because the graph or model will be integrated into the printed page, there is no “Top” edge value.

> Click the **[Graph]** radio button, enter an appropriate title and then click the **[Save to List]** button (the old "Print" button). The title will appear in the **Figure List**. More than one figure can be saved to this list, as required. **[Exit]** from the **Figure List** window.

> To demonstrate that the figure is saved, **[Clear/Reset]** the Graph window display, click the

[Options][Figure List] menu item again, click the **[Show Figure]** button at the bottom of the window and the "saved" graph is re-constructed. Any saved figure can be displayed by selecting it from the **Figure List** and clicking the **[Show Figure]** button. This saving feature is only temporary and is cleared on loading a new file or exiting the program. Click **[Exit]** to leave the **Figure List** window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

5. Preparing and printing the report.

> Click the **[Edit][Trial Report]** menu item. The **Trial Report** is also temporary in that loading new data or exiting the program clears the page.

The **Trial Report** window is a basic word processing page that permits the creation of text and figure printed output. For this demonstration type the following at the top of the **Trial Report** page.

Demonstration Text Page

The following graph shows the hip, knee and ankle motion during walking.

> Enter one space after this last line and then make sure that the cursor is positioned and activated at the extreme left side of the page.. Previously "saved" models of graphs can now be placed on the page by including the proper "code".

> Note the figure list drop down menu (with arrow). The default selection is in the top line display area, which, in this case, is the graph just recently saved. Click the **[Insert Figure]** button. The code line is added to the **Trial Report**. The **.fa** (figure add) instructs the printing process to include the correct figure. Additional text, usually after a space, can be added to the page.

> Click the **[Print]** button to display the **[Print Option]** window. If a printer is currently available for the computer, click **[Proceed with Printing]** or else **[Cancel Current Printing].**

The **Trial Report** facility in **Hu-m-an** provides many options. Specific values from the current data can be inserted into the text, tables can be constructed and decisions with conditional responses can be created. These facilities are incorporated into the full versions of **Hu-m-an** and planned future practice exercises will cover them in more detail.

> Click **[Exit]** to leave the **Trial Report** window. On exiting **Hu-m-an**, the user will be questioned as to whether or not the recent changes should be retained. Respond **[Yes]** or **[No]** at this time. Remember that the **Trial Report** page is cleared when new data are loaded and on exiting the program. The **Trial Report** page can optionally be saved as a "text" file and re-loaded at a future time, if that is preferred.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Back

This concludes the **Printing Graphs and Basic Reports** practice exercise.

The user can now experiment with creating graphs, models, report pages and printing them in order to expand one's understanding of how **Hu-m-an** operates. Reading the **Hu-m-an Manual** on these topics will also be helpful.

There is no question that experience and practice are important for developing the skills for using the program effectively.

When ready, click the **[File][Exit]** menu item to leave the program normally.

Back

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8 . PREPARING A SIMPLE MACRO FILE

HU-M-AN

Forward

Preparing a Simple Macro File.

Before starting this exercise the user should be familiar with the **Calculations with Digitized Data** exercise and should review it again, if necessary.

Macros are saved procedures which can then be used as short cuts for repeated analyses. Using source data digitized in the previous exercise, the hip, knee and ankle angles will be calculated and processed, saving the procedures to a **Macro** file en route. The source data will then be re-loaded and the same calculations made, but this time using the **Macro** instead of using manual direction.

Macro files can be very comprehensive and might include calculations, data processing, graph and model preparation, decision making, and printing of individualized multi-page reports. This sort of tool has many implications for skill performance monitoring, periodic rehabilitation assessment, data smoothing comparisons, and pilot project evaluations, to name only a few.

Click **[Forward]** for the next panel.

Forward

HU-M-AN

Forward Back

1. Activating Macro saving.

> Click the **[File][Load Trial]** menu item, mark the **walk.ht0** source data, and click **[OK].**

> Click **[R1]**, **[C]** and play **[>]** to review the video and data.

> Click the **[Options][Edit Macro Files]** menu item to display the **Macro Files** window.

> A **Macro** file can be saved within the same directory as the source data, or to the **Local Macro Area,** or elsewhere, if preferred. For this exercise the **Local Macro Area** will be used.

> Click the **[Local Macro Area]** button and mark **one** of the available **Macro** sub-directories (**macro01**, **macro02**, etc.) and then click the **[Change Path]** button.

> If this exercise has been done before and a file, **calc01.hmf,** is listed, then mark this file and click **[Delete Macro File]** responding **[Yes]** to the delete inquiry.

> Click the **[Open New Macro]** button to display the **New Macro** window. Enter **calc01** (for Calculation macro) as the **New file name**. The maximum length is eight letters or numbers for a file name. For this process do not include an extension, as a default extension, **.hmf** (**Hu-m-an** macro file), is supplied by the program.

> Now click **[OK]** to initiate **Macro** file creation. You will notice at this time that a small **Macro Save Active** window will appear in the top border of the screen.

> Click **[Exit]** to close the **Macro Files** window leaving the small **Macro Save Active** window on the screen.

Click **[Forward]** for the next panel.
Forward **Back**

HU-M-AN

Forward **Back**
2. Calculations with the Macro Save Active.

It is good protocol to insert a **File Check for Macro** procedure at the beginning of a **Macro**. This procedure confirms that the data about to be processed contain the correct number of coordinate pairs and critical points to match the data upon which the **Macro** was based. **Macro** file execution can be very unforgiving, when there are discrepancies in the user entered data.

> Click the **[Options][Miscellaneous Commands]** menu item. Click the **[File Check for Macro]** button. Since there is a **Macro Save Active,** a **Macro Building** window will appear asking for a save confirmation. Click **[Yes].** A beep sound will confirm that an instruction has been saved to the **Macro** file. Click **[Exit]** to leave the **Miscellaneous Commands** window.

> Click the **[Calculate][Relative Angle]** menu item. The default **Hip angle** is already the correct first selection, so click **[Calculate]**. Again, since there is a **Macro Save Active,** a **Macro Building** window will appear asking for a save confirmation. Click **[Yes].** A beep sound will again confirm that an instruction has been saved to the **Macro** File.

> Re click the **[Calculate][Relative Angle]** menu item. Again, by default the **Hip Angle** is automatically placed in the second location, but this time replace by selecting the **Knee angle** from the **Pre-defined Angles** list. Click **[Calculate]**, responding **[Yes]** to the **Macro Building** inquiry.

> Repeat the process one more time calculating the **Ankle angle** and saving the procedure to the **Macro** file.

> From this point on, if using on-screen instructions, it will be necessary to occasionally move the instruction panel in order to observe different windows on the screen. The instruction panel should be kept in corners of the screen, as best possible, and away from the middle, so as not to hide the small **Macro Building** window.

> Select the **Hip**, **Knee** and **Ankle** angles from the **Graph Data Control** list to view the initial results of the calculations and then click **[Clear/Reset]**.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

3. Processing the calculated data.

> Click the **[Edit][Calculated or Graph Data]** menu item to display **the Calculated Graph Data** window.

> As before, very basic three point moving average smoothing will be applied to the data. Mark the **Hip angle** in the **Calculated Graph Data** list and then click the **[Immediate 3 Pt. MA]** button. Again the **Macro Building** window will appear so respond **[Yes].** Repeat the procedure for both the knee and ankle, each time marking, smoothing and saving.

> Similar to the first processing of this source data, a common scale will be established for all three angles. Mark the **Hip angle** and click the **[Scale-Decimals-Units]** button. Enter 200 as the **Maximum** value, and 50 as the **Minimum** value, and then click **[OK].** Again click **[Yes]** to the **Macro Building** inquiry. Repeat the process for both the **Knee** and **Ankle angles** by marking, clicking **[Scale-Decimals-Units],** entering the two values, clicking **[OK]** and confirming the **Macro** save with **[Yes].**

> If a mistake has been made, go back and repeat the process.

> As the data processing is now complete, click **[Exit]** in the **Calculated Graph Data** window and then click **[Close]** on the small **Macro Save Active** window.

> Select the **Hip**, **Knee** and **Ankle** angles from the **Graph Data Control** list to review the processed angles and then click **[Clear/Reset].**

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

4. Viewing the contents of the new Macro file.

> Click the **[Options][Edit Macro Files]** menu item. Click the **[Local Macro Area]** button and then mark the sub-directory where the new **Macro** is stored, and then click **[Change Path]**. The Macro file, **calc01.hmf,** should now appear at the top of the **Macros** listing. If the wrong sub-directory has been accessed, click the **[Local Macro Area]** and try again.

> With a single click mark the **calc01.hmf Macro** file. The contents of the new **Macro** is displayed for viewing. Study the listing.

> Click **[Exit]** in the **Macro Files** window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward Back

5. Testing the new Macro.

> The original unprocessed source data will be used to test the newly constructed Macro. Click the **[File][Load Trial]** menu item, mark the **walk.ht0** file and click **[OK]** to load the data. Answer **[Yes]** to the load without saving the results question since it is no longer needed. Center the model data by clicking **[R1]** and **[C].**

> Notice that no data are listed in the **Graph Data Control**.

> Click the **[Options][Edit Macro Files]** menu item. Click the **[Local Macro Area]** button and then mark the sub-directory where the original Macro was saved, and then click **[Change Path]**. The Macro file, **calc01.hmf,** should now appear at the top of the **Macros** listing. If the wrong sub-directory has been accessed, click the **[Local Macro Area]** and try again. Mark **calc01.hmf** to view its contents.

> Click the **[Execute]** button in the **Macro Files** window. Respond **[Yes]** to the **Caution** inquiry. Notice that with this one key stroke the processed data appear in the **Graph Data Control** list.

> Mark and display the **Hip**, **Knee** and **Ankle** graph data for review.

Click **[Forward]** for the next panel.

Forward Back

HU-M-AN

Back

6. Summary.

Macro files can be registered within the **Hu-m-an** program, so that they appear in the **Macros** window accessed through the **View** menu item. This listing makes popular **Macros** easily accessible.

Advanced **Macro** files can include graph and model saving, and complete individualized report preparation and printing, making this a potentially very powerful tool for automated analyses.

The facility to create an advanced **Macro** files is available, but reasonable practice with the **Hu-m-an** program is required in order to be successful.
Many examples of how **Macro** files are used can be found in the **Example Laboratories**.

The **Demonstrations** used with **Hu-m-an** are themselves extensions of the same **Macro** development process.

♦ This completes the **Preparing a Simple Macro File** exercise. Click **[File][Exit]** to leave the **Hu-m-an** program. Answer **[Yes]** to exit the program without saving the results.

Back

9 . THE PRINTED PAGE MACRO FILE

HU-M-AN

Forward

The Printed Page Macro File.

The objective of this practice exercise is to prepare a macro that produces a two-page printed report including a graph and comparative data. It is typical of macros that might be used in a clinic or testing laboratory where repeated analyses of similar data sets are carried out.

Before starting this exercise the user should be familiar with the **Calculations with Digitized Data** and **Preparing a Simple Macro File** practice exercises. In particular, the **calc01.hmf** macro file must be present in one of the **Local Macro Area** sub-directories. If you find that the **calc01.hmf** file is not present (accessed at the beginning of the exercise), then the **Preparing a Simple Macro File** exercise must be re-done before beginning this exercise.

Macros are saved procedures which can then be used as short cuts for repeated analyses. **Macro** files can be very comprehensive and might include calculations, data processing, graph and model preparation, decision making, and printing of individualized multi-page reports. This sort of tool has many implications for skill performance monitoring, periodic rehabilitation assessment, data smoothing comparisons, and pilot project evaluations, to name only a few.

Click **[Forward]** for the next panel.

Forward

HU-M-AN

Forward Back

1. Re-running the macro produced in the Preparing a Simple Macro File exercise.

> Click the **[File][Load Trial]** menu item, mark the **walk.ht0** source data, and click **[OK].**

> Click **[R1]**, **[C]** and play **[>]** to review the video and data.

> Click the **[Options][Edit Macro Files]** menu item to display the **Macro Files** window.

> Click the **[Local Macro Area]** button and mark the **macro01** sub-directory. Click the **[Change Path]** button. If the **calc01.hmf** file is found in the Macros list proceed to the next instruction. If the **calc01.hmf** file is not found, click the **[Local Macro Area]** button again, mark the **macro02** sub-directory and click the **[Change Path]** button. If the **calc01.hmf** file is not found, repeat this for all macro sub-directories. If the **calc01.hmf** file is not found click **[Exit]** to leave the **Edit Macro File** window and then click the **[File][Exit]** main menu item to exit the program and then repeat the **Preparing a Simple Macro File** practice exercise.

> Assuming you have located the **calc01.hmf** file, if other .hmf files are present in the same sub-directory, they should be removed. In turn mark each of these files, click the **[Delete Macro]** button and respond **[Yes]** to the caution. **DO NOT DELETE THE CALC01.HMF FILE.**

> Mark the **calc01.hmf** file in the **Macros list**. The contents should **exactly** list the following procedures.

File Check
Hip angle
Knee angle
Ankle angle
3 Point Moving average of Hip angle
3 Point Moving average of Knee angle
3 Point Moving average of Ankle angle
Manual Max and Min for Hip angle
Manual Max and Min for Knee angle
Manual Max and Min for Ankle angle

> If the contents do not match exactly, then the macro may not be correct and cause problems in executing this practice exercise. if in doubt, click **[File][Exit]** to exit the program and repeat the **Preparing a Simple Macro File** practice exercise.

> Click the **[Execute]** button to run the macro and respond **[Yes]** to the caution inquiry. The end result is the calculation and processing of the hip, knee and ankle motion in walking. Plot and review the hip, knee and ankle angles listed in the **Graph-Data Control** window. The scales for all three data sets should have a maximum of 200 degrees and a minimum of 50 degrees.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Overview of macro style for multi-page reports.

Although many individual styles can be adapted to the creation of macros the following procedures have been found to be successful. The procedures were developed to accommodate ease of future modification and to avoid potential errors.

1. The calculation of variables (e.g. angles, C. of G.'s, velocities etc.) and data processing (e.g. scaling, smoothing normalization, etc.) should be kept as separate macro files. The previously constructed **calc01.hmf** macro, for example, is a calculation macro. It is recommended that these be titled as **calculation macros** by using names such as **calc01.hmf**, **calc02.hmf**, etc., so that these files are easily recognized.

2. The macros that create each page should be kept separate and named appropriately, for example, **page01.hmf**, **page02.hmf,** etc..

3. Similarly, text pages that provide the text template for the printed output should be named **page01.txt**, **page02.txt**, etc..

4. Each page should be constructed independently, that is, with no previous calculations or processes present, even if this means the re-calculation of required variables. This eliminates problems that often occur during macro development, and during future modifications.

5. If a multi-page macro is produced, then a **master.hmf** file is created.

General process for creating a multi-page macro file.

a) Generate concept template for page, that is, create in your mind or using pencil and paper a general outline of the printed output.
b) Create a calculation macro of the required variables for the page (e.g. **calc01.hmf**).
c) Create the page macro (**page01.hmf**).
- Establish an independent start.
- Run calculation macro for page.
- Develop and save to list any required figures or graphs for the page.
- Select and identify any specific data values required.

Close page macro.
d) Create the text template for the page and save (**page01.txt**).
e) Add the text page to the page macro and finish with the printing command. Close the page macro.
f) Create any additional pages in an identical fashion.
g) Create a master macro to produce multi-page output.

Click **[Forward]** for the next panel.

Forward Back

HU-M-AN

Forward Back

2. Creating the First Page of a Multi-page Macro

A macro for producing a two-page report that includes a graph and table with printed text will now be created following the general outline procedures. The outline procedures are presented first (in bold) followed by the specific instructions for their execution.

a) Generate concept template for page, that is create in your mind or using pencil and paper a general outline of the printed output.

The first page will introduce the analysis and then show a graph of the hip, knee and ankle joint motion during walking which includes variable labels and critical point identification.

b) Create a calculation macro of the required variables for the page (calc01.hmf).

The calculation macro has already been prepared (**Preparing a Simple Macro File**) and in this case is titled **calc01.hmf**.

c) Create the page macro (page01.hmf).
- Establish an independent start.
- Run calculation macro for page.
- Develop and save to list any required figures or graphs for the page.
Close page macro.

> Click the **[Options][Edit Macro Files]** menu item to display the **Macro Files** window.

> To start this exercise you need to locate the local macro sub-directory where the calculation macro **calc01.hmf** resides.

> Click the **[Local Macro Area]** button and mark the available **Macro** sub-directory (**macro01**, **macro02**, etc.) where **calc01.hmf** resides and then click the **[Change Path]** button. If you select the wrong sub-directory, click the **[Local Macro Area]** button and try again.

> Click the **[Open New Macro]** button to display the **New Macro** window. Enter **page01** as the **New file name**. The maximum length is eight letters or numbers for a file name. For this process do not include an extension, as a default extension, **.hmf** (**Hu-m-an** macro file), is supplied by the program. Click **[OK].** If a **File Exits** error window is displayed, it means an existing file was not deleted. Simply click **[OK]** to this message, click **[Cancel]** in the **New Macro** window, mark the existing **page01.hmf** macro and click the **[Delete Macro File]** button responding **[Yes]** to the caution inquiry. Now start again at the beginning of this paragraph.

> Click the **Execute Independent Start Command** check box. Now click **[OK]** to initiate **Macro** file creation and respond **[Yes]** to the caution about deleting all previously created data.. You will notice at this time that a small **Macro Save Active** window will appear in the top border of the screen.

> Click **[Exit]** to close the **Macro Files** window leaving the small **Macro Save Active** window on the screen.

> To run the **calculation** macro within this **page** macro, click the **[Options][Miscellaneous Commands]** menu item. Click the **[Browse]** button, the **[Local Macro Area]** button; mark the correct macro sub-directory and click **[OK];** and then mark the **calc01.hmf** calculation macro and again click **[OK]**. The **[Use Macro File Path]** check box should remain checked. Now click the **[Execute a Macro (Nested)]** button and respond **[Yes]** to the **Macro saving** inquiry. Note that the hip, knee and ankle angles are now calculated and listed in the **Graph-Data Control** window. **[Exit]** the **Miscellaneous Commands** window.

> To develop and save a graph of the hip, knee and ankle angles proceed as follows. With the **[Wide]** check box marked in the **Graph-Data Control** window, click the **Hip angle** listing. Now click the **[Narrow]** check box and the **Knee angle** listing, and then the **[Dash]** check box and the **Ankle angle** listing. If you make a mistake, simply **[Clear/Reset]** and re-plot since nothing is saved during this operation. To label the graph, click the **[label]** button at the bottom right the **Graph-Data Control** window. In the **Label Graph** window text box, type **Hip** and then click the **[Display Label]** button. the **Hip** label will appear on the left side of the graph. Click the mouse arrow over the label **Hip**, and holding the mouse button down, drag it to an appropriate location and then click the **[Update Label]** button. Using the same procedure create and locate the following labels: **Knee**, **Ankle**, **Heel Contact**, **Toe Off**, and the second **Heel Contact**. While the **Label Graph** window is displayed, you can click on and re-locate any of the labels. You can also **[Cut]** labels you wish to delete. **[Exit]** the **Label Graph** window. Now click the **[Options][Figure List]** menu item. Click the **[Graph]** check box. Enter the new title **Hip, Knee and Ankle Displacement in Walking** and then click the **[Save to List]** button. Click **[Yes]** to the **Macro saving** inquiry. Since this is being saved to a macro, a **Macro Selection** window is displayed for critical points. Since we are plotting from the start to the end, the default entries are correct, and therefore click **[OK].** Note that the graph title appears in the list box at the bottom of this window. **[Exit]** the **Figure List** window.

Click the **[Close]** button in the small **Macro Saving Active** window at the top.

> If you wish, at this time you can test the **page01.hmf** macro. First **[Clear/Reset]** the **Graph** window. Use the **[Options][Edit Macro Files]** menu item and then locate the **page01.hmf** macro file in the **Local Macro Area**. Mark this file and then click the **[Execute]** button, responding **[Yes]** to the caution inquiry. To display the graph, click the **[Options][Figure List]** menu item and then click the **[Show Figure]** button. Click **[Exit]** to leave this window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

d) Create the text template for the page and save (page01.txt).

> Click the **[Edit][Trial Report]** menu item. If the text window is not clear, click the **[Clear]** button and respond **[Yes]** to the caution. Starting with the very top text line type in the following (include spaces and internal blank lines):

Analysis of Walking

The graph below illustrates the coordination of
the hip, knee and ankle displacement during normal
walking.

Basic word processing is provided by **Hu-m-an**. Although usually sufficient in most cases, where more sophisticated techniques are required, graphs, figures and data can be exported to a commercial third party word processor. A fixed font is used in **Hu-m-an** and WYSIWYG (what you see is what you get), except for figures graphs and imported values which are indicated by codes. In particular, automatic carriage returns are not provided and therefore lines should be kept short as to accommodate the individual differences between printers. This is somewhat of a trial and error process although it is very easy to modify the text template in the future, as required.

> To enter the code for including the previously prepared graph on the page, locate the text cursor to the immediate right of the word walking. by placing the mouse arrow their and clicking. Now, press the Enter key twice (for line spaces) and then click the **[Insert Figure]** button near the top of this window. Since we only saved one graph no selection is necessary at this time, but in the future, if more than one graph is available, then a selection can be made from the provided list. The typing on the text page should now look exactly as follows:

Analysis of Walking

The graph below illustrates the coordination of
the hip, knee and ankle displacement during normal
walking.

.fa 1 Hip, Knee and Ankle Displacement in Walking

The **.fa** is the code that instructs the **Hu-m-an** printing process to select the correct figure or graph. It must be at the extreme left with the period in the first column.

> To save the text template page, click the **[Save As]** button, then the **[Local Macro Area]** button, mark the correct macro sub-directory, click **[OK].** The **Path** as identified in this window should read something like **?:\hu-m-an\macros\macro01** where **?** represents the local drive. Now replace the default ***.txt** with the **page01.txt** name and then click **[OK].** If a question about replacing an existing file appears, this simply means that the lab had been done previously, and therefore respond **[Yes]** to replacement. The page text template is now complete. **[Exit]** the **Trial Report** window, responding **[No]** to the caution about retaining changes as this is only a temporary holding area..

Click **[Forward]** for the next panel.

Forward Back

HU-M-AN

Forward Back

e) Add the text page to the macro and finish with the printing command. Close the page macro.

> Click the **[Options][Edit Macro Files]** menu item. Click the **[Local Macro Area]** button and mark the available **Macro** sub-directory where **page01.hmf** file resides and then click the **[Change Path]** button.

> Mark the **page01.hmf** file and click the **[Add to this Macro]** button You will notice at this time that a small **Macro Save Active** window will appear in the top border of the screen.

> Click **[Exit]** to close the **Macro Files** window leaving the small **Macro Save Active** window on the screen.

> Click the **[Edit][Trial Report]** menu item. Click the **[Load]** button, responding **[Yes]** to the caution. Locate the **page01.txt** in the **Local Macro Area**, mark it and click **[OK]** to load this text file, responding **[Yes]** to the **Macro save** inquiry. **[Exit]** the **Trial Report** window resounding **[No]** to the retain changes inquiry.

> Click the **[File][Print Trial Report]** main menu item, responding **[Yes]** to the **Macro save** inquiry. For now, when the **Print Options** window appears, click the **[Cancel Current Printing]** button. Now click the **[Close]** button in the small **Macro Save Active** window at the top. **The page01.hmf** macro is now complete!

Click **[Forward]** for the next panel.

Forward Back

HU-M-AN

Forward Back

3. Testing the new page01.hmf Macro.

> The original unprocessed source data will be used to test the newly constructed macro. Click the **[File][Load Trial]** menu item, mark the **walk.ht0** file and click **[OK]** to load the data. Answer **[Yes]** to the load without saving the results question since it is no longer needed. Center the model data by clicking **[R1]** and **[C].**

> Notice that no data are listed in the **Graph Data Control**.

> Click the **[Options][Edit Macro Files]** menu item. Click the **[Local Macro Area]** button and then mark the sub-directory where the original Macro was saved, and then click **[Change Path]**. The macro file, **page01.hmf,** should now appear in the **Macros** listing. If the wrong sub-directory has been accessed, click the **[Local Macro Area]** and try again. Mark **page01.hmf** to view its contents.

> Click the **[Execute]** button in the **Macro Files** window. Respond **[Yes]** to the **Caution** inquiry. Notice that with this one key stroke the processed data appear in the **Graph Data Control** list and the **Print Options** screen appears. If a printer is connected, select the appropriate printer from the list, enter your name in the **Header** text box and click the **[Proceed with Printing]** button. If a printer is not available, click **[Cancel Current Printing**]. It is a good idea to print the page one test at this point. If a correct graph is not produced, then you should start again at **2. Creating the First Page of a Multi-page Macro**.

Forward Back

HU-M-AN

Forward Back

4. Creating the Second Page of a Multi-page Macro

A macro for producing the second page of the printed report will now be created following the general outline procedures. The outline procedures are presented first (in bold) followed by the specific instructions for their execution.

a) Generate concept template for page 2, that is create in your mind or using pencil and paper a general outline of the printed output.

The second page will contain a table that identifies the maximum, minimum and range of knee joint displacement from heel contact to heel contact, and then identify the knee angle at toe lift as part of a text line.

b) Create a calculation macro of the required variables for the page (e.g. calc01.hmf).

The calculation macro has already been prepared and used previously.

c) Create the page macro (page02.hmf).

- **Establish an independent start.**
- **Run calculation macro for page.**
- **Select and identify any specific data values required.**

Close page macro.

> Click the **[Options][Edit Macro Files]** menu item to display the **Macro Files** window.

> Click the **[Local Macro Area]** button and mark the available **Macro** sub-directory (**macro01**, **macro02**, etc.) where **calc01.hmf** resides and then click the **[Change Path]** button. If you select the wrong sub-directory, click the **[Local Macro Area]** button and try again.

> Click the **[Open New Macro]** button to display the **New Macro** window. Enter **page02** as the **New file name**. The maximum length is eight letters or numbers for a file name. For this process do not include an extension, as a default extension, **.hmf** (**Hu-m-an** macro file), is supplied by the program. Click **[OK].** If a **File Exits** error window is displayed, it means an existing file was not deleted. Simply click **[OK]** to this message, click **[Cancel]** in the **New Macro** window, mark the existing **page02.hmf** macro and click the **[Delete Macro File]** button responding **[Yes]** to the caution inquiry. Now start again at the beginning of this paragraph.

> Click the **Execute Independent Start Command** check box. Now click **[OK]** to initiate **Macro** file creation and respond **[Yes]** to the caution about deleting all previously created data.. You will notice at this time that a small **Macro Save Active** window will appear in the top border of the screen.

> Click **[Exit]** to close the **Macro Files** window leaving the small **Macro Save Active** window on the screen.

> To run the **calculation** macro within this **page** macro, click the **[Options][Miscellaneous Commands]** menu item. Click the **[Browse]** button, the **[Local Macro Area]** button; mark the correct macro sub-directory and click **[OK];** and then mark the **calc01.hmf** calculation macro and again click **[OK]**. The **[Use Macro File Path]** check box should remain checked. Now click the **[Execute a Macro (Nested)]** button and respond **[Yes]** to the **Macro saving** inquiry. Note that the hip, knee and ankle angles are now calculated and listed in the **Graph-Data Control** window. **[Exit]** the **Miscellaneous Commands** window.

> To select the specific values in which we are interested proceed as follows. Click the **[Options][Select Values and Decisions]** button. **The Select Values and Decisions** window is probably one of the most complicated and yet one of the most powerful tools found in **Hu-m-an**. The key is the **Value Table**, a storage area for up to forty values that can be recalled at a later time. Five of the values are shown on the screen and are initially set to zero. The **Table Pointer** directs data to a specific table slot and is initially set to **1**. Note that the **Find** portion of the screen is the top third and this is where we will initially work.

> From the list of variables presented select the **Knee angle** (the first, **Hip angle**, is the default). From the measure options list (**Find the**.), click **Maximum** and from the **Locate** list select **Size** (the default). From the newly presented critical point identifier lists (**between....and**), select the first **Right heel contact** from the first list and the **Second R. heel contact** from the second list. If completed correctly the answer text should read **Maximum Knee angle between Right heel contact and Right heel contact**. Now click the **[Find]** button, and respond **[Yes]** to the **Macro save** inquiry. Note that the **Table Pointer** automatically indexes to **2**. Now select **Minimum** and again click **[Find]** and respond **[Yes],** and then select **Range** and click **[Find]** and respond **[Yes].** Finally, select the **Value** option (instead of **Maximum** etc.), identify **Toe off** (instead of **Right heel contact**), and then click **[Find]** and respond **[Yes].** Note that the four selected values are now displayed in the **Value Table**. Remember the order in which they are listed. Now **[Exit]** the **Selected Values and Decisions** window and click **[Close]** in the small **Macro Save Active** window at the top.

Forward **Back**

HU-M-AN

Forward Back

d) Create the text template for the page and save (page02.txt).

> Click the **[Edit][Trial Report]** menu item. If the text window is not clear, click the **[Clear]** button and respond **[Yes]** to the caution. Starting with the very top text line type in the following:

Analysis of Walking

Table I below identifies selected values for right knee displacement between heel contacts.

Table I

Right Knee Displacement Between Heel Contacts

Maximum
Minimum
Range

At the point of right toe lift the knee angle was found to be degrees.

Basic word processing is provided by **Hu-m-an**. Although usually sufficient in most cases, where more sophisticated techniques are required, graphs, figures and data can be exported to a commercial third party word processor. A fixed font is used in **Hu-m-an** and WYSIWYG (what you see is what you get), except for figures graphs and imported values which are indicated by codes. In particular, automatic carriage returns are not provided and therefore lines should be kept short as to accommodate the individual differences between printers. This is somewhat of a trial and error process although it is very easy to modify the text template as required.

> To enter the code for the selected values, position the cursor line 5 spaces to the right of the word **Maximum** in your text (use spaces as required), and then click the **[Table]** button (under the Insert Values heading). The default **%t01 6.1f** will be displayed. Leave one space and then type **degrees**. Repeat the process for the **Minimum** and **Range** entries, lining up these codes vertically with the first one. Now position the text cursor one space after the words...**found to be**..., and then click the **[Text]** button, which inserts the %v01 6.1f code.

> The **01** following the **%t** or **%v** codes identifies the **Value Table** location for the number, while the **6.1f** identifies the number of placeholders (6) followed by the number of desired decimals (1) to be displayed. Modify the entries to correctly replace the values (i.e. the **01** to **02** for the minimum etc.), and then replace all **6.1f** entries with **5.1f** which means the angle values will be presented with one decimal. The final text page should look something like the following (the codes should compare **exactly**.)

Analysis of Walking

Table I below identifies selected values for right knee displacement between heel contacts.

Table I

Right Knee Displacement Between Heel Contacts (Degrees)

Maximum	**%t01 5.1f**
Minimum	**%t02 5.1f**
Range	**%t03 5.1f**

At the point of right toe lift the knee angle was found to be %v04 5.1f degrees.

> To save the text template page, click the **[Save As]** button, then the **[Local Macro Area]** button, mark the correct macro sub-directory, click **[OK].** The **Path** as identified in this window should read something like **?:\hu-m-an\macros\macro01** where **?** represents the local drive. Now replace the default **File Name** with the **page02.txt** name and then click **[OK].** If a question about replacing an existing file appears, this simply means that the lab had been done previously, and therefore respond **[Yes]** to replacement. The page text template is now complete. **(Make sure you have the correct title and are not replacing the page01.txt file!)**

> The **page02.txt** macro with selected values can be tested as follows. Note that the **[Convert % codes]** button is checked by default. This means that on loading a file, any % codes will be converted to their designated values. Click the **[Load]** button. Respond **[Yes]** to the caution Replace.. inquiry and then locate the correct macro sub-directory. Mark the **page02.txt** file and click **[OK].** Review the values. Remember that this will only work if the correct values have been identified using the **Select Values and Decisions** window. Also note that if you wish to load the original **page02.txt** file for modification, you must de-activate the **[Convert % codes]** button to retrieve the coded file. <u>Proceed with caution here, as a common mistake is to confuse the coded and code converted files and overwriting the important coded file!</u>

> **[Exit]** the **Trial Report** window, responding **[No]** to the inquiry.

Forward **Back**

HU-M-AN

Forward **Back**

e) Add the text page to the macro and finish with the printing command. Close the page macro.

> Click the **[Options][Edit Macro Files]** menu item. Click the **[Local Macro Area]** button and mark the available **Macro** sub-directory where **page02.hmf** file resides and then click the **[Change Path]** button.

> Mark the **page02.hmf** file and click the **[Add to this Macro]** button You will notice at this time that a small **Macro Save Active** window will appear in the top border of the screen.

> Click **[Exit]** to close the **Macro Files** window leaving the small **Macro Save Active** window on the screen.

> Click the **[Edit][Trial Report]** menu item. Make sure the **[Convert % codes]** button is active and then click the **[Load]** button, responding **[Yes]** to the caution. Locate the **page02.txt** in the **Local Macro Area**, mark it and click **[OK]** to load this text file, responding **[Yes]** to the **Macro save** inquiry. **[Exit]** the Trial Report window responding **[No]** to the retain changes inquiry.

> Click the **[File][Print Trial Report]** menu item, responding **[Yes]** to the **Macro save** inquiry. For now, when the **Print Options** window appears, click the **[Cancel Current Printing]** button. Now click the **[Close]** button in the small **Macro Save Active** window at the top. The **page02.hmf** macro is now complete!

Forward **Back**

HU-M-AN

Forward **Back**

5. Testing the new page02.hmf Macro.

> The original unprocessed source data will be used to test the newly constructed Macro. Click the **[File][Load Trial]** menu item, mark the **walk.ht0** file and click **[OK]** to load the data. Answer **[Yes]** to the load without saving the results question since it is no longer needed. Center the model data by clicking **[R1]** and **[C].**

> Notice that no data are listed in the **Graph Data Control**.

> Click the **[Options][Edit Macro Files]** menu item. Click the **[Local Macro Area]** button and then mark the sub-directory where the original Macro was saved, and then click **[Change Path]**. The macro file, **page02.hmf,** should now appear in the **Macros** listing. If the wrong sub-directory has been accessed, click the **[Local Macro Area]** and try again. Mark **page02.hmf** to view its contents.

Click the **[Execute]** button in the **Macro Files** window. Respond **[Yes]** to the **Caution** inquiry. Notice that with this one key stroke the processed data appear in the **Graph Data Control** list and the **Print Options** screen appears. If a printer is connected, select the appropriate printer from the list, enter your name in the **Header** text box and click the **[Proceed with Printing]** button. If a printer is not available, click **[Cancel Current Printing].** It is a good idea to print the page two test page at this point. If a correct page with table is not produced, then you should start again at **4. Creating the Second Page of a Multi-page Macro.**

Forward **Back**

HU-M-AN

Forward **Back**

6. Creating the Master macro for multi-page printing.

> Click the **[Options][Edit Macro Files]** menu item to display the **Macro Files** window.

> Click the **[Local Macro Area]** button and mark the available **Macro** sub-directory (**macro01**, **macro02**, etc.) where the other macro files reside and then click the **[Change Path]** button.

> Click the **[Open New Macro]** button to display the **New Macro** window. Enter **master** as the **New file name**. The maximum length is eight letters or numbers for a file name. For this process do not include an extension, as a default extension, **.hmf** (**Hu-m-an** macro file), is supplied by the program.

> **Do not** Click the **Execute Independent Start Command** check box. Now click **[OK]** to initiate **Macro** file creation. You will notice at this time that a small **Macro Save Active** window will appear in the top border of the screen.

> Click **[Exit]** to close the **Macro Files** window leaving the small **Macro Save Active** window on the screen.

> Click the **[Options][Miscellaneous Commands]** menu item. Use the **[Browse]** button and locate the **Local Macro Area** and macro sub-directory that holds your previous macro files. Mark the **page01.hmf** file and click **[OK].** Click the **[Execute a Macro (Nested)]** button, click the **[Cancel Current Printing]** in the **Print Options** window and then respond **[Yes]** to the Macro saving inquiry.

> Repeat for **page02.hmf** by using the **[Browse]** button and locate the **Local Macro Area** and macro sub-directory that holds your previous macro files. Mark the **page02.hmf** file and click **[OK].** Click the **[Execute a Macro (Nested)]** button, click the **[Cancel Current Printing]** in the **Print Options** window and then respond **[Yes]** to the Macro saving inquiry.

> **[Exit]** the **Miscellaneous Commands** window.

> Click **[Close]** in the small **Macro Saving Active** window at the top. The **master macro** is now complete.

Forward **Back**

HU-M-AN

Forward **Back**

7. Testing the completed master macro file.

> The original unprocessed source data will be used to test the newly constructed Macro. Click the **[File][Load Trial]** menu item, mark the **walk.ht0** file and click **[OK]** to load the data. Answer **[Yes]** to the load without saving the results question since it is no longer needed. Center the model data by clicking **[R1]** and **[C].**

> Notice that no data are listed in the **Graph Data Control**.

> Click the **[Options][Edit Macro Files]** menu item. Click the **[Local Macro Area]** button and then mark the sub-directory where the original Macro was saved, and then click **[Change Path]**. The macro file, **master.hmf,** should now appear in the **Macros** listing. If the wrong sub-directory has been accessed, click the **[Local Macro Area]** and try again. Mark **master.hmf** to view its contents.

> Click the **[Execute]** button in the **Macro Files** window. Respond **[Yes]** to the **Caution** inquiry. Notice that with this one key stroke the processed data appear in the **Graph Data Control** list and the **Print Options** screen appears. If a printer is connected, select the appropriate printer from the list, enter your name in the **Header** text box and click the **[Proceed with Printing]** button.

> **When the Master Macro execution is not successful.**
1) If one of the pages in not correct, you can try to repeat the creation of that page only, and then re-execute the **master macro**.
2) Use your own ingenuity to de-bug problems!
3) Ask for assistance, if available.
4) Re-do the exercise, very carefully!

Forward Back

HU-M-AN

Back

8. Summary.

The macro development process has been illustrated in some detail. The result of this exercise is a package of four macro files and two text files, namely:

calc01.hmf
page01.hmf
page01.txt
page02.hmf
page02.txt
master.hmf

This macro package can now be applied to any data set similar to **walk.ht0**. The collection order, number of pairs of coordinates and the number of critical points must be identical. The macro package can be copied to another directory or disk.

Macro files can be registered within the **Hu-m-an** program, so that they appear in the **Macros** window accessed through the **View** menu item. This listing makes popular **Macros** easily accessible. See the **Hu-m-an Manual** for details.

Many examples of how **Macro** files are used can be found in the **Example Laboratories**.

The **Demonstrations** used with **Hu-m-an** are themselves extensions of the same **Macro** development process.

> This completes **The Printed Page Macro File** exercise. Click the **[File][Exit]** main menu item to leave the **Hu-m-an** program. Answer **[Yes]** to exit the program without saving the results.

Back

10 . AUTOMATIC TRACKING PRACTICE

Forward

Automatic Tracking Practice
(Note that if the instruction panel is ever lost, it can be re-displayed by clicking the [Help][Exercise Help] menu item. Also, it may be convenient to make the help window full-screen when first reading, and then downsizing when activating the commands.).

This **Practice Exercise** will guide the user through the process of **Automatic Tracking** as part of a 2-D data collection.

The following video files have been prepared for this practice session.

1. <walkk.avi> Treadmill walking, 30 fps, 4 steps @ 2.5 mph.
2. <walkl.avi> Level walking,60 fps, 1 step
3. <runc.avi> Treadmill running, 30 fps, 4 steps @ 6.0 mph.
4. <rund.avi> Level running, 60fps, 1 step

This **Practice Exercise** will guide the user through the process of beginning a simple original biomechanical analysis by creating a digitized data base from a source **.avi** file using automatic tracking. If using on-screen instructions, it will also be useful to maximize this instruction panel for easier display and reading of some sections and then downsize when operating program.

Before starting, the **<Digitizing a New AVI File> Practice Exercise** should be completed.

Forward

Forward Back

1. Planning the Analysis.
Similar to the **<Digitizing a New AVI> Practice Exercise** and **<Frame by Frame Digitizing> Demonstration** the right leg during walking will be analyzed. This time, however, up to four steps of data will be collected.

To accomplish this task, a six point planar model of the right leg will be used with markers located at the:

1. mid-superior iliac spine (MSIS, located directly above and in line with the hip joint center in erect standing)
2. hip (greater trochanter)
3. knee (femoral epicondyle)
4. ankle lateral malleolus
5. toe (at front of shoe near ground level)
6. heel (at the back of the heel near ground level)

With these markings planar measurements of hip, knee and ankle measurements can be made.

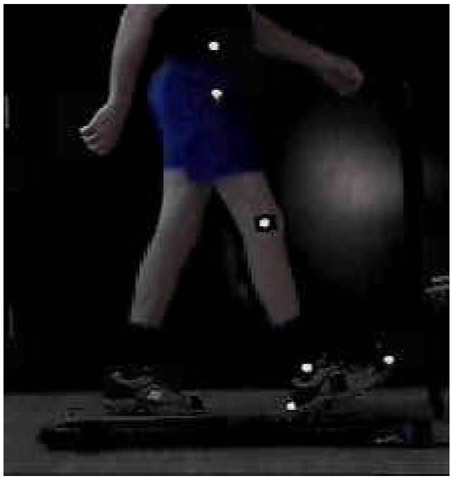


Figure 1
6 Point
Template

Figure 2
(Normal and wrapped
3/4 inch markers)

The markers for this exercise were ¾inch Styrofoam spheres wrapped in reflective tape (3M 7610). (See Figure 2) The video is a sagittal view of a complete right leg walking cycle. The video capture system (the one used for the sample source videos in this exercise) has been found to result in no distortion and, therefore, the aspect ratio is 1.00.

The treadmill sequences are 30fps and have been taped over a black background with low level light to accentuate marker reflection. The ground sequences are 60 fps created by splitting fields with the EditV32 application available on the **HMA Technology Inc.** web-site. In this case a lighter mixed background was used.

The objective is to illustrate some variety to demonstrate how automatic tracking can be modified for difference situations

Click **[Forward]** for the next panel.
Forward Back

Forward Back

2. Considerations

There are a number of factors to consider when preparing video files for automatic tracking.

a) The use of reflective tape increases the success of automatic tracking significantly.
b) To provide sufficient reflection from markers a light source must be positioned near the camera. In this case the light source was a 150 watt flood light. Powerful spot lights or intense lighting is not required. See **Figure 3**.

Figure 5
Light source for reflective markers.

c) A small exposure time is important, especially for tracking rapid motion. Small exposures time result in underexposed video's, however this is a benefit since it enhances the differentiation between the background and reflective markers.
d) Test capture sessions should be used to eliminate all possible white reflecting surfaces that might interfere with the markers.

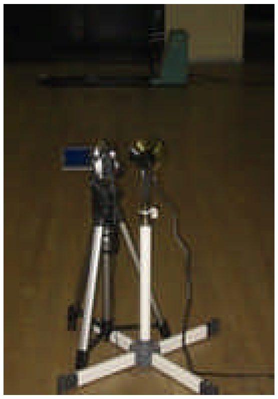


Figure 6
Capture configuration for Practice Exercise.

e) Higher frame rates are critical for monitoring rapid motion. If the marker displacement between frames is large, particularly when combined with direction change, the prediction success is substantially reduced.

Forward Back

Forward Back

3. Automatic Tracking Practice Exercise #1

In this first exercise, we will track a single toe point during walking.

> Click the **[File][Load Trial]** menu item. In the Load Trial window mark the **walkk.avi** file and click **[OK]**. "Play" **[>]** the video and then click **[R1]** to re-set to the start.

At this point we need to import the “Single Point” collection template.

> Click the **[Edit][Trial Set Up]** menu item to display the <Trial Setup> window.

> Survey the **List of Trial Set Up Titles**. Locate the and mark the **<Single Point>** item and click **[Load],** responding **[Yes]** to the caution query.

Click **[Exit]** in the **TRIAL SET UP** window.

We can now move directly to the automatic digitizing procedures.

Click **[Forward]** for the next panel.
Forward Back

Forward Back

4. Digitizing and Automatic Tracking

> Click the **[Options][Digitize]** menu item to display the **Digitizing Screen** and the **Digitize** window.

> Before proceeding with automatic tracking, two frames of data must be collected. This locates the target marker and its initial movement pattern.
>
> Position the mouse cursor on the toe marker and click to collect the data for the first frame.
>
> Now click the mouse over the **Digitizing Screen** to automatically advance the video to frame 1. Collect the data for the second frame by again clicking the mouse arrow while positioned over the toe marker.
>
> Click the mouse over the **Digitizing Screen** to advance the video to frame 2.
>
> We are now ready to initiate the automatic tracking process.
>
> Click the **[Auto-Tracking]** button in the **<Digitize>** window (found about 1/3 down the window) to display the **<Auto Tracking>** window.

Click **[Forward]** for the next panel.

Forward Back

Forward Back

5. Automatic Tracking Settings.

There are a number of settings to review before proceeding with automatic tracking. The automatic tracking procedure basically defines a search rectangle based on the previous motion, and then searches this rectangle for the target marker. It is looking for a target marker whose pixel RBGs values exceed a set threshold. If it does not find the target marker, it continues the search for a defined number of attempts before quitting.

The setting you should review before initiating the automatic tracking procedure are:

1. **Prediction [X] [Y]**. The location of a search square is predicted based on the previous motion of the marker, when **[X]** and **[Y]** components have been activated. Deactivating **[X]** and/or **[Y]** means that either the **[X]** and/or **[Y]** position is fixed at the last known position during the search process. The default mode is to predict both **[X]** and **[Y]** motion and we will start our first search using this setting.

2. **Add.** This setting forces a higher or lower search depending on whether the value is plus or minus.

3. **Search Area**. This sets the size of the search square in pixels. The default size is 40 pixels. This search square size is commonly used for reasonably slow motion such as in as normal walking stride and at image sizes used in this exercise, but at times it is also appropriate for faster movements. For faster movement, for example running, as search square of 60 pixels is normally more successful. Faster motions result in greater displacement between frames and it more difficult to predict locations. The trade off is between selecting a large enough search square to locate the marker, although not too large where it will possibly locate a different marker in error. Users generally find an optimum search size depending for similar sized images and movements.

4. **Misses**. This sets the number of frames over which attempts will be made to locate lost markers. Markers are typically lost when covered momentarily by another part of the body or and object. The greater the number of misses included, the higher the possibility of locating a different marker in error.

5. **Low White Level**. Markers are located by using their RGB colour value. Pure white is (255,255,255). The **Low White Level** sets the minimum value which is accepted. The default is 170 which means that markers need to have a minimum RGB level of (170,170,170) before they are detected. The possible range for this value is determined by the colour of the background and non-target areas. The **<Show Pixel Colour>** procedure available through the **<Auto-Tracking**> window allows uses to see the colour levels at any place in the video frame. The tracking process locates the middle of the located pixels and therefore it is best to not use too high a value for white level if the marker is not of uniform brightness throughout.

6. **Marker List Box**. The list box at the bottom of the <Auto-tracking> window identifies the markers which are on the search list. When some markers are complete and correct while others are incomplete or correct, this permits the users to limit the marker search so as to not destroy good data that is already complete. The default setting is to include all markers.

7. **Show Search**. Selecting this option means that the position of the search square will be shown and motion paused when the **[Auto Track (Process)]** procedure has been activated. This is a very useful option to assist in identifying problems in the automatic location procedure.

8. **Show Pixel Color**. Selecting this option means that when the mouse cursor is clicked when over the video screen, the **RGB** value of the selected pixel will be displayed. The is useful when trying to define an optimum **Low Color Level**.

Click **[Forward]** for the next panel.
Forward Back

Forward Back

6. Automatic Tracking.

We will start by using the default settings and therefore are ready to begin automatic tracking.

> **Make sure that the video window is unobstructed. The tracking is performed by evaluating the pixel colours on the screen**. Click the **[Auto-Track (Process)]** button and respond **[Yes]** to the proceed question.

That's it! If you have been successful here will be an "+" marker over the toe in the last frame.

> Click the play button **[>]** in the **[Digitizing]** window to review your collection. To review it more slowly use the single frame advance **[|>].**
> Click the **[Exit]** button in the [**Digitizing]** window to close both the **Digitizing Screen** and [Auto-Tracking] window.
> From the main screen, click the play button **[>]** in the **<Video-Model Control>** window to view the model of the single point collection in motion. In this case the marker is represented by a circle.

That is the end of **Exercise #1**. Proceed to the next panel for **Exercise #2**.

Click **[Forward]** for the next panel.
Forward Back

Forward Back

7. Automatic Tracking Practice Exercise #2

In this exercise, we will load the same walking video, but will track all the markers

> Click the **[File][Load Trial]** menu item. In the Load Trial window mark the **walkk.avi** file and click **[OK]**. "Play" **[>]** the video and then click **[R1]** to re-set to the start.

At this point we need to import the "**6 Pt. Lower Limb**" collection template.

> Click the **[Edit][Trial Set Up]** menu item to display the **<Trial Setup>** window.

> Scroll down the **List of Trial Set Up Titles** and locate and mark the **<6 Pt. Lower Limb>** template and click **[Load],** responding **[Yes]** to the caution query.

Click **[Exit]** in the **TRIAL SET UP** window.

We can now move directly to the automatic digitizing procedures.

Click **[Forward]** for the next panel.
Forward **Back**

Forward **Back**

8. Digitizing and Automatic Tracking

> Click the **[Options][Digitize]** menu item to display the **Digitizing Screen** and the **Digitize** window.
> Click the **[Fit to Size]** button in the **<Digitize>** window**.**
> Before proceeding with automatic tracking, two frames of data must be collected. This locates the target markers and their initial movement pattern.
> Collect the data for the following markers in the order listed, clicking on the **Digitizing Screen** at the end of each frame collection to advance the video.

1. mid-superior iliac spine (MSIS, located directly above and in line with the hip joint center in erect standing)
2. hip (greater trochanter)
3. knee (femoral epicondyle)
4. ankle lateral malleolus
5. toe (at front of shoe near ground level)
6. heel (at the back of the heel near ground level)

At the end of the two frame collection you should be on frame 2 (having collected frame 0 and 1).

> **Make sure that the video window is unobstructed. The tracking is performed by evaluating the pixel colours on the screen**. Click the **[Auto-Tracking]** button in the **<Digitize>** window (found about 1/3 down the window) to display the **<Auto Tracking>** window.
> We will use all of the default settings therefore click the **[Auto Track (Process)]** to complete the tracking procedure.

That's it! If you have been successful, the display of the last screen will show the completed model. If you were not successful, repeat the instructions for **Exercise #2** and repeat the procedure.

Common errors:

1. Incorrect order of collection. Re-collect the data for the first two frames. Note that after auto-tracking, the collection mode is set to **<Point over Frames>**. This must be changed to **<Frame by Frame>** digitizing (at the top of the **<Digitizing>** window) before proceeding with the **<Re-collect this Frame>** option

> Click the **[Exit]** button in the **<Digitize>** to return to the main window.

\> Click the play button **[<][Digitize]** in the **<Video-Model Control>** window to review the results again

If you have been successful you are ready to proceed to Exercise #3.

Click **[Forward]** for the next panel.

Forward Back

Forward Back

9. Automatic Tracking Practice Exercise #3

The instructions for Exercise #3 will be less detailed, since the basic process has been covered

In this exercise, we will digitize a **subject walking on the ground**. The field of view is about 3-4 m. and so the figure is considerably smaller than in the first exercise. In addition, the light level higher and the background mixed

\> Load the **walkl.avi** file.
\> Go to the **[Edit][Trial Set Up]** window and load the **<6 Pt. Lower Limb>** template.
\> Return to the main window and then open the **<Digitizing>** window. Click the **[Fit to Size]** button in the **[Digitizing]** control window.
\> Digitize the first two frames and move to the next frame (frame 2).

The collection points are:
1. mid-superior iliac spine (MSIS, located directly above and in line with the hip joint center in erect standing)
2. hip (greater trochanter)
3. knee (femoral epicondyle)
4. ankle lateral malleolus
5. toe (at front of shoe near ground level)
6. heel (at the back of the heel near ground level)

\> Open the **<Auto-Tracking>** window.
\> Click the [Reset] button to ensure we are starting with the default settings.
\> Since the figure is substantially smaller reduce the "**Search Size**" to **20 pixels**. The foreground/background differentiation is also not as great and therefore set the "**Low White Level**" to **190**. The best settings are normally determined by testing with a sample collection and then documenting these settings for a given test situation. The examples given in this **<Practice Exercise>** provide a variety of conditions as a starting point.
\> Double check the settings and then click **[Auto Track (Process)]** to initiate the tracking procedure.

<u>That's it!</u> If you have been successful, the display of the last screen will show the completed model. If you were not successful, repeat the exercise carefully.

\> Click the **[Exit]** button in the **<Digitize>** to return to the main window.

\> Click the play button **[>]** in the **<Video-Model Control>** window to review the results again

If you have been successful, you are now ready to move to **Exercise #4.**

10-9

Click **[Forward]** for the next panel.
Forward   Back

Forward Back

10. Automatic Tracking Practice Exercise #4

The instructions for **Exercise #4** will again be less detailed, since the basic process has been covered

In this exercise, we will digitize a **subject treadmill running** at 6 mph.

> Load the **runc.avi** file.
> Go to the **[Edit][Trial Set Up]** window and load the **<6 Pt. Lower Limb>** template.
> Return to the main window and then open the **<Digitizing>** window and click the "**Fit to Size**" button.
> Digitize the first two frames and advance to the next frame (frame 2).

The collection points are the markers at:
1. mid-superior iliac spine (MSIS, located directly above and in line with the hip joint center in erect standing)
2. hip (greater trochanter)
3. knee (femoral epicondyle)
4. ankle lateral malleolus
5. toe (at front of shoe near ground level)
6. heel (at the back of the heel near ground level)

> Open the **<Auto-Tracking>** window.
> Click the **[Reset]** button to ensure we are starting with the default settings.
> In the treadmill walking we used a "**Search Size**" of 40 pixels. Even at 60 fps the pixel displacement between frames is greater, therefore change this setting to **50 pixels**. Also, since we are under low light conditions we again can used a "**Low White Level**" of **170**. It is best to use a lower setting here if possible, as the search can find the full extent of the marker and therefore more accurately determine its center.
> click the **[Auto-Track (Process)]** button to initiate the tracking procedure. When complete, click the play **[>]** button in the **<Digitize>** screen to review the results.
> This time you will find that you have been successful except for the **MSIS** marker is lost after the first step. To retain all the correct data, click **the [Clear]** button above the marker list in the **<Auto Tracking>** window and click the **MSIS** marker, as it is the only one we need to process, In treadmill running where the motion of the treadmill offsets the motion of the subject incorrect predictions can occur. As a test de-activate the **[X]** and**[Y] Predict** option, and re-start the **[Auto-Track (Process)].** After processing click the play **[>]** button in the **<Digitize>** screen to review the results.
> **That's it!**

If you have been successful, you are now ready to move to the final **Exercise #5.**

Click **[Forward]** for the next panel.

Forward BacK

Forward Back

11. Automatic Tracking Practice Exercise #5

The instructions for **Exercise #5** will again be less detailed, since the basic process has been covered

In this exercise, we will digitize a **subject running on the ground.**

> Load the **rund.avi** file.
> Go to the **[Edit][Trial Set Up]** window and load the **<6 Pt. Lower Limb>** template.
> Return to the main window and then open the **<Digitizing>** window and click the "**Fit to Size**" button.
> Digitize the first two frames and advance to the next frame (frame 2).

The collection points are the markers at:
1. mid-superior iliac spine (MSIS, located directly above and in line with the hip joint center in erect standing)
2. hip (greater trochanter)
3. knee (femoral epicondyle)
4. ankle lateral malleolus
5. toe (at front of shoe near ground level)
6. heel (at the back of the heel near ground level)

> Open the **<Auto-Tracking>** window.
> Click the **[Reset]** button in the **<Auto Tracking>** window so we can start with the default settings.
> In the normal walking using a video with the same width of field we used a "**Search Size" of 20 pixels**. Since running incorporates more marker movement we will set the **"Search Size" to 30 pixels**. Also, again our light is brighter and background differentiation is less therefore set the "**Low White Level" to 190**.
> For the initial pass, both the **[X]** and **[Y] Predict** options should be activated.
> **Make sure that the video window is unobstructed. The tracking is performed by evaluating the pixel colours on the screen**. Click the **[Auto-Track (Process)]** button to initiate the tracking procedure. When complete, click the play **[>]** button in the **<Digitize>** screen to review the results.
> This time you will find that you have been successful except for the **MSIS and hip** markers which show a transfer from one location to the other. To retain all the correct data, click the [**Clear]** button above the marker list in the **<Auto Tracking>** window and click the **MSIS and hip** markers as they are the ones we need to process. Since the subject is actually moving forward this time de-activate only the **[Y] Predict** option, and re-start the **[Auto-Track (Process)].** Click the play **[>]** button in the **<Digitize>** screen to review the results.
> **That's it …well, almost**. This time the **MSIS** marker is lost from frame 33 on.
> First, click the "**hip**" entry in the marker list so it is de-activated. Since it is complete we do not want to re-process it.
> This time, as a demonstrate, we will use a **manual correction**. Play or single frame advance to frame 33. Click the down arrow on the drop down list (In the <**Digitize**> window), to display the collection points and select the MSIS marker. Note that the collection mode is "**Points Over Frames**" (at the top of this window) which is required for the manual replacement of points.
> The correct **MSIS** marker is missing in frame 33 so put the mouse pointer in the vicinity and

click the RIGHT mouse button which registers a “zero” for a missing point. Now click the LEFT hand mouse button to advance to frame 34.

> Continue this procedure until you get to frame 40 where the marker is just beginning to make its reappearance. Now use the LEFT hand mouse button to collect the MSIS marker and a second LEFT click to advance the video for the next two frames. After digitizing the MSIS marker in frame 41 you should advance to frame 42.
> If you make mistakes in the manual corrections, you can go back again and repeat the process.
> We can now re-start the tracking by clicking the **[Auto-Track (Process)].**
> When processing is complete, click the play **[>]** button in the **<Digitize>** screen to review the results.
> The pixels between frames 33 and 40 are still missing as we manually digitized them as zeros. We can force interpolation for the hidden points by clicking the **[Fill Missing Points]** button in the **<Auto Tracking>** Window.
> We are now complete. Review the results which should now be correct and complete.

If you have been successful, you have now completed all the exercises and reviewing both the settings and many manual intervention corrections

Click **[Forward]** for the next panel.
Forward Back

Back

12. What next?

That concludes the automatic tracking practice for this exercise. If you have 3D installed then the **Demonstration** <**Lower Limb Tracking / 3D Analysis**> provides some additional examples and practice in different situations again.

Hints for data correction in automatic tracking:

> After an interval when a marker goes missing, you can manually digitize two frames and then re-start the auto-tracking.
> Missing markers can be interpolated using the **[Fill Missing Points]** procedures as long as there are correct markers before or after this interval.
> If markers are incorrect and you wish to remove its value for a particular frame, select the marker from the list, and instead of clicking the left hand mouse button, click the right hand mouse button. This sets the marker value to zero which is interpreted as a missing marker.
> If you have not done so read **Chapter 7** in the **Reference Manual**.

Good luck on your digitizing and tracking!

Click **[Forward]** for the next panel.

Back

11 . A FIRST "GENERAL" 3D COLLECTION

Forward

A First “General” 3D Collection
(Note that if the instruction panel is ever lost, it can be re-displayed by clicking the [Help][Exercise Help] menu item).

This **Practice Exercise** will guide the user through the process of preparing a **General 3D Data** set. **General 3D Data** refers to collections where joint centers are estimated directly as opposed to using external markers as a guide to calculating joint centers. External markers can, of course, still be used as a guide to digitizing the required joint center.

Specifically, this **Practice Exercise** will collect data for the upper limb and ball during an overhand throw, followed by analysis of selected measures.

Before starting, the user should be experienced at two-dimensional digitizing and analysis, and in addition the following “3D” related **Demonstrations** should have been completed.

Hu-m-an Overview - General 3D
Control Matrix Digitizing (Specifically <u>Con-a</u>)
Generating General 3D Data

This demonstration will introduce:

1. **Planning the analysis.** The basic requirements for 3D general data generation.
2. **Data collection.** Two-dimensional digitizing for 3D data.
3. **Application of the DLT.** Creation of the 3D data set.
4. **Analysis of the data.** A example of selected measurements.

Joint Center Marking.
It is good clinical practice to carefully mark joint centers to improve consistency and accuracy in digitizing. Skilled data collectors recognize, however, that for two-dimensional analysis, surface markers only aid in identifying the true underlying joint center. The center of surface markers often do not fall directly over the true joint center, as a result of incorrect placement, shifting of clothing or surface tissue, and rotation of the limb or segment under investigation. Beginners can introduce error by incorrectly assuming that the markers are always accurate. The absence of joint centers in many of the videos provided in **Hu-m-an** is intentional, with the objective of providing practice in identifying joint centers as a basis for accurate portrayal of the underlying segment. During the digitizing process, the line drawn between collected points should accurately represent the segment in question. Videos with joint markings are also provided for other practice sessions. Biomechanical analysis is used for gaining insight into human movement and skill performance and, at this stage, each instructor and student will need to determine the importance and practicality of using joint center markings depending on the situation. For research purposes, joint center marking becomes a far more important issue.

Remember that this <u>Instruction Window</u> can be closed, moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components. It is often preferable to complete labs using a hard copy print out instead of from <u>on the screen</u> windows, and in this case the <u>Instruction Window</u> should be closed.

Click **[Forward]** for the next panel.

Forward

HU-M-AN

Forward Back

1. Planning the Analysis.
The assumed starting point is that video files are available of an appropriate control matrix and a subject executing an overhand throw from two cameras. For this exercise these 4 files are:

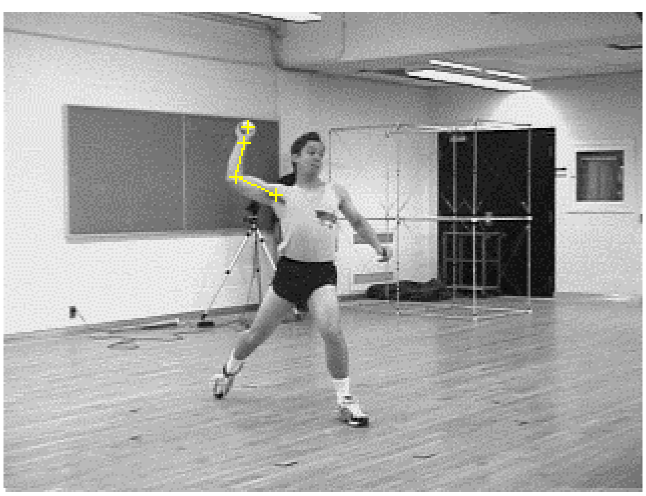
con1.avi - control matrix from camera 1
con2.avi - control matrix from camera 2
throw1.avi - overhand throw from camera 1
throw2.avi - overhand throw from camera 2

In addition, two example pre-digitized files of the throw and a completed 3D file with the selected calculations has been provided.

example1.ht0 - digitized overhand throw 2D file from camera 1
example2.ht0 - digitized overhand throw 2D file from camera 2
example.h30 - 3D data with selected variables (remember, this file is only visible after using the **[Go to 3D]** procedure)

The 18 point, 4 cubic meter control matrix (**con-a**) will be used, together with the associated **con-a.rea** real value file.

For the overhand throw, four points will be collected:
1. ball
2. wrist
3. elbow
4. shoulder



11-3

Figure 1 Collection Points

For this particular demonstration, it will be assumed that the video files have not been trimmed or necessarily synchronized. As a separate operation not demonstrated here, the **Dual** option for simultaneous display of two videos is a useful tool to determine the synchronization of the video files.

For expediency, the current collection will be very short, simply concentrating on the 8 frames leading up to the release.

The user should become familiar with switching between the **[Boot Area]**, the directory where the exercise begins, and the **[Local Data Area]**, which is the local directory where the data is to be saved.
Similarly the user should be comfortable with using **the [Go to 2D]** and **[Go to 3D]** buttons in the **<Load Trial>** window, which switches the file listing from 2D to 3D files.

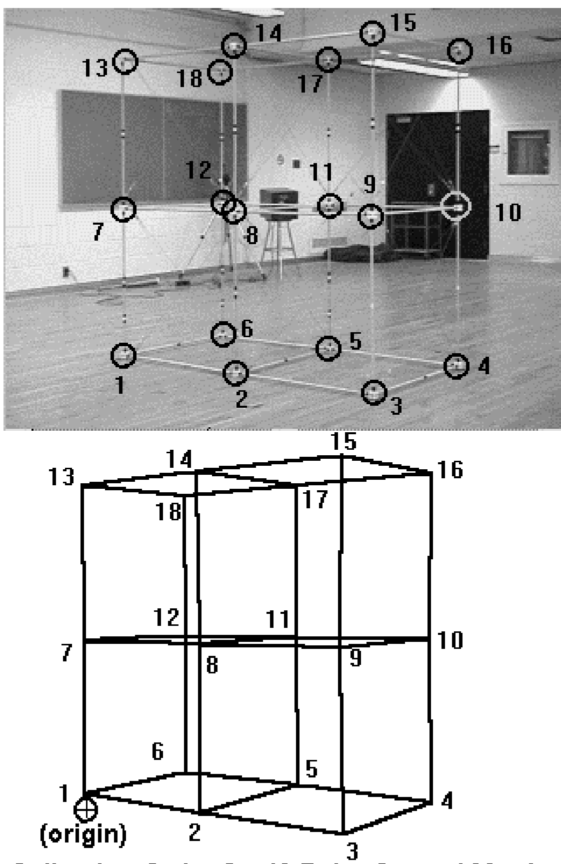
Click **[Forward]** for the next panel.
Forward **Back**

HU-M-AN

Forward Back

2. Data Collection – Digitizing the Control Matrix

Figure 2 below shows a video of the control matrix as viewed from camera #1 and a schematic of the same 18 points. The order of collection must be the same for all views. The **con-a.rea** real value file shows the coordinate values assigned to the 18 points in forming the global frame of reference.



Collection Order for 18 Point Control Matrix
Viewed From Camera 1

"Real Value" file (in box)
for 18 Point Control Matrix
(e.g. 'con-a.rea')
for Origin under Pt. 1
at Ground Level

X	Y	Z Coordinate	Collection Point
18 1			
0.000	0.000	0.018	1
1.000	0.000	0.018	2
2.000	0.000	0.018	3
2.000	1.000	0.018	4
1.000	1.000	0.018	5
0.000	1.000	0.018	6
0.000	0.000	1.018	7
1.000	0.000	1.018	8
2.000	0.000	1.018	9
2.000	1.000	1.018	10
1.000	1.000	1.018	11
0.000	1.000	1.018	12
0.000	0.000	2.018	13
1.000	0.000	2.018	14
2.000	0.000	2.018	15
2.000	1.000	2.018	16
1.000	1.000	2.018	17
0.000	1.000	2.018	18

Figure 2 Control Matrix

> Click the **[File][Load Trial]** menu item. In the **<Load Trial>** window mark the **con1.avi** file and click **[OK]**.

> Click the **[Edit][Trial Set Up]** menu item to display the **<Trial Set Up>** window.

> From the **List of Trial Set Up Titles**, scroll down and mark (click) **the 18 Pt. Control (a)** template. Click the **[Load]** button, responding **<Yes>** to the caution and then **[Exit]** the **<Trial Set Up>** window.

> Click the **[Options][Digitize]** menu item to display the **<Digitizing>** window.

> Click the **[Regular]** option radio button located approximately one-half down the **<Digitize>** control window.

Click **[Forward]** for the next panel.

Forward Back

HU-M-AN

Forward Back

Digitizng

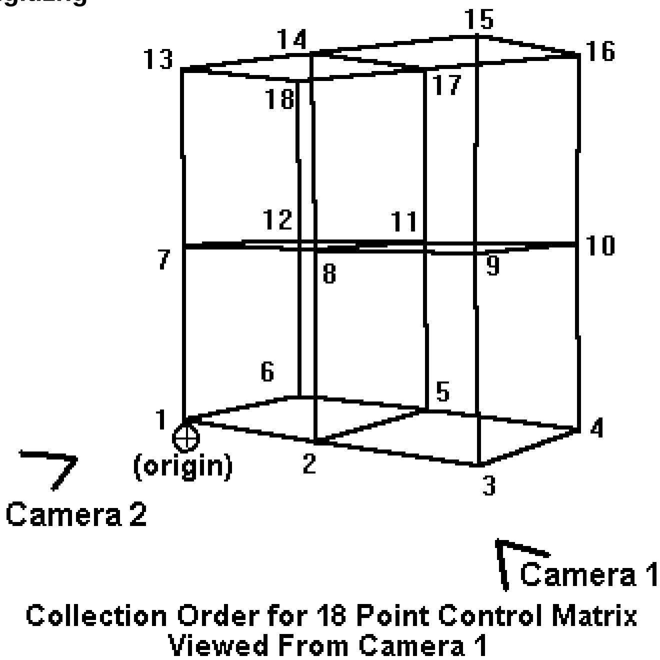


Figure 3 Collection Order

Digitize in order the 18 control points. Note that with proper digitizing, the connecting lines should follow the rod dowels.

> After the 18th point is collected, if any points need to be adjusted, click on the **[Replacement Mode]** option (about one-third down the **<Digitize>** control window) and move the erroneous points. **When finished, re-click the [Replacement Mode] option to turn off.**
> Now, re-click the mouse over the video screen to advance to the next frame.
> Click the **[Repeat Collection]** button (not the **[Re-collect this Frame]** button], to automatically digitize the second frame. The control videos in **Hu-m-an**, by default, contain three frames.
> Now, re-click the mouse over the video screen to advance to the next frame, and again click the **[Repeat Collection]** button.
> Click the **[Exit]** button at the bottom of the **<Digitize>** control window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Saving the Control Matrix Data

> Click the **[File][Save As]** menu item.
> The current path is the **Practice Exercise** disk area on the CD or Server. Since these are typically read only disks, the path needs to be changed to a different area. The **Local Data Area** is used for this purpose. Click the **[Local Data Area]** button at the bottom of the **<Save Trial As>** window. Sub-directories **[user01]**, **[user02],** etc., will now be listed. Select one of these, mark it and click the **[Change Path]** button. If files already exist in this directory, click the **[Up One Level]** button, and then try another **user** directory. It is possible to delete files from this window, using the **[Delete]** button in the bottom left, if this is appropriate.
> The current assigned **File Name** is **con1.ht**. The **.avi** extension is reserved for video files only. Add a zero to the end of the name completing it as **con1.ht0**. This follows the **Hu-m-an** recommended protocol of naming original source data as **.ht0**.
> Now click the **[Save]** button looking at the message area at the bottom for the **"Save Successful"** confirmation.
> **[Exit]** the **<Save Trial As>** window.

If the **Save Successful** confirmation message does not appear, do not make a final exit from the **Hu-m-an** program or the data may be lost. Re-trace the save procedures or obtain help from an experienced user.

> Now repeat the process, digitizing data from the **con2.avi** control matrix file. If necessary go back to **2. Data Collection – Digitizing the Control Matrix** and follow the instructions substituting **con1** with **con2**. Remember on saving the new data to go to the same **<User>** area.
> At the conclusion of this process you should end up with a **con1.ht0** and **con2.ht0** file in one of the **user** directories

The accuracy of the final results is determined in large part by the accuracy of the control matrix data used in the **Direct Linear Transform**. The **con?.ht0** data can be re-loaded at any time, and corrections can be made using the **[Replacement Mode]** procedure. **The most important check is that the displayed connecting lines fall directly on the dowel rods.**

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Checking the Control Matrix 3D Results

As an optional check, a three-dimensional model of the control matrix will now be constructed to visually inspect the success of the procedure.

The first task is to transfer the real data file, in this case **con-a.rea**, to the same directory. For original analysis this file is created using a text editor and then saved to the proper directory using normal procedures. **Hu-m-an** provides special procedures when using template control files

Transferring the **con-a.rea** file.

- **>** Click the **[Utilities][Transfer Control Matrix File][con-a real value file]** menu item. An information message box is shown which lists the directory for copying the **con-a.rea** file. This should be the **user** directory, which contains the saved control files. Respond **[Yes]** if this is true. If a current **con-a.rea** file exists it can be overwritten.
- **>** The directory to which the **con-a.rea** file is to be copied is based on the most recently saved file. If this operation is executed at a different time and the message box shows an incorrect target destination, then the **con1.ht0** file should be re-loaded from the proper <u>user</u> directory and then re-saved prior to again proceeding with the current instruction.

- **>** **Applying the DLT**
- **>** Click the **[File][Load Trial]** menu item. Click the **[Local Data Area]** button and then select the sub-directory where the control data is saved and click the **[Change Path]** button to view the directory listing.
- **>** Click **the [Go to 3D]** button and click on the **[Apply DLT]** checkbox. The 3 files, **con-a.rea**, **con1.ht0** and **con2.ht0** should be listed.
- **>** The **[Control Files]** radio button is checked by default, the **Camera No.** is set to **2** by default and the **Select Camera 1 Control File** listing is high-lighted.
- **>** Click on the **con1.ht0** and then the **con2.ht0** listing to update the control file names.
- **>** Now select the **[Control Real]** radio button and click on the **con-a.rea** file.
- **>** Finally, click on the **[Source Data]** radio button and click on the **con1.ht0** and **con2.ht0** files again, as these are also the target data.
- **>** Now click on the **[OK]** button to activate the **DLT** application.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Checking the Three-dimensional Results (Continued)

If the **DLT** application has been successful then a 4-square model will appear in the **<Model>** window. If not successful, then repeat the procedure carefully, and if necessary, re-view the appropriate **Demonstrations** to understand the required operations.

When successful, a new **<Model Rotation>** window will also be displayed on the screen.

- **>** Click on **[Axis]** button in the **<Model Rotation>** window to display the global **XYZ** axis orientation.
- **>** Click and **hold** the appropriate up-arrows to set the **X** value to about **35,** and the **Y'**(prime) value to about **35**. Click the **[Center]** button on the right side of the **<Model Rotation>** window
- **>** Now **click and hold** the **Z**'' (double prime) button and observe the rotating 4-square meter control matrix.

If the figure is correct, you are now ready to proceed with subject digitizing.

To be visually correct, the object should be rotating counter-clockwise as the **Z** value increases, and the **XYZ** axes should correspond to the normal right-hand rule. If it is in reverse, this is not an error, but you are, by default, seeing the reverse figure. This is akin to the seeing the inside and outside views of a **3D** cube drawn in two dimensions. With practice you can force yourself to see the correct orientation**. Visual perception is one of the difficulties of 3D analysis and presentation!**

A **[Reset]** button is provided to set all values at their starting point.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Data Collection – Digitizing the Performance Video Data

Figure 4 below shows a sample video frame of the subject performing the overhand throw as viewed from camera #1. As described in the planning section, four points will be collected:

1. ball
2. wrist
3. elbow
4. shoulder

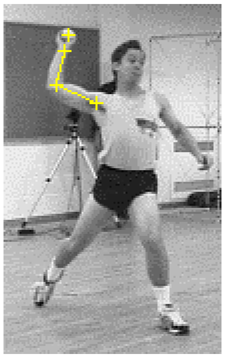


Figure 4 Subject Data Collection

To review a sample collection:

> Click the **[File][Load Trial]** menu item. Note that, as a result of the previous DLT operation, you may not be in the proper directory. If the **example** files are not present, click the **[Boot Area]** button to return to the original directory area. In the **<Load Trial>** window mark the **example1.ht0** (camera #1) file, and click **[OK]**. **]**. Note that **.ht** files are 2D files and the title bar in the window should be **<u>Load 2D Trial</u>**. If necessary use the **[Go to 2D]** button.

> Click the **[Options][Digitize]** menu item to display the subject with an overlay of the digitized points and the connecting lines. Use the single frame advance (**[|>]**) and view the collected points throughout the performance. Move the **<Digitize>** control window if necessary. In particular, pay attention to the selected joint centres and the ball after release. When finished, click the **[Exit]** button.

> Follow the same procedure to load and view the **example2.ht0** file, which is from camera #2.

Click **[Forward]** for the next panel.
<u>Forward</u> **<u>Back</u>**

HU-M-AN

<u>Forward</u> **<u>Back</u>**

Digitizing the performance videos.
You are now ready to digitize the movement video files.

> Click the **[File][Load Trial]** menu item. In the **<Load Trial>** window mark the **throw1.avi** (camera #1) file, and click **[OK]**. As previously explained, if you are not in the proper location, click the **[Boot Area]** button to return to the original directory area.

> Click the **[Edit][Trial Set Up]** menu item to display the **<Trial Set Up>** window.

> From the **List of Trial Set Up Titles**, scroll down and mark (click) the **<u>4 Pt. Upper Limb w Ball</u>** template. Click the **[Load]** button, responding **<Yes>** to the caution and then **[Exit]** the **<Trial Set Up>** window.

> Since only a small interval of the actual throw will be digitized at this time, it is necessary to set up a trial sub-sequence. Click the single frame forward button (**[|>]**) until you reach frame **38** and then advance the **<Start>** frame number in the **<Video-Model Control>** window to the same **38** number. Again using the single frame forward button (**[|>]**), advance the video until you reach frame **45** and then set the **<End>** frame number in the **<Video-Model Control>** window to the same **45** number.

> Click the **[Utilities][Set a New Trial Sub-Sequence]** menu item and respond **[Yes]** to the caution message. The **Start** and **End** boxes should now display **<u>0</u>** and **<u>7</u>** respectively. You are now prepared for a limited 8-frame collection.

- **>** Click the **[Options][Digitize]** menu item to display the **<Digitizing>** window.
- **>** Click the **[Predict]** option, about 2/3 down the **<Digitize>** window.
- **>** Digitize in order (as shown in the **<Digitize>** control window) the center of the ball, followed by the wrist, elbow and shoulder joints centers for frame zero. Click the left mouse button one more time (with the arrow anywhere over the video), to automatically advance one frame, and continue to digitize a until all the frames are complete. Note that connecting lines will overlay the segments to permit a visual inspection of the collection accuracy. **You may need estimate points when the hand and wrist are not clear and move the <Digitize> control window to see the ball flight.**
- **>** When all eight frames (0-7) have been successfully digitized **[Exit]** the **<Digitizing>** control window. You may now play the digitized model (and video overlay model) if you wish.

Click [Forward] **for the next panel.**

Forward **Back**

HU-M-AN

Forward **Back**

Saving the Performance Data for the First Video

- **>** Click the **[File][Save As]** menu item.
- **>** The current path is the **Practice Exercise** disk area on the CD or Server. It is necessary to save the performance data in the same **Local Data Area** that was used for the control matrix data. Click the **[Local Data Area]** button in the **Save As** window, select the same user area as previously identified, and click the **[Change Path]** button. You should see a listing of the previous control **ht** files.
- **>** The current assigned **File Name** is will be **throw1.ht**. The **.avi** extension is reserved for video files only. Add a zero to the end of the name completing it as **throw1.ht0**. This follows the **Hu-m-an** recommended protocol of naming original source data as **.ht0**.
- **>** Now click the **[Save]** button looking at the message area at the bottom for the **"Save Successful"** confirmation.
- **>** **[Exit]** the **<Save Trial As>** window.

If the **Save Successful** confirmation message does not appear, do not make a final exit from the **Hu-m-an** program or the data may be lost. Re-trace the save procedures or obtain help from an experienced user.

Continuing to Digitize the Second Video

- **>** Click the **[File][Load Trial]** menu item. In the **<Load Trial>** window mark the **throw2.avi** (camera #2) file, and click **[OK]**. As previously explained, if you are not in the proper location, click the **[Boot Area]** button to return to the original directory area.
- **>** Proceed with processing the second video file in exactly the same manner as for the first video file. Go back to the previous instruction panels, if necessary. This includes:
  - loading the collection template, **4 Pt. Upper Limb w Ball**
  - setting the same **trial sub-sequence** (frames 38-45) as for video #1. Both video files for this exercise are the same length and have been synchronized. You end up with the same length (0-7) trial.
  - digitizing the eight frames of data
  - saving the **throw2.ht0** file to the same **<Local User Area>** sub-directory.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Establilshing the Control Real Data File

At this point, four files should have been saved to the same **Local User Area** sub-directory, namely:
con1.ht0
con2.ht0
throw1.ht0
throw2.ht0

The final file required is the **real value** file for the control matrix. This file was already transferred in making the **DLT** application check procedure and it does not need to be repeated at this time. When a user provided control matrix is employed, then a text editor is used to create the proper **.rea**, real value file.

For review the transfer procedure was: (These do not need to be repeated at this time)

****
In our case, since the **18 Pt. Control (a)** template was used, the built in procedure can be applied to transfer the required **con-a.rea** file to the source data sub-directory.

> Click the **[Utilities][Transfer Control Matrix File][con-a real value file]** menu item. Carefully read the destination directory to confirm it is the same location as used for the source digitized data. The destination location is set when the data is saved after digitizing. If the **[Set Local Control]** procedure is activated at a different time, then the destination can be re-set by loading a digitized file (e.g. **con1.ht0**), and re-saving it over itself. Then proceed with the **[Set Local Control File]** function.

> Assuming the destination directory is correct, respond **[Yes]** to the **Query** question. If a control file is already present it can be replaced.

****

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

3. Application of the Direct Linear Transform.

> Starting from the main **Hu-m-an** window, click the **[File][Load Trial]** menu item. Go to the same **[Local Data Area]** where the previous files were saved.
> Click the **[Go to 3D]** button and then click the **[Apply DLT]** checkbox.
> Five files should be listed, namely:

con-a.rea - the real value file recently transferred, and the four source data digitized data files,
con1.ht0
con2.ht0
throw1.ht0
throw2.ht0

> The default number of cameras, listed as **2** is correct.
> The **[Control Files]** radio button is activated by default and the **Select Camera 1 Control File** item is hi-lighted.
> Click the **con1.ht0** file listing and then the **con2.ht0** file to enter these files in the **Select** list.
> Click the **[Control Real]** radio button and select the **con-a.rea** file.
> Click the **[Source Data]** radio button and select the **throw1.ht0** and **throw2.ht0** files.
> Now click the **[OK]** button to create and apply the **Direct Linear Transform**.

If all operations have been successful then a side view of the arm and ball are shown in the model window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Viewing the results

On successful application of the **DLT** the small **<Model Rotation>** window will be displayed. By default the **[X-Z]** or side view is shown. Selecting the **[X-Y]** option displays a top view while the **[Y-Z]** displays a head-on view.

> Clicking and holding the up or down arrow for the **Z (double prime)** axis will rotate the model about the **Z-**axis from this position. The **[Reset]** button returns the model to the start position.
> Experiment with the various views playing the data to familiarize yourself with the three-dimensional representation. It is critically important to fully understand the visual representations before proceeding with analysis.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

4. Analysis of the Data

To demonstrate the potential power of three-dimensional analysis, even with this very short and limited collection, five measures will be calculated:
- elbow angle displacement
- elbow velocity
- upper arm orientation in the horizontal plane
- upper arm orientation in the vertical plane.
- ball speed

The elbow and upper arm motions are of course critical to performance success and cannot be measured using traditional two-dimensional analysis.

To start, a **critical** or event time will be set to define the point of release.

> Click the **[Edit][Trial Set Up]** menu item and ten click the **[Subject – Trial Data]** button to display the **<Subject – Trial Data>** window. Click the **[Add]** button in the **<Subject – Trial Data>** window and replace the **1** with the word **Release**, enter **5** for the frame number and click to check the **[Activate]** box. Frame **5** is the nearest point to ball release. This can be confirmed by single framing the video, while the **<Subject – Trial Data>** window is still visible. Click the **[Exit]** button in the **<Subject – Trial Data>** window and then click the **[Exit]** button in the **<Trial Set Up>** window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Analysis of the Data (continued)

To calculate the elbow angle and velocity:

> Click the **[Calculate][Relative]** menu item to display the **<Relative Angle>** window.
> At the top or the window click the **[3D – Interior]** angle option.
> The **<Elbow angle>** is the default pre-defined angle so it can be used here.
> Click the **[Add Ref. Lines to display model]** option and then click **[Calculate]** complete the operation.
> Click the new **[(3D Interior) Elbow angle]** entry in the **<Graph-Data Control>** window to display the elbow angle.
> Click the **[Calculate][Velocity]** menu item to display the **<Velocity>** window.
> The **(3D Interior) Elbow Angle** is the default target entry and so click the **[Calculate]** button to complete the operation.
> Click the new **[(3D Interior) Elbow angle velocity]** entry in the **<Graph-Data Control>**

window to display the elbow angular velocity.

Note that in the **<Model>** display window, the arms of the selected angle are hi-lighted to confirm the angle selected and calculated.

> Click the **[R2]** button in the **[Video-Model Control]** window to remove this temporary hi-lighting.
> Click the **[Clear/Reset]** button in the **<Graph-Data Control>** window to clear the graph screen.

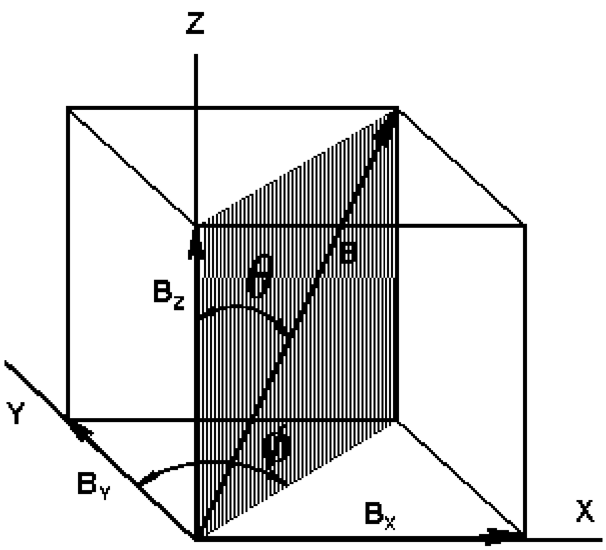
Click **[Forward]** for the next panel.
Forward **Back**

HU-M-AN

Forward **Back**

Analysis of the Data (continued)

The absolute angular orientation of a line segment can be described by **theta** and **phi** as illustrated in the figure below.



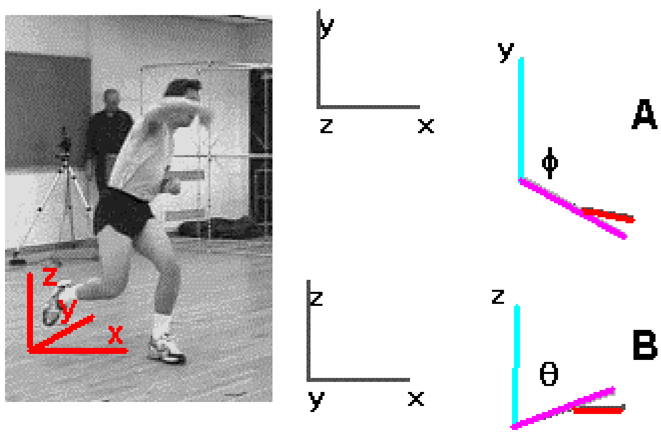
Theta is the angle of segment (e.g. **B**) or line with respect to a vertical, and **phi** is angle of the segment projected to the **X-Y** plane. In **Hu-m-an**, **phi** is measured with respect to the **Y** global axis.

In the analysis of throwing, these measurements give interesting information about the motion of the upper arm in the horizontal plane and its elevation with respect the vertical.

The absolute orientation angles of the upper arm segment.
To calculate phi:

> Click the **[Calculate][Absolute]** menu item to display the **<Absolute Angle>** window.
> At the top or the window, click **the [3D Orientation]** angle option and then the newly displayed **[phi in <X-Y> wrt Y]** option (already activated by default).

> Click the **<Upper arm (wrt shoulder)>** entry which correctly identifies the shoulder and elbow as being the **Vertex** and **Distal** points of the selected segment.
> Finally click on the **[Add Ref. Lines to display model]** option and then click **[Calculate]** complete the operation.
> Click the new **[(phi in <X-Y> wrt Y) Upper arm …]** entry in the **<Graph-Data Control>** window to display the upper arm rotation angle.
> Click the **[X-Y]** plane in the **[Model Rotation]** window and the **[C]** button in the **[Video-Model Control]** window to display the figure with the reference lines shown (**Y** in turquoise, and the upper arm segment projected to the **X-Y** plane in purple). Play the video and model to view the changing orientation. The figure below shows the approximate angle **phi** for the frame 6. Note that in this case it is measured clockwise from the **Y** axis.
> Click **[R2]** in the **<Video-Model Control>** window and **[Clear/Reset]** in the **<Graph-Data Control>** Window.



A) Top View (X-Y plane) for **<u>phi</u>**.
B) Front View (X-Z plane) for **<u>theta</u>**.
(Global axis in turquoise, projected segment or segment in purple, forearm in red.)

To calculate <u>theta</u>:
> Click the **[Calculate][Absolute]** menu item to display the **<Absolute Angle>** window.
> At the top or the window, click **the [3D Orientation]** angle option and then the newly displayed **[theta wrt Z]** option
> Click the **<Upper arm (wrt shoulder)>** entry, which correctly identifies the shoulder and elbow as being the **Vertex** and **Distal** points of the selected segment.
> Finally click on the **[Add Ref. Lines to display model]** option and then click **[Calculate]** complete the operation.
> Click the new **[(theta wrt Z Upper arm …]** entry in the **<Graph-Data Control>** window to display the upper arm vertical orientation angle.
> Click the **[X-Z]** plane in the **[Model Rotation]** window and the **[C]** button in the **[Video-Model Control]** window to display the figure with the reference lines shown (**Z** in turquoise, and the upper arm in purple). Play the video and model to view the changing orientation.
> Click **[R2]** in the **<Video-Model Control>** window and **[Clear/Reset]** in the **<Graph-Data Control>** Window.

Click **[Forward]** for the next panel.

<u>Forward</u> **<u>Back</u>**

HU-M-AN

Forward **Back**

Analysis of the Data (continued)

To calculate ball speed:

> Click the **[Calculate][Velocity]** menu item to display the **<Velocity>** window.
> Click on the **[Ball]** entry in the **<Coordinate Data>** list on the left, click the **[Resultant Speed]** option at the bottom of the window and click the **[Calculate]** button to complete the operation.
> Click the new **[Ball velocity …]** entry in the **<Graph-Data Control>** window to display the measure of ball speed.

Saving the Results:

These results **MUST** now be saved for future reference and practice.

> Click the **[File][Save Trial As]** menu item to display the **<Save Trial>** window.
> You should already be in the originally selected **User** area. If you are not, then use the normal **User Area** access features to locate the same directory.
> A default title such as **throw1.h3** will be listed (.h3 is the default extension for 3D data files). This should be amended and a number or letter should be added so that the title reads something like **throw.h3a**.
> Click the **[Save]** button, confirm that a successful operation has been completed and then **[Exit]** the **[Save Trial]** window.

Click **[Forward]** for the next panel.

Forward **Back**

HU-M-AN

Forward **Back**

Reviewing the results.

Looking at Previously Prepared Results
The results for previously prepared data will be viewed first, followed by the results generated as part of the **Practice Exercise**.

> Click the **[File][Load Trial]** menu item to display the **<Load 3D Trial>** window.
> Click the **[Boot Area]** button to set the proper sub-directory. The file **example.h30** should be listed. If only 2D files are listed, click the **[Go to 3D]** button.
> Click to mark the **example.h30** file and click **[OK].**

This file has been produced in exactly the same manner as the file produced for the current exercise. The **<Graph-Data Control>** window in the bottom left of the screen lists the same five variables that have been calculated previously.

- **>** Click the **[3D Interior] elbow angle** entry. This elbow angle illustrates the elbow extension exhibited as part of the throwing action.
- **>** Click the **[phi in <X-Y> wrt Y …]** entry. This shows the angular displacement for the upper arm projected to the **X-Y** plane.
- **>** Click the **[theta wrt Z …]** entry. This shows the vertical elevation of the upper arm projected with respect to the **Z**-axis.
- **>** Click the **[Clear/Reset]** button to clear the graph screen.
- **>** Click the **Ball Speed** entry. This shows that the speed of ball reaches 23 m/s for this recreational, sub-maximal throw.
- **>** Click the **[Clear/Reset]** button to clear the graph screen.
- **>** Click the **[3D Interior] Elbow velocity**. Note that maximum velocity occurs at the point of release.
- **>** Click the **[Clear/Reset]** button to clear the graph screen.

Click **[Forward]** for the next panel.
Forward **Back**

HU-M-AN
Forward **Back**

Reviewing the results (continued).

Looking at Results of the Practice Exercise.

- **>** Click the **[File][Load Trial]** menu item to display the **<Load 3D Trial>** window. Remember that you can switch between the 3D and 2D file displays by clicking the **[Go to 2D]** or **[Go to 3D]** button, depending on which is active.
- **>** Click the **[Local User Area]** button and locate the directory where you stored the data prepared as part of the **Practice Exercise**.
- **>** Click to mark the **throw.h3a** file (the file you previously saved) and click **[OK].**

Now review in the same manner the five measures calculated as part of the exercise. They should be reasonably similar to the example.h30 data (depending on your digitizing!). If they are significantly different then you may want to repeat the **Practice Exercise** again.

Click **[Forward]** for the next panel.
Forward **Back**

HU-M-AN
Back

End of the Practice Exercise.

This **Practice Exercise** demonstrates some of the powerful features of three-dimensional analysis, since it is not possible to calculate either the elbow angle or upper arm rotation using standard 2D techniques.

It also illustrates the possibility, within the teaching framework, of illustrating key concepts without having to collect long and tedious data sets.

With the practice exercise complete, click the normal **[File][Exit]** menu item to leave the program.

Click **[Forward]** for the next panel.

Back

12 . "CLINICAL" 3D DATA GENERATION [WITH AUTO-TRACKING]

Forward

Clinical 3D Data Generation (with auto-tracking)

(Note that if the instruction panel is ever lost, it can be re-displayed by clicking the [Help][Exercise Help] menu item).

This **Practice Exercise** will guide the user through the process of preparing a **Clinical 3D Data** set. **Clinical 3D Data** refers to collections where external markers are used to mathematically determine the underlying joint centers and position identifiers.

Specifically, this **Practice Exercise** will collect data for the right shank (or calf) and foot during treadmill walking using "**auto-tracking**", followed by analysis of selected measures. By design, normal **Styrofoam** markers are used to demonstrate it is possible when implementing automated tracking. This also permits practice of some additional correction procedures which will be useful for original work. . The use of 3M 7610 reflective tape would make digitizing more efficient and more effective. This is not an easy exercise and instructions should be read and followed carefully.

The **Demonstration** and **Practice Exercises** for clinical data presented within **Hu-m-an** are guided by the **Vaughan et al. compact disk presentation GaitCD (© 1999) with details provided in the included text Dynamics of Human Gait.** This CD and accompanying material are highly recommended to those wishing to learn more about clinical biomechanical gait analysis.

Before starting, the user should be experienced at two-dimensional digitizing and analysis, and in addition the following **3D** related **Demonstrations** should have been completed.

1. **Hu-m-an Overview - General 3D**
2. **Hu-m-an Overview – Clinical 3D**
3. **Control Matrix Digitizing (Specifically Con-d)**
4. **Generating General 3D Data**

This demonstration will introduce:

1. **Planning the analysis.** The basic requirements for **3D Clinical Data** generation.
2. **Data collection.** Two-dimensional digitizing for 3D data.
3. **Application of the DLT** and creation of the 3D data set.
4. **Proceeding from the Collection Model to the Anatomical Model.** Application of a pre-defined macro.
5. **Viewing the Kinematic Results.** An example of selected measurements.

Remember that this Instruction Window can be closed, moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components. It is often preferable to complete labs using a hard copy print out instead of from on the screen windows, and in this case the Instruction Window should be closed.

Click **[Forward]** for the next panel.

Forward

Forward Back

1. Planning the Analysis.

The assumed starting point is the availability of video files of an appropriate control matrix and a subject during a treadmill walk that have been captured from two cameras. For this exercise these 4 files are:

con1.avi	- control matrix from camera 1
con2.avi	- control matrix from camera 2
walk1.avi	- view of walking from camera 1
walk2.avi	- view of walking from camera 2

The steps involved in establishing the **Clinical 3d Data** are:

1. Digitize the control matrix from each camera
2. Provide (copy or create) control matrix real data file (**.rea**)
3. Digitize performance video for each camera using "auto-tracking"
4. Apply the **Direct Linear Transform**
5. Provide (copy or create) subject anthropometric **Supplementary Data File** (**.sdf**)
6. Application of a prepared macro for joint center and defined point calculations
7. Application of a prepared macro for calculation of selected kinematic values (ankle plantar-flexion/dorsi-flexion, inversion/eversion, valgus/varus.)

The equations and procedures presented by Vaughan et al. in the compact disk presentation GaitCD (© 1999) and detailed in the included text Dynamics of Human Gait are followed for calculation of joint centres, defined points and joint ankle calculations.

The video files of walking have already been trimmed and synchronized. It is possible, within **Hu-m-an**, to alternatively accomplish this function using the **[Utilities][Set a New Trial Sub-sequence]** procedure. This was demonstrated in the general collection **Practice Exercise**.

The 14 point, approximately 0.5 cubic meter control matrix (**Con-d**) will be used, and as required, the **con-d.rea** real value file.

For tracking the shank and foot motion, data from five carefully placed external markers will be collected. This is a partial **Helen Hayes** (Kadaba et al. 1990) marker set.

The five collection points are:

1. right metatarsal Head **II**
2. right heel
3. right lateral malleolus
4. right tibial wand
5. right femoral epicondyle

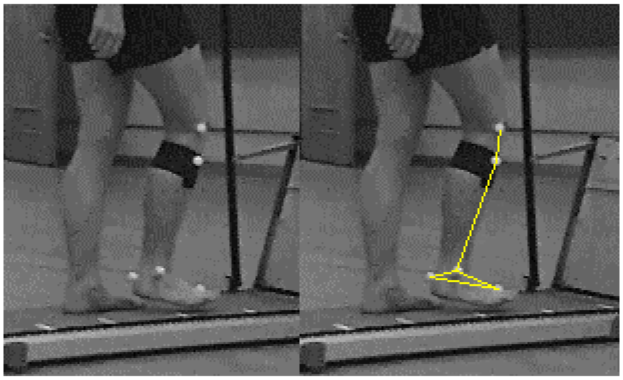


Figure 1 Collection Points

The trimmed and synchronized videos start approximately 3 frames before the first right heel contact and end approximately 3 frames after second right heel contact and contain a total of 40 frames (0-39).

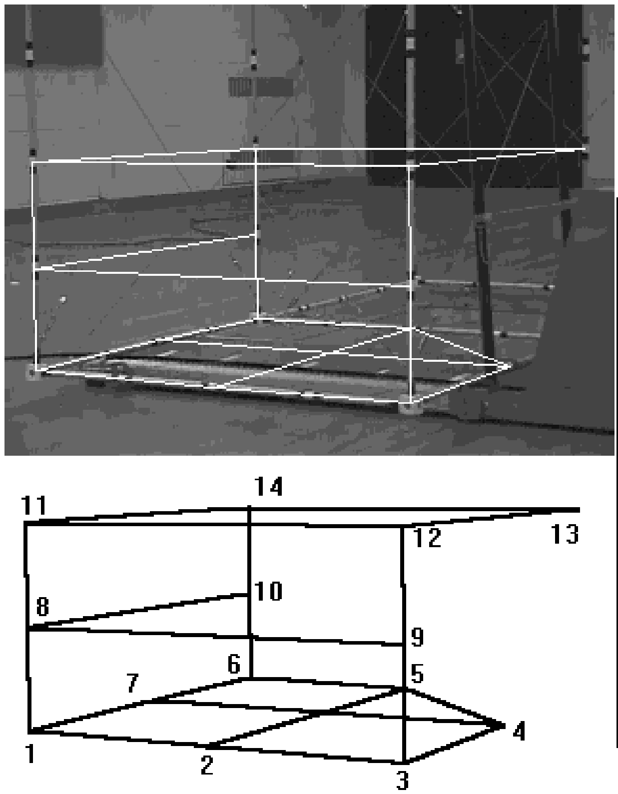
Click **[Forward]** for the next panel.

Forward   Back

Forward   Back

2. Data Collection – Digitizing the Control Matrix

Figure 2 below shows a picture of the control matrix as viewed from camera #1 and a schematic of the same 14 points. The order of collection must be the same for all views. The **con-d.rea** real value file shows the coordinate values assigned to the 14 points in forming the global coordinate grid.



Control Order for
14 Point Control Matrix
Viewed From Camera 1

"Real Value" file (in box)
for 14 Point Control Matrix
(e.g. 'con-d.rea')

X	Y	Z	Collection Point
14 1			
0.000	0.000	0.000	1
0.500	0.000	0.000	2
1.000	0.000	0.000	3
1.000	0.500	0.000	4
0.500	1.000	0.000	5
0.000	1.000	0.000	6
0.000	0.500	0.000	7
0.000	0.000	0.250	8
1.000	0.000	0.250	9
0.000	1.000	0.250	10
0.000	0.000	0.500	11
1.000	0.000	0.500	12
1.000	1.000	0.500	13
0.000	1.000	0.500	14

X Y Z Coordinate

Figure 2 Control Matrix

> Click the **[File][Load Trial]** menu item. In the **<Load Trial>** window mark the **con1.avi** file and click **[OK]**.
> Click the **[Edit][Trial Set Up]** menu item to display the **<Trial Set Up>** window.
> From the **List of Trial Set Up Titles**, scroll down and mark (click) **the 14 Pt. Control (d)** template. Click the **[Load]** button, responding **<Yes>** to the caution and then **[Exit]** the **<Trial Set Up>** window.
> Click the **[Options][Digitize]** menu item to display the **<Digitizing>** window.
> Click the **[Regular]** option radio button located approximately one-half down the **<Digitize>** control window.

Click **[Forward]** for the next panel.

Forward Back

Forward Back

Digitizng

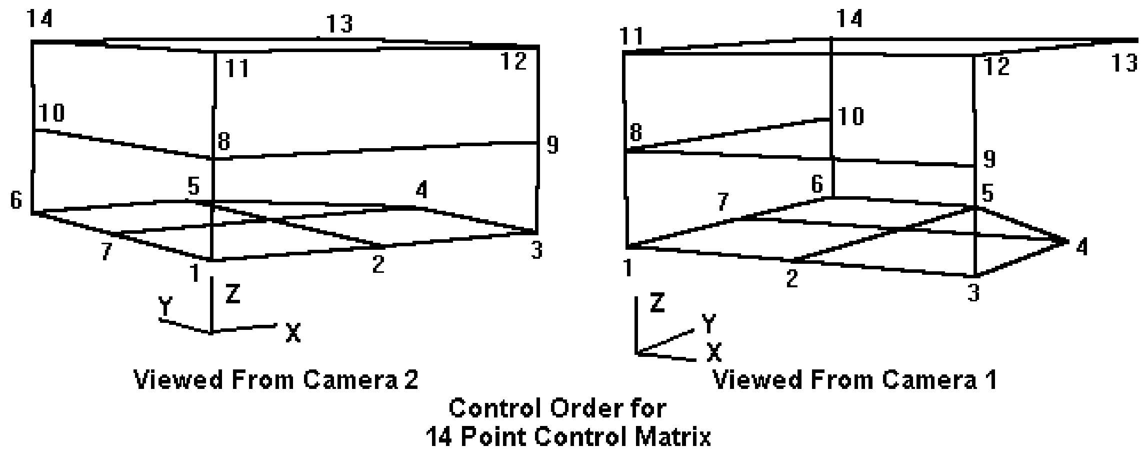


Figure 3 Collection Order

- **>** Digitize in order the 14 control points. Note that with proper digitizing, the connecting lines should follow the rod dowels, when they are present. Move the **<Digitizing>** control window if necessary. Re-do the **Control Matrix Digitizing** <u>**Demonstration**</u> for the **14 Pt. Template (d)** if you have difficulties. Note that the tape markings are at 25 cm intervals. This template uses the 50 cm markers on each level, and the levels are 25 cm apart.
- **>** After the 14th point is collected, if any points need to be adjusted, click on the **[Replacement Mode]** option (about one-third down the **<Digitize>** control window) and move the erroneous points. **When finished re-click the [Replacement Mode] option to turn off.**
- **>** Now, re-click the mouse over the video screen to advance to the next frame.
- **>** Click the **[Repeat Collection]** button (not the **[Re-collect this Frame]** button), to automatically digitize the second frame. (The control videos in **Hu-m-an**, by default, contain three frames.)
- **>** Now, re-click the mouse over the video screen to advance to the next frame and again click the **[Repeat Collection]** button.
- **>** Click the **[Exit]** button at the bottom of the **<Digitize>** control window.

Click **[Forward]** for the next panel.

<u>Forward</u> <u>Back</u>

<u>Forward</u> <u>Back</u>

Saving the Control Matrix Data

- **>** Click the **[File][Save As]** menu item.
- **>** The current path as shown near the top of the **<Save File>** window should be the **Practice Exercise** area of the Ehuman program or network server (**list13** for **Ehuman** or **list10** for sever configuration). Since these folders are typically **read only**, the path needs to be changed to a different area. The **Local Data Area** is used for this purpose. Click the **[Local Data Area]** button in the **Save As** window. Sub-directories, **[user01]**, **[user02],** etc., will now be listed. Select one of these, mark it and click the **[Change Path]** button. If files already exist in this directory, click the **[Up One Level]** button, and then try another <u>**user**</u> directory. It is possible to delete files from this window, using the **[Delete]** button in the bottom left, if this is appropriate.
- **>** The current assigned **File Name** is **con1.ht**. The **.avi** extension is reserved for video files only. Add a zero to the end of the name completing it as **con1.ht0**. This follows the **Hu-m-an** recommended protocol of naming original source data as **.ht0**.
- **>** Now click the **[Save]** button looking at the message area at the bottom for the **"Save Successful"** confirmation.

> **[Exit]** the **<Save Trial As>** window.

If the **Save Successful** confirmation message does not appear, do not make a final exit from the **Hu-m-an** program or the data may be lost. Re-trace the save procedures or obtain help from an experienced user.

> Now repeat the process, digitizing data from the **con2.avi** control matrix file. Remember to use the same **[Local Data Area]** for saving the data.

If necessary go back to **2. Data Collection – Digitizing the Control Matrix** and follow the same instructions again, substituting **con1** with **con2**.

> At the conclusion of this process you should end up with a **con1.ht0** and **con2.ht0** file in one of the **user** directories

The accuracy of the final results is determined in large part by the accuracy of the control matrix data used in the direct linear transform. The **con_.ht0** data can be re-loaded at any time, and corrections can be made using the **[Replacement Mode]** procedure. **The most important check is that the displayed connecting lines fall directly on the dowel rods.**

Click **[Forward]** for the next panel.
Forward Back

Forward Back
Checking the Control Matrix 3D Results

As an optional check, a three-dimensional model of the control matrix will now be constructed to visually inspect the success of the procedure.

The first task is to save or copy the real data file, in this case **con-d.rea** , to the same directory. For original analysis, this file is created using a text editor and then saved to the proper directory using normal procedures. **Hu-m-an** provides special procedures when using template control files

Setting the con-d.rea file.

> Click the **[Utilities][Transfer Control Matrix File][con-d real value file]** menu item. An information message box is shown which lists the target directory for copying the **con-d.rea** file. This should be the user-directory, which contains the saved control files. Respond **[Yes]** if this is true. If a current **con-d.rea** file exists it can be overwritten.

> The directory to which the **con-d.rea** file is to be copied is based on the most recently saved file. If this operation is executed at a different time and the message box shows an incorrect destination, then the **con1.ht0** file should be re-loaded from the proper user directory and then re-saved prior to proceeding with this instruction.

Applying the DLT

> Click the **[File][Load Trial]** menu item. Click the **[Local Data Area]** button and then select the sub-directory where the control data is saved and click the **[Change Path]** button to view the directory listing.

> Click **the [Go to 3D]** button and click on the **[Apply DLT]** checkbox. The 3 files, **con-d.rea**, **con1.ht0** and **con2.ht0** should be listed.

> The **[Control Files]** radio button is checked by default, the **Camera No.** is set to **2** by default

and the **Select Camera 1 Control File** listing is high-lighted.
> Click on the **con1.ht0** and then the **con2.ht0** listing to select the control file titles.
> Now select the **[Control Real]** radio button and click on the **con-d.rea** file.
> Finally, click on the **[Source Data]** radio button and again click on the **con1.ht0** and **con2.ht0** files again, as these are also the target data for this test.
> Now click on the **[OK]** button to activate the **DLT** application.

Click **[Forward]** for the next panel.
Forward Back

Forward Back
Checking the Three-dimensional Results (Continued)

If the **DLT** application has been successful then a rectangular model will appear in the **<Model>** window. If not successful, then repeat the procedure carefully, and if necessary, re-view the appropriate **Demonstrations** to understand the required operations.

When successful, a new **<Model Rotation>** window will also be displayed on the screen.

> Click on **[Axis]** button in the **<Model Rotation>** window to display the global **XYZ** axis orientation.
> Click and **hold** the appropriate up-arrows to set the **X** value to about **35,** and the **Y'**(prime) value to about **35**. Click the **[Center]** button on the right side of the **<Model Rotation>** window
> Now **click and hold** the **Z**'' (double prime) button and observe the rotating ~0.5-square meter control matrix.

If the figure is correct, you are now ready to proceed with subject digitizing.

To be visually correct, the object should be rotating counter-clockwise as the **Z** value increases, and the **XYZ** axes should correspond to the normal right-hand rule. If it is in reverse, this is not an error, but you are, by default, seeing the reverse figure. This is akin to the seeing the inside and outside views of a **3D** cube drawn in two dimensions. With practice you can force yourself to see the correct orientation**. Visual perception is one of the difficulties of 3D analysis and presentation!**

A **[Reset]** button is provided to set all values at their starting point.

Click **[Forward]** for the next panel.
Forward Back

Forward Back
Data Collection – Digitizing the Performance Video Data

Figure 5 below shows a sample video frame of the subject walking on the treadmill as viewed from camera #2. As described in the planning section, five points will be collected:

1. right metatarsal Head II

2. right heel
4. right lateral malleolus
5. right tibial wand
6. right femoral epicondyle

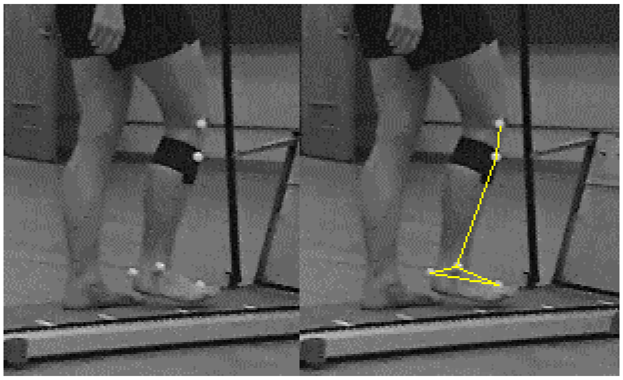


Figure 5 Subject Data Collection

To review a sample collection:
Although it is not necessary to review a sample collection, it is possible to do so. Data for the current walk are stored with the video files in the **…\walks-3d\walkc** data area.

The procedures to review the sample collection are:

> Click the **[File][Load Trial]** menu item. In the **<Load Trial>** window click the **[Program/Server Data Area]** button in the bottom right corner. Click to mark the **<Walks-3d>** sub-directory and then click the **[Change Path]** button. Now click to mark the **<Walkc>** sub-directory and again click the **[Change Path]** button. Click on the newly displayed **walkc1.ht0** file(camera #1), and click **[OK]**.

Note that on returning to the **<Load Trial>** window later, you will remain in the **walkc** sub-directory. To change to the proper practice exercise directory, remember to simply click the **[Boot Area]** button at the bottom right of the window.

> Click the **[Options][Digitize]** menu item to display the subject with an overlay of the digitized points and the connecting lines. Use the single frame advance (**[|>]**) and view the collected points throughout the performance. Move the **<Digitize>** control window if necessary. In particular, pay attention to the collected joint centers. When finished, click the **[Exit]** button.

> Follow the same procedure to load and view the **walkc2.ht0** file, which is from camera #2.

Click **[Forward]** for the next panel.
Forward Back

Forward Back

Digitizing the performance videos.
You are now ready to digitize the movement data.

> Click the **[File][Load Trial]** menu item. Click the **[Boot Area]** button to display the four **avi**

files, **con1.avi**, **con2.avi**, **walk1.avi** and **walk2.avi**. In the **<Load Trial>** window mark the **walk1.avi** (camera #1) file, and click **[OK]**.

> Click the **[Edit][Trial Set Up]** menu item to display the **<Trial Set Up>** window. From the **List of Trial Set Up Titles**, scroll down (near the bottom) and mark (click) the **<u>HHset - 5 Pt. R. (a)</u>** template. Click the **[Load]** button, responding **<Yes>** to the caution and then **[Exit]** the **<Trial Set Up>** window.

Since the entire available video is to be analyzed and the provided files have already been synchronized and trimmed, we can move directly to the digitizing procedure. To implement the "**auto-tracking**" procedure, the first two frames of data are collected to identify the target markers and their initial motion"

> Click the **[Options][Digitize]** menu item to display the **<Digitizing>** window. Digitize in order (as shown in the **<Digitize>** control window), the center of the styrofoam spheres located at the **right metatarsal Head II, right heel, right lateral malleolus, right tibial wand, and right femoral epicondyle**, for frame zero (**NOTE ORDER**). Click the left mouse button one more time (with the arrow anywhere over the video), to automatically advance one frame, and continue to digitize a second frame (frame 1). Note that connecting lines will overlay the segments to permit a visual inspection of the collection accuracy. After completing the second frame, click the left mouse button one more time to advance the video to the third frame (frame 2).

> We are now ready to implement "**auto-tracking**".

Click **[Forward]** for the next panel.
<u>Forward</u> <u>Back</u>

<u>Forward</u> <u>Back</u>
Auto-tracking

> Click the **[Auto-tracking]** button in the **[Digitize]** control window to display the **<Auto-tracking>** window.

> We will use the default "Low White Level" (170) and "Search Area" (40). These values are related to lighting, background and marker brightness, and is best determined through trial and error for a given experimental venue.

> Click the **[Auto-Track(Process)]** button in the **<Auto-tracking>** window, responding **[Yes]** to the confirmation question.

The "**Auto-tracking**" procedure is now implemented with the final video frame and super-imposed model shown on completion. If instructions have been carefully followed the super-imposed model on the final frame will be complete except for a missing heel point. This results from a tracking error which now can be corrected. If additional points are missing then you will need to make corrections for these based on your knowledge gained from the previous **Demonstrations** and **Practice Exercises.** There are at times differences in the presentation of video clips on different computers due to de-compression drivers, video cards etc. and therefore it is possible that your results may differ somewhat from the results expected in these directions.

To make corrections:

> It is important to be as accurate as possible in digitizing the center of each marker since the predicted movement is measured from these values.

> Use the single frame advance button in the **<Digitize>** control window to begin scanning the collection. You will find that the heel and lateral malleolus makers become confounded beginning with frame 27.

- **>** With frame 27 showing, select the "**R. Lateral Malleolus**" from the drop down list in the **[Digitize]** control window. Manually digitize the "R. Lateral Malleolus". Now, click the left mouse again to advance to frame 28, digitize and advance to frame 29. Again digitize the lateral malleolus but **do not advance the frame after digitizing the frame 29 point.** If you did, correct using the single frame backward button.
- **>** On frame 29 you will find that the heel marker is also slightly misplaced. Select the "**R Heel**" marker from the drop-down list and manually digitize this point. Now click the left mouse again to advance to frame 30.
- **>** Click the **[Auto-Track (Process)]** button in the **<Auto-tracking>** window to restart the digitizing process at this frame. Respond **[Yes]** to the confirmation question.
- **>** At the end, again you will find that the **R. Heel** marker is still missing. This time you will notice that it is missing for frames 35-39. Go back to frame 35, select the "**R. Heel**" from the drop down list and manually digitize the heel using a second click to advance to the next frame. Complete up to and including frame 39.
- **>** Make a final check on the completeness and correctness of the data set. Make any other adjustments necessary using the drop-down list procedure used above.
- **>** When complete click the **[Exit]** button in the **<Digitizing>** control window to return to the main screen.

Click **[Forward]** for the next panel.
Forward Back

Forward Back
Saving the Performance Data for the First Video

- **>** Click the **[File][Save As]** menu item.
- **>** The current path is the **Practice Exercise** area of the Program or Server. It is necessary to save the performance data in the same **Local Data Area** that was used for the control matrix data. Click the **[Local Data Area]** button in the **Save As** window, select the same user area as previously identified, and click the **[Change Path]** button. You should see a listing of the previous control **ht** files.
- **>** The current assigned **File Name** will be **walk1.ht**. The **.avi** extension is reserved for video files only. Add a zero to the end of the name completing it as **walk1.ht0**. This follows the **Hu-m-an** recommended protocol of naming original source data as **.ht0**.
- **>** Now click the **[Save]** button looking at the message area at the bottom for the **"Save Successful"** confirmation.
- **>** **[Exit]** the **<Save Trial As>** window.

If the **Save Successful** confirmation message does not appear, do not make a final exit from the **Hu-m-an** program or the data may be lost. Re-trace the save procedures or obtain help from an experienced user.

Click **[Forward]** for the next panel.
Forward Back

Forward Back

Auto-tracking

Continuing to Digitize the Second Video

> Click the **[File][Load Trial]** menu item. In the **<Load Trial>** window mark the **walk2.avi** (camera #2) file, and click **[OK]**. As previously explained, if you are not in the proper location, click the **[Boot Area]** button to return to the original directory area.
> Proceed with processing the second video file in exactly the same manner as for the first video file. Go back to the previous instruction panels, if necessary. This includes:
- loading the collection template, **HHset - 5 Pt. R.**
- digitizing the first two frames of data
- displaying the **<Auto-tracking>** window
- Activate the **[Auto-Track (Process)]** the data implementing the "Auto-tracking" procedure.
- This time you will find that the marker brightness drops significantly in frame 25. Starting at this frame select the Right Metatarsal Head II from the drop down list and digitize frames 25-27 ending up on frame 28
- Now click the [Auto-Tracking ({Process)] button. This time you should be successful
- If your individual collection does not show a successful result, use any procedures with which you are now familiar to make corrections
- saving the **walk2.ht0** file to the same **<Local User Area>** sub-directory

Click **[Forward]** for the next panel.
Forward Back

Forward Back
Creating the Control Real Data File

At this point, four files should have been saved to the same **Local User Area** sub-directory, namely:
con1.ht0
con2.ht0
walk1.ht0
walk2.ht0

The final file required is the **real value** file for the control matrix. This file was already transferred in making the **DLT** application check procedure and it does not need to be repeated at this time. When a user provided control matrix is employed, then a text editor is used to create the proper **.rea** real value file.

Click **[Forward]** for the next panel.
Forward Back

Forward Back
3. Application of the Direct Linear Transform.

> Starting from the main **Hu-m-an** window, click the **[File][Load Trial]** menu item. Click the **[Local Data Area]** button and locate the same user directory where the four previous data files are saved.

> Click the **[Go to 3D]** button and then click the **[Apply DLT]** checkbox.
> Five files should be listed, namely:
>
con-d.rea - the real value file recently transferred, and the four source data digitized data files:
con1.ht0
con2.ht0
walk1.ht0
walk2.ht0

> The default number of cameras, listed as **2** is correct.
> The **[Control Files]** radio button is activated by default and the **Select Camera 1 Control File** item is also hi-lighted.
> Click the **con1.ht0** file listing and then the **con2.ht0** file, to enter these files in the **Select** list.
> Click the **[Control Real]** radio button and select the **con-d.rea** file.
> Click the **[Source Data]** radio button and select the **walk1.ht0** and **walk2.ht0** files.
> Now click the **[OK]** button to create and apply the **Direct Linear Transform**.

If all operations have been successful then a side view of the shank and foot collection points are shown in the model window.

Click **[Forward]** for the next panel.
Forward Back

Forward Back
Viewing the results

On successful application of the **DLT** the small **<Model Rotation>** window will be displayed. By default the **[X-Z]** or side view is shown. Selecting the **[X-Y]** option displays a top view while the **[Y-Z]** displays a head-on view.

> Clicking and holding the up or down arrow for the **Z (double prime)** axis will rotate the model about the **Z-**axis from this position. The **[Reset]** button returns the model to the start position.
> Experiment with the various views playing the data to familiarize yourself with the three-dimensional representation. It is critically important to fully understand the visual representations before proceeding with further calculations and analysis.

Remember that the model will appear somewhat strange in that it portrays the externally collected landmarks.

Saving the Results:

At this point it is good practice to save these results for future reference and as a safeguard for unexpected data-file loss.

> Click the **[File][Save Trial As]** menu item to display the **<Save Trial>** window.
> You should already be in the originally selected **User** area. If you are not then use the normal **[Local Data Area]** search.
> A default title such as **walk1.h3** will be listed (**.h3** to identify this as a **3D** file). A letter or number should be added and the **walk1** title amended (the name of the first 2D file), so that

the title reads something like **walk.h3a**.

> Click the **[Save]** button, confirm that a successful operation has been completed and then **[Exit]** the **[Save Trial]** window.

Click **[Forward]** for the next panel.

Forward Back

Forward Back

4. Proceeding from the Collection Model to the Anatomical Model

The next objective is to use the data from the external marker points to calculate the internal anatomical reference points.

Preparation for execution of the macros requires the construction of a file containing the anthropometric measurements for the subject.

Supplementary Data File

The **Supplementary Data File** is created with a standard text editor and given the extension **.sdf**. For this particular exercise the file is titled **walk.sdf** and is of the following **exact** form:

```
-----------------------------------------------------
20     Supplementary Data File
64.90  kg  1   Total body mass
0.240  m   2   ASIS breadth
0.460  m   3   R.Thigh length
0.465  m   4   L.Thigh length
0.450  m   5   R.Mid-thigh circumference
0.440  m   6   L.Mid-thigh circumference
0.430  m   7   R.Calf length
0.430  m   8   L.Calf length
0.365  m   9   R.Calf circumference
0.365  m   10  L.Calf circumference
0.108  m   11  R.Knee diameter
0.112  m   12  L.Knee diameter
0.260  m   13  R.Foot length
0.260  m   14  L.Foot length
0.060  m   15  R.Malleolus height
0.060  m   16  L.Malleolus height
0.074  m   17  R.Malleolus diameter
0.073  m   18  L.Malleolus diameter
0.098  m   19  R.Foot breadth
0.096  m   20  L.Foot breadth
---------------------------------------------------
```

Notes:

1. The first line 20 indicates the number of anthropometric measures. Even though this particular exercise utilizes a limited number of measures, all 20 values must be provided. When proceeding with original analysis, it is important that this file be of exactly the same form with only the numeric anthropometric values updated for the subject under investigation. See **Vaughan et al. (GaitCD © 1999)** for details of the measures.
2. For the current **Practice Exercise**, the **Supplementary Data File** is already provided in the

boot directory and no further action is required on the part of the user. **For original analysis, the file must reside in the same directory as the other source data files.**

Preparing for Macro Execution:
Hu-m-an provides macros for joint center calculations, and joint kinematic analysis. Two macros based on the **Helen Hayes** marker set are included, one for a full, two-limb 15 point collection and one for the current exercise of a one-right lower limb 5 point collection.

Executing the Analysis Macro:
> Click the **[Options][Edit Macro Files]** menu item.
> Click the **[Program/Server Macro Area]** button.
> Click **[HH-sets]** to mark, and then click the **[Change Path]** button to move into this sub-directory.
> Click **[5-8set-r]** to mark, and then click the **[Change Path]** button to move into this sub-directory. This sub-directory houses the macros to convert a 5 point collection into an 8 point collection for the right shank and foot and complete the selected kinematic analysis.
> Finally, click the **0master.hmf** file and click the **[Execute]** button to apply the macro and respond **[Yes]** to the **<Caution>** query.
> Click **[OK]** to the information message. This message explains that the original 5-point collection is expanded to an 8-point file with the addition of the new joint centers and you can respond **[Yes]** to the caution.
> The caution is shown, and as directed, again respond **[Yes]**.
> A confirmation window is displayed at the conclusion of the processing. Respond **[Yes]**.

Click **[Forward]** for the next panel.
Forward Back

Forward Back
Viewing the figure-model results

On successful application of the macro, a different model configuration is displayed, based on the newly created joint centers. Click **[C]** to center the model if necessary. By default the **[X-Z]** or side view is shown. Selecting the **[X-Y]** option displays a top view while the **[Y-Z]** displays a head-on view.

> Clicking and holding the up or down arrow for the **Z (double prime)** axis will rotate the model about the **Z** axis from this position. The **[Reset]** button returns the model to the start position.
> Experiment with the various views playing the data to familiarize yourself with the three-dimensional representation. As before, it is critically important to fully understand the visual representations.

Saving the Results:

At this point it is again good practice to save these results for future reference and as a safeguard for unexpected data-file loss.

> Click the **[File][Save Trial As]** menu item to display the **<Save Trial>** window.
> You should already be in the originally selected **User** area. If you are not then use the normal **[Local Data Area]** search.
> Since the saved results of the previous **DLT** application was **walk1.h3a**, this will be listed as the default title (**.h3** to identify this as a **3D** file). It is good protocol to retain the original file

so the current file should be changed to something like **walk.h3b**.

> Click the **[Save]** button, confirm that a successful operation has been completed and then **[Exit]** the **[Save Trial]** window.

If the **Save Successful** confirmation message does not appear, do not make a final exit from the **Hu-m-an** program or the data may be lost. Re-trace the save procedures or obtain help from an experienced user.

Click **[Forward]** for the next panel.
Forward Back

Forward Back

Adding Critical or Event Times.

To assist with interpretation of the data it is advantageous to add **Critical** or event times to the graph presentation.

> Click the **[Edit][Trial Set Up]** menu item and ten click the **[Subject – Trial Data]** button to display the **<Subject – Trial Data>** window.

> Click the **[Add]** button in the **<Subject – Trial Data>** window and replace the **1** with the word **Right Heel contact**. Enter **4** as the frame number and click to check the **[Activate]** box. The selection of frame **4** for the heel contact can be confirmed by single framing the video, while the **<Subject – Trial Data>** window is still visible.

> Repeat this operation adding the frame for right toe lift (frame **25**) and the second right heel contact (frame **36**). Remember to click the **[Activate]** box for all critical points so graph vertical lines will be displayed.

> When finished click the **[Exit]** button in **the <Subject – Trial Data>** window and then click the **[Exit]** button in the **<Trial Set Up>** window.

Note that the critical or event times need to be entered after the macro application since part of this procedure is loading a new 8-point template for the newly created joint centers. This clears previous critical points. It is possible to re-run the macro a second time although it will be necessary to re-enter the critical point information. This emphasizes the necessity of saving the data at appropriate times.

Click **[Forward]** for the next panel.
Forward Back

Forward Back

5. Viewing the Kinematic Results

Click the new entries in the **<Graph-Data Control>** window to display the calculated data. These include:

R.Ankle (ext/flex) - right angle plantar flexion (positive) and dorsiflexion (negative).
R.Ankle (valgus/varus) - right angle valgus (positive) and varus (negative).
R.Ankle (inversion/eversion) - right ankle inversion (positive) and eversion (negative)

If your digitizing has been reasonably precise you will likely note the expected dorsiflexion/plantar flexion, valgus/varus and inversion/eversion patterns that occur during the stance phase, frame

5 to frame 27.

Click **[Forward]** for the next panel.
Forward   Back

Back
End of the Practice Exercise.

All the tools are now in place for original gait analysis. The procedures for the full double-limb, 15 point **Helen Hayes** marker set are identical to the modified single-limb, 5 point marker set.

Experience users can create completely new marker sets with accompanying macros,

With the **Practice Exercise** complete, click the normal **[File][Exit]** menu item to leave the program.

Click **[Back]** for the previous panel.
Back

EXAMPLE LABORATORIES

CONTENTS **Page**

The printed copies of the **Example Laboratories** included in this manual are exact copies of the on-screen instruction panels. Solid bar horizontal lines separate the individual instruction panels. The **Forward** and **Back** underlined words are hypertext, accessed only when used on-screen.

21 . INTRODUCTION TO LABORATORIES

HU-M-AN
Forward

Introduction to Laboratories

Example Laboratories are significantly different from **Demonstrations,** in that they provide instructions **only**, and program execution is left entirely to the user.

(Note that the right side scroll bars can be used to display parts of this instruction panel, if they are not shown.)

To execute a **Laboratory** simply click on the desired exercise and then follow the instruction panels presented. Many help screens require that the scroll bars be used in order that all the information can be read. It is often helpful to maximize the window for easier reading, or to move or minimize the window for better viewing.

In some cases it may be easier to work from a printed copy of the instructions and close the **Instruction Window.** A 'PDF' format file of the Laboratories and Practice Exercises is available from the web-page http://www.hma-tech.com/???

There are two additional menu items under the **[Help]** main menu item of the **Hu-m-an** program. The **[Exercise Help]** item re-displays the current exercise instruction window, if it has been closed, and the **[Options]** item allows for changes in the **Instruction Window** font size.

When using the laboratory instruction panels, occasionally palette sharing will cause problems with the coloring of the video window. An easy correction is made by clicking the left hand mouse button, while the mouse arrow is over the video window.

For a brief review on elements related to manipulating windows see **REVIEW OF `WINDOWS` FUNCTIONS**

Click **[Forward]** for next panel. **Forward**

HU-M-AN

Return

REVIEW OF SELECTED WINDOW FUNCTIONS (Accessed through hypertext)

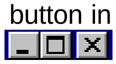
The instruction window can be manipulated in a number of ways:

Forward **Back** (These are not active.)

[Forward] and **[Back]** hypertext are placed at the beginning and at the end of each page and control the display of the next or previous instruction panel, respectively.

It is particularly important to know how to maximize, minimize and normalize the instruction window, while executing exercises and laboratories. This is very helpful to enable the user to better view the entire screen, as necessary.

Starting with a Normal Sized Instruction Window.

If the instruction window is of normal size, then it can be maximized (full screen) by using the center **square page** button in the top right corner, or minimized by using the **single bar** button in the top right corner.  The window can also be re-sized by placing the cursor over the wide window borders and by clicking and dragging, as with normal window procedures.

Starting with a Maximized Instruction Window.

If the instruction window is maximized (full screen), then it can be reduced to normal size by using the center `**overlapping square**` button in the top right corner, or minimized by using the `**single bar**` button in the top right corner. 

Starting with a Minimized Instruction Window.

If the Instruction Window has been minimized, then it can be returned to the current size by clicking the appropriate **bar button OR** clicking the **<Help><Exercise Help>** menu item.

Continue **[Forward]** for more information.

Return

HU-M-AN

Back

Exiting a Laboratory

At the end of a **Laboratory**, the user must activate the normal **Hu-m-an** program exiting procedures.

The **[File]** item is selected from the main menu bar and then followed by clicking the listed **[Exit]** menu item.

Note that, in order to access the **Hu-m-an** main menu bar items, when the help/instruction window is maximized, the window will need to be down-sized by using the top right window buttons.

THE INTRODUCTION TO LABORATORY EXERCISE IS NOW COMPLETE. AS DESCRIBED ABOVE, IN ORDER TO EXIT THE HU-M-AN PROGRAM, CLICK THE [FILE] MENU ITEM FROM THE MAIN MENU BAR AND THEN SELECT THE [EXIT] MENU ITEM.

Back

Back

22 . PROJECTILE ANALYSIS
- SHOT PUT AND VERTICAL TOSS

HU-M-AN

Forward

PROJECTILE ANALYSIS: SHOT PUT AND VERTICAL TOSS

Purpose

1. To demonstrate the application of videography to linear motion analysis and to introduce manual calculation of selected basic kinematic parameters.
2. To introduce specific manual measurements of position, displacement and velocity.
3. To investigate projectile motion and, in particular, predict the range that a shot is thrown based on release characteristics.
4. To estimate the acceleration of gravity based on vertical projectile analysis.

Notebook:

1. Copy of data table (complete).
2. Print out of shot put results.
3. Print out of vertical toss results.

Video Sequence

The data are to be collected from two provided video sequences:
a) - Scaling rod for shot put and subject executing shot put throw
b) - Scaling rod for vertical toss and subject throwing shot put vertically.

For this laboratory, it is assumed that the aspect ratio is 1.0. As part of the exercise, a scaling factor is calculated manually. A brief **Review of Math Fundamentals** is available.

Remember that this Instruction Window can be moved, maximized, minimized or re-sized as desired during the execution of the laboratory components.

Click **[Forward]** to continue.

Forward

HU-M-AN

Forward Back

Part I - Shot Put Analysis

1. Activate the **[File]**, **[Load Trial]** menu item. Single click the **shotput.ht1** file and then click **[OK]**.

2. Select the **[Options]**, **[Instant Calculation]** menu item and following the display of the digitizing screen, click the **[Digitize Sample Points]** option (radio button), listed under **Measures**.

3. Now select the **[Utilities]**, **[User Programs], [Projectile Analysis]** menu item to display the laboratory data sheet.

4. As well as recording data to the computer window data sheet, a hard copy of the data sheet is also prepared.

To print a blank data sheet:
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **<u>Print Blank Data Sheet</u>** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the blank data sheet from the printer.

If data sheet columns do not line up, try re-printing after selecting a new font by clicking the **[Printer Fonts]** button on the **Print Option** window.

Overview
(**<u>This is an overview of the laboratory. Do not execute the instructions at this time</u>**.)

Based on manual calculations and using digitized coordinates, the following kinematic values are to be calculated:

1. Scaling Factor.
2. Horizontal Velocity of the shot put at release.
3. Vertical Velocity of the shot put at release.
4. Resultant Velocity at release.
5. Angle of shot (with respect to the horizontal) at release.
6. Height of the shot from the ground at release.
7. Horizontal Range of the shot from release to landing. (Predicted)

After placing the arrow tip on the required locations and clicking the left hand mouse button, the resulting (x,y) coordinates, using basic video units (Not scaled at this point), are displayed in the **Frame** area of the **Instant Calculation** window. **<u>When recording displayed coordinates, do not include decimals</u>.**

Note that there are forward play, backward play, stop, single frame forward and single frame backward buttons for video control. The first frame (frame **0**) is the scaling rod with the following frames showing the shot put sequence. **The video timing is the standard 30 frames/second.** After recording the designated values on the **data sheet,** the 7 measures listed above are calculated in order. After each calculation, a **[Check]** button is clicked to determine if the answer is correct. A correct solution is required before proceeding to the next step. The program computes the answers based on the table of values provided by the user. This ensures that the procedures applied by the user are correct although the answers may still contain error if the original table of values is not accurate. **Include a minimum of 4 significant figures for each answer.** (For the scaling factor, due to leading zeros, this means six decimal places).
Click **[Forward]** to continue.

<u>Forward</u> **<u>Back</u>**

Forward Back

DATA COLLECTION - SHOT PUT ANALYSIS
(**Now perform each operation as described. Record coordinates on both the computer window and hard copy data sheets**.)

SCALING FACTOR

1. By **pointing and clicking**, find the **y** coordinates for the top and the bottom of the scaling rod and **record** them in the appropriate text box in the data sheet window and on the hard copy data sheet. The outer edge of the black strips on the scaling rod as shown in the figure below identify the correct collection points.

SHOT PUT ANALYSIS

2. Use the VCR controls to advance (etc.) the video and to determine the frame of release (defined to be that point when the shot put is first cleared of the hand). **Record** (point and click), the (x,y) coordinates for the center (center of gravity) of the shot (Release Frame (1)).

3. Advance the video forward **ONE** frame and again **record** the (x,y) coordinates for the center of the shot (Release Frame (2)).

4. **Record** (point and click) the **y** coordinate of the ground. If the forward foot of the shot putter is not on the ground, single frame advance until contact is made. A point at the bottom of the forward foot is chosen and assumed to be in the same plane as the shot. This point is used to determine the height of the shot above the ground at the time of release.

The **Projectile Motion - Shot Put** data sheet should now be complete.

Click **[Forward]** to continue.

Forward Back

HU-M-AN
Forward Back

SHOT PUT CALCULATIONS
Using a calculator perform the following calculations:

1. Given that the length of the scaling rod from top to bottom is 1.800 meters (measured to the nearest millimeter), calculate an appropriate scaling factor. (Include a minimum of 4 significant figures in the answer. For the scaling factor, due to leading zeros, this means six decimal places.)

$$S.F. = \frac{\text{Real Length}}{\text{Image Length}}$$

[Check]

Click the **[Check]** button. If the answer is not correct, review the collection and calculation. **The correct answer must be given in order to proceed.**

Click the **Up** arrow next to the answer box to advance to the next calculation. **The Up and Down arrows are used to change the displayed calculation item at any time.**

2. Calculate the instantaneous horizontal, vertical and resultant velocity using the simple finite difference technique based on the data from release frames 1 and 2. Remember that the video speed is 30 frames per second. (D represents the time between measurements.) For most accurate results, express time as a fraction or ensure 4 significant figures are used.

$$v_x = \frac{(x_2 - x_1)(S.F.)}{\Delta t}$$

$$v_y = \frac{(y_2 - y_1)(S.F.)}{\Delta t}$$

$$v_r = \sqrt{v_x^2 + v_y^2}$$

[Check] each calculation.

Click **[Forward]** to continue.
Forward Back

HU-M-AN
Forward Back

3. Calculate the angle of release with respect to the horizontal:

   a) using the shot put position values of frame 1 and 2.

$$\theta = \tan^{-1} \frac{y_2 - y_1}{x_2 - x_1}$$

b) using V_x and V_y.

$$\theta = \tan^{-1} \frac{v_y}{v_x}$$

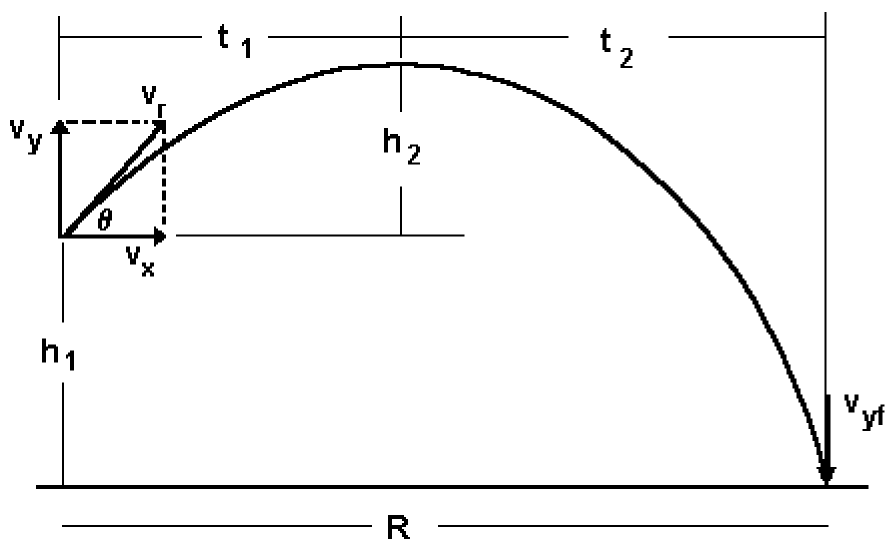
[Check]

4. Calculate the real height of release for the shot.

(Hint: use the release point, the ground coordinate and the scaling factor.)

[Check]

5. Calculate (predict) the horizontal range that the shot will travel before it hits the ground. This can be accomplished by using different but equivalent mathematical approaches. Be familiar with both approaches described below, although **only one is required to complete the laboratory exercise**.



h1 - height of release
h2 - height shot rises from release
t1 - time from release to peak height
t2 - time from peak height to landing
Vx - horizontal velocity at release
Vy - vertical velocity at release
V r - resultant velocity at release
Vyf - vertical velocity on landing
R - 'range' horizontal distance from release to landing

g - acceleration of gravity = 9.810 m/s/s

Method a) This approach uses five equations to determine the final range and is used to demonstrate the various kinematic measures that can be calculated.

$$t_1 = \frac{v_y}{g} \quad h_2 = \frac{v_y^2}{2g} \quad v_{yf} = \sqrt{2g(h_1 + h_2)}$$

$$t_2 = \frac{v_{yf}}{g} \quad R = v_x(t_1 + t_2)$$

[Check]

Method b) This approach uses a single equation, which, in essence, combines the equations of Method a).

$$R = \frac{v_x v_y + v_x \sqrt{v_y^2 + 2gh_1}}{g}$$

[Check]

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

Part I of the exercise is now complete. (If you have been successful!)

Click the **[Print]** button in the **Projectile Motion - Shot Put** window to obtain a hard copy of the results. A **[Print Option]** screen will appear. Ensure that the correct printer is selected and enter the user's name in the **Optional Header** text box. Click [**Proceed with Printing],** when ready.

Click the [**Exit]** button near the bottom of the **Instant Calculation** window.

Click **[Forward]** to continue.
Forward Back

HU-M-AN

Forward Back

Part II - Vertical Toss Analysis

1. Activate the **[File]**, **[Load Trial]** menu item. Single click the **verttoss.ht1** file and then click

[OK].

2. Select the **[Options]**, **[Instant Calculation]** menu item and following the display on the digitizing screen, click the **[Digitize Sample Points]** option listed under **Measures**.

3. The **Projectile Motion** data sheet should still be visible. If it is not, then re-display it by selecting the **[Utilities]**, **[User Programs], [Projectile Motion]** menu item. From the **PROJECTILE MOTION - SHOTPUT** window click the **[Vertical Toss]** radio button to access the correct data sheet. **(PROJECTILE MOTION - VERTICAL TOSS)**

Overview

(**<u>This is an overview of the laboratory. Do not execute the instructions at this time</u>**.)

Based on manual calculations using digitized coordinates, the following kinematic values are to be determined:

1. Scaling Factor for vertical toss sequence.
2. Estimate of the acceleration of gravity.

After placing the arrow tip on the required locations and clicking the left hand mouse button, the resulting (x,y) coordinates, using basic video units (Not scaled at this point), are displayed in the **Instant Calculation** window. **When recording displayed coordinates, do not include decimals unless otherwise instructed.**

Note that there are forward play, backward play, stop, single frame forward and single frame backward buttons for video control. The first frame (frame **0**) is the scaling rod with the following frames showing the vertical toss sequence. **The timing is the standard 30 frames/second.**

After recording the designated values on the **data sheet,** the two required measures are calculated in order. After each calculation, the **[Check]** button is clicked to determine if the answer is correct. A correct solution is required before proceeding to the next step. **Include a minimum of 4 significant figures for each answer.** (For the scaling factor, due to leading zeros, this means six decimal places.)

Click **[Forward]** to continue.

<u>Forward</u> **<u>Back</u>**

HU-M-AN

<u>Forward</u> **<u>Back</u>**

DATA COLLECTION - VERTICAL TOSS ANALYSIS
(**<u>Now perform each operation as described. Record coordinates on both the computer window and hard copy data sheets</u>**.)

SCALING FACTOR

1. By `pointing and clicking`, find the **y** coordinates for the top and the bottom of the scaling rod and **record** them in the appropriate text box in the data sheet window and hard copy data sheet.

VERTICAL TOSS ANALYSIS

2. Use the VCR controls to advance the video and determine the frame of release (defined to be that point when the shot put is first clear of the hand). **Record** (point and click), the (y) coordinate for the center (i.e., center of gravity) of the shot (Coordinate of Release).

3. Advance the video forward until the shot reaches its peak height before returning to the ground and again **record** the (y) coordinate for the center of the shot (Maximum Height).

4. Use the single frame buttons to determine the number of frames it takes for the shot to go from the point of release (**call this frame zero**) to a position of equal height on its return from the ground. Note that it is often not possible to identify the end frame precisely, since the exact point may occur between frames. Estimate the number of frames to the nearest tenth (e.g. 31.6). This is the only time that a decimal is included on the data sheet.

The **Projectile Motion - Vertical Toss** data sheet should now be complete.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

VERTICAL TOSS CALCULATIONS

1. Given that the length of the scaling rod from top to bottom is 1.800 meters, calculate an appropriate scaling factor. (Include a minimum of 4 significant figures in your answer. For the scaling factor, due to leading zeros, this means six decimal places.)

$$S.F. = \frac{\text{Real Length}}{\text{Image Length}}$$

[Check]

Click the **[Check]** button. If the answer is not correct then re-confirm collection and calculation. The correct answer must be given in order to proceed.

Click the **Up** arrow to advance to the next calculation. The **Up** and **Down** arrows are used to change the displayed calculation at any time.

2. Calculate an estimate of the acceleration of gravity using the equation below. The time is taken from the point of release to the same point on return. Remember that the video speed is 30 frames per second. The height of the toss is calculated from the point of release to the point of maximum height (scaled!).

$$g = \frac{8h}{t^2}$$

g = estimate of the acceleration of gravity.

h = distance from the point of release to maximum height (meters)
t = time from release to return to the same level (seconds)

[Check]

The true value for the acceleration of gravity is 9.810 m/s/s. With reasonably accurate data, the value should be 9.81 m/s/s +/- 1.0 m/s/s.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Back

Part II of the exercise is now complete. (If you have been successful.)

Click the **[Print]** button in the **Projectile Motion - Vertical Toss** data sheet window to obtain a hard copy of the results. The **Print Option** screen will appear. Ensure that the correct printer is selected and enter the user's name in the appropriate location. Click **[Proceed with Printing],** when ready.

Click the **[Exit]** button near the bottom of the **PROJECTILE MOTION - VERTICAL TOSS** window. Answer **[Yes]** to the '**Continue?**' question. **[Exit]** the **Instant Calculation** window.

The **Projectile Motion laboratory** is now complete**.**

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is also available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this Laboratory** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

To exit this laboratory select the **[File]** menu item and then the **[Exit]** menu item.

Back

HU-M-AN

Return

REVIEW OF MATH FUNDAMENTALS

Table of Contents

1.0 Algebraic Order of Operations

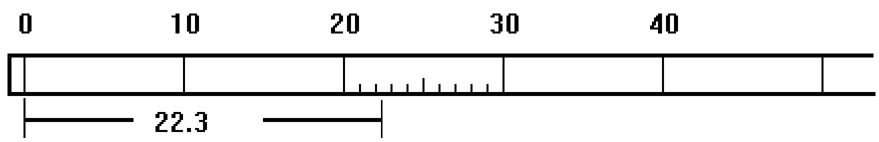
- brackets
- powers, radicals
- multiplication, division
- addition, subtraction

321.0 + 0.433 (544.0 - 321.0) = 321.0 + 0.433 (223.0) = 321.0 + 96.6 = 417.6

2.0 Experimental Data and Significant Figures

- Significant figures: the number of figures that have real meaning.
- The use of calculators makes knowledge of significant figures important as they often display more digits than you should report. Similarly, knowledge of significant figures is important to ensure that accuracy of reported results is not unnecessarily weakened.

a) Every measurement should include one estimated figure. The estimate should usually be made to one-tenth of the smallest division



Even though there is some uncertainty, there is still some knowledge of the last digit and therefore it is included as a significant figure.

Notes:

- In "rounding off", a value of 5 or greater is rounded up and a value of 4 or less is rounded down.
- Leading zero's are not counted as significant figures.

Examples

a) Write the numbers 35.625 and 0.042803 using 2, 3 and 4 significant figures.

36	35.6	35.63
0.043	0.0428	0.04280

b) The level of uncertainty in a measurement is usually taken as plus or minus one-fifth of the smallest division of the scale used.

22.3 +/- 0.2 +/- 0.2 is the "possible error" or "level of uncertainty"

Percent uncertainty

0.2 / 22.3 * 100 = 0.897% - several tenths of a percent uncertainty

The number of significant figures provides a rough measure of the percent uncertainty. As a rough guide:

2 significant figures	- several percent uncertainty
3 significant figures	- several tenths of a percent uncertainty
4 significant figures	- several hundredths of a percent uncertainty

c) In general, for addition and subtraction, the accuracy of the result is governed by the last figure of the least accurate measurement.

d) In general, for multiplication and division, the number of significant figures in the result should be equal to the number of significant figures in the factor containing the least number.

Examples

b) Answer the following questions using appropriate significant figures.

i) 32.47 + 0.333 = 32.80

ii) 47.24 + 0.092 - 6.3 = 41.0

iii) (23.2) (21.749) = 505

iv) (1.800) / (220.0) = 0.008182

Notes:

- the "percent uncertainty" in an answer should be roughly the same as the percent uncertainty of the original components.
- For multiplication and division, while one can always determine in a given problem whether to do so or not, keeping one more significant figure in the product or quotient than found in the cruder factor is often a reasonable thing to do.
- Practical consideration: three are times in problem solving when a physical quantity is presumed to be more accurate than the number of significant figures specified.
- The objective of the current presentation for significant figures is to provide a framework for representation of reasonable and understandable accuracy.

3.0 Scientific Notation

- Sometimes there is a natural ambiguity as to the intended number of significant figures in a reported result. For example, if the distance between two markers is 6700 m then the last two zeros may be significant figures or they may just show where the decimal point is. This ambiguity can be avoided by using scientific notation, where every number is expressed with exactly one digit to the left of the decimal and then multiplied by the appropriate power of 10.

286 is expressed as $2.86 \bullet 10^2$

0.006053 is expressed as $6.053 \bullet 10^{-3}$

a) To add or subtract two numbers in scientific notation, one first has to convert them to numbers with the same exponent.

$$2.86 \bullet 10^2 + 2.263 \bullet 10^3 = 0.286 \bullet 10^3 + 2.263 \bullet 10^3 = 2.549 \bullet 10^3$$

b) To multiply or divide two numbers is straight forward since multiplying or dividing powers of 10 is accomplished by adding or subtracting the exponents respectively.

3.1 Questions: Express in scientific notation

a) the product of 356 and 2000

$$(3.56 \bullet 10^2) (2.000 \bullet 10^3) = 7.12 \bullet 10^5$$

b) the product of 356 and 0.0000200

$$(3.56 \bullet 10^2) (2.00 \bullet 10^{-5}) = 7.12 \bullet 10^{-3}$$

c) the quotient of 356 divided by 2000

$$(3.56 \bullet 10^2) / (2.000 \bullet 10^3) = 7.12 \bullet 10^{-1}$$

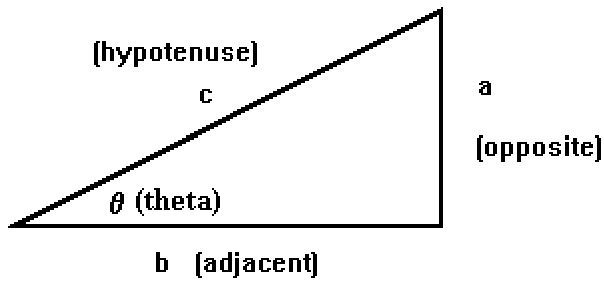
d) the quotient of 356 divided by 0.0000200

$$(3.56 \bullet 10^2) / (2.00 \bullet 10^{-5}) = 7.12 \bullet 10^7$$

4.0 Trigonometry

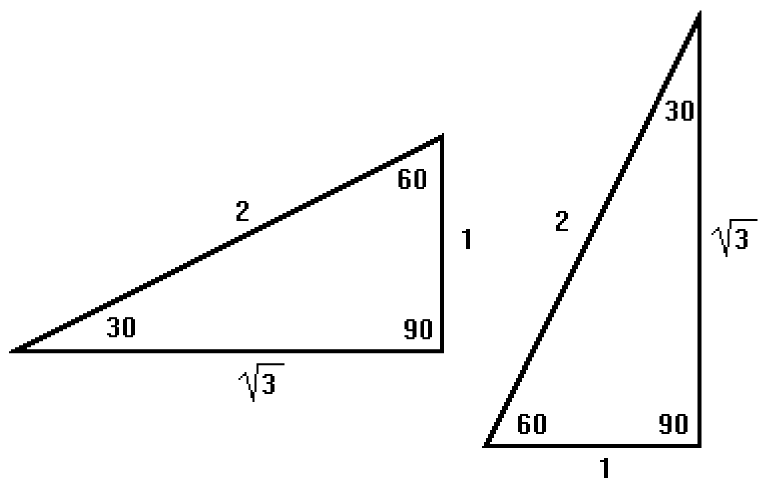
Trigonometric Functions

- Sine, cosine and tangent are three fundamental trigonometric functions.
- Normally defined in terms of the ratios of sides of a right triangle.



$$\sin\theta = \frac{\text{opp.}}{\text{hyp.}} = \frac{a}{c} \qquad \cos\theta = \frac{\text{adj.}}{\text{hyp.}} = \frac{b}{c} \qquad \tan\theta = \frac{\text{opp.}}{\text{adj.}} = \frac{a}{b}$$

Examples:



$$\sin 30 = \frac{1}{2} = 0.500 \qquad \cos 30 = \frac{\sqrt{3}}{2} = 0.866 \qquad \tan 30 = \frac{1}{\sqrt{3}} = 0.577$$

$$\sin 60 = \frac{\sqrt{3}}{2} = 0.866 \qquad \cos 60 = \frac{1}{2} = 0.500 \qquad \tan 60 = \frac{\sqrt{3}}{1} = 1.732$$

Inverse Trigonometric Functions

- Answers the question: "What is the angle whose sine (cosine, tangent) is …?"
- Uses the notation, for example, "**Inverse sine**", "**$\sin^{-1}$**" or "**arcsine**" (arc functions).

$$\text{If} \quad \sin\theta = d\text{, then} \quad \theta = \sin^{-1} d$$

Example: What is the angle whose sine is 0.500?

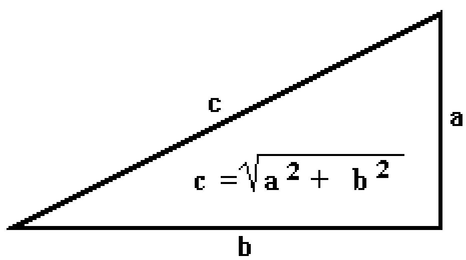
$$\theta = \sin^{-1}(0.500) = 30 \text{ degrees}$$

Pythagorean Theorem

$$c^2 = a^2 + b^2$$

- In a right triangle the square of the hypotenuse is equal to the sum of the squares of the other two sides.

- It is most commonly used to find the length of an unknown side, for example,



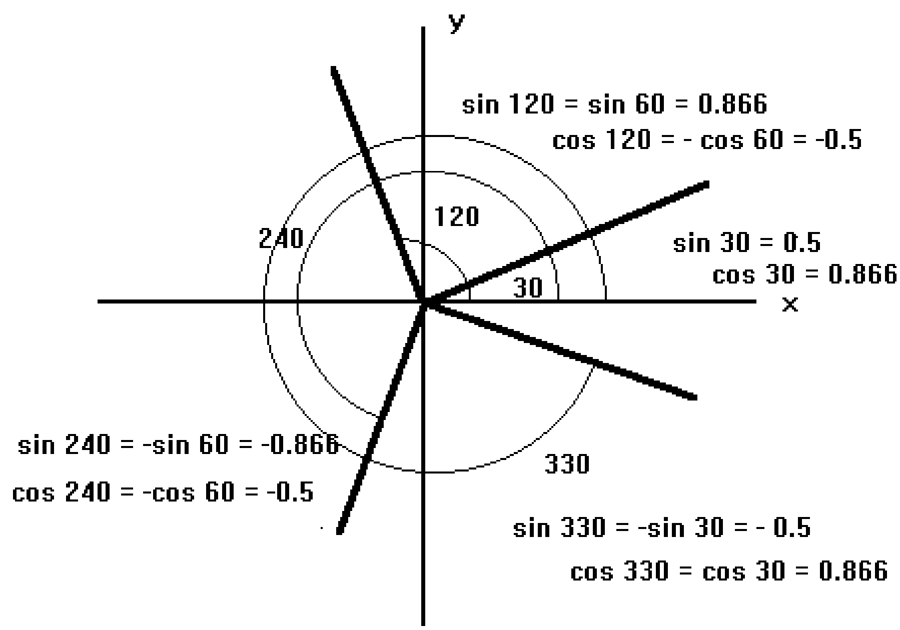
Trigonometric Functions for = 0 degrees to = 360 degrees

- The angle is always measured counterclockwise from the positive horizontal axis to the hypotenuse of the right triangle.

- The trigonometric functions are positive or negative depending on the quadrant.

- the opposite and adjacent sides of the triangles are considered positive or negative depending on which side of the axis they are on, while the hypotenuses are always considered positive.

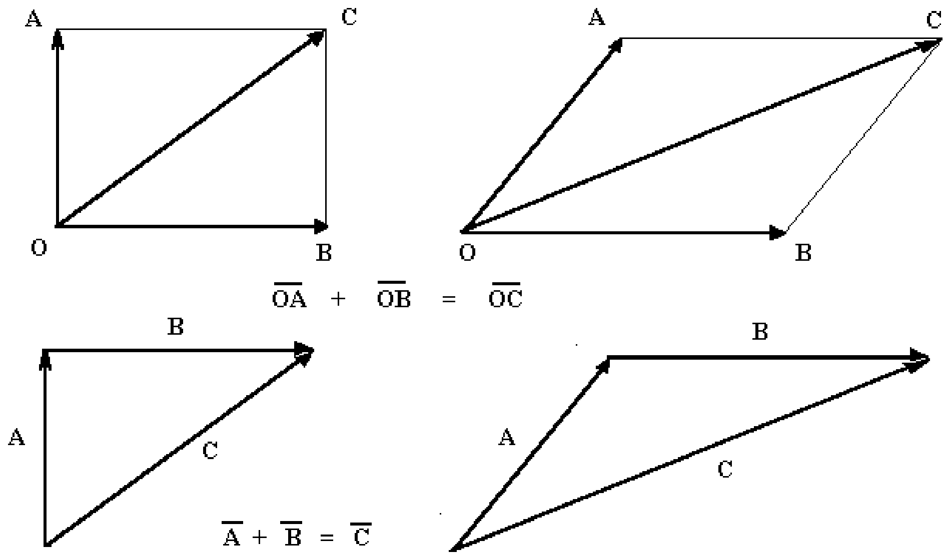
- Note that only in the first quadrant is the angle of interest , inside the triangle.



5.0 Scalar and Vectors

- a scalar is a quantity that has only magnitude (size)
  - examples are length, volume, distance and speed
  - adds by ordinary rules of arithmetic

- a vector is a quantity that has both magnitude (size) and direction
  - examples are displacement, velocity, and force
  - add according to the Parallelogram law
  - can be extended to the Triangle of Vectors or the Polygon of Vectors



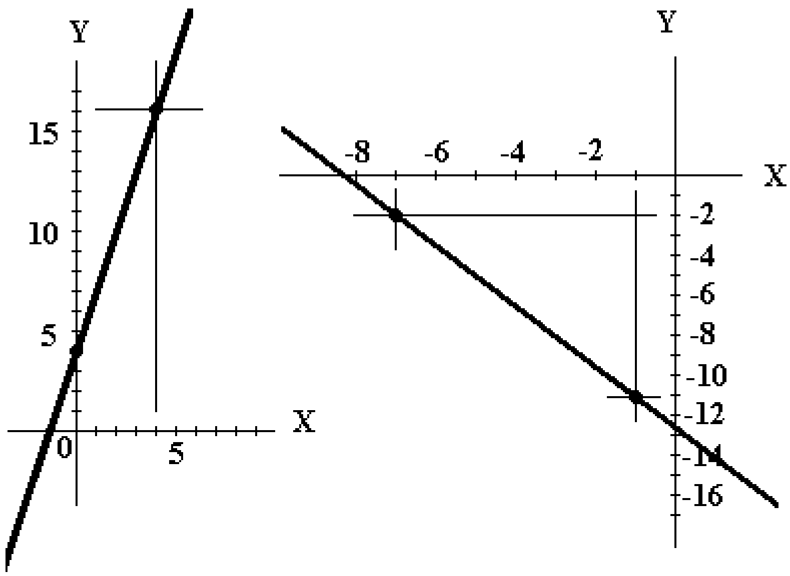
6.0 Slopes and Rates of Change

Slopes and Tangents

- slope = rise / run slope = $(y_2 - y_1) / (x_2 - x_1)$
- a tangent line is a line that touches a curve at one and only one point, and is the slope of the curve at that point.

6.1 Questions

a) Determine the slope of the line for each graph below.



slope = rise / run
slope = (y2 - y1) / (x2 - x1)
= 12 / 4 = 3

slope = rise / run
slope = (y2 - y1) /(x2 - x1)
= -9 / 6 = - 3/2
= - 1.5

Back

23 . INSTANT CALCULATION

HU-M-AN
Forward

INSTANT CALCULATION

Purpose
1. To introduce immediate kinematic measurement.
2. Specifically to introduce measurement of:
   - linear displacement and velocity.
   - relative angles and velocities.
   - absolute angles and velocities.
3. To practice immediate kinematic measurement through analysis of a track sprint start.

Pre-requisite:
1. Complete/review the **Instant Calculation** Demonstration.
This laboratory essentially reproduces for practice, the **Instant Calculation** Demonstration.

Notebook:
1. Completed print out of **Instant Calculation** answer sheet.
2. Printed copy of quiz results.

Remember that this Instruction Window can be moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components.

Click **[Forward]** to continue.

Forward

HU-M-AN
Forward **Back**

Overview
(**This is an overview of the laboratory. Do not execute the instructions at this time**.)
In this exercise selected measurements will be made using the provided video of a simulated sprint start. Measurements include:

1. Length (or distance) from a single frame and between frames.
2. Linear velocity.
3. Absolute angle.
4. Absolute angular velocity.
5. Relative angle.
6. Relative angular velocity.

Theory and Procedures
Prior to making any measurements the aspect ratio (if not known to be 1.0), and scaling factor must be applied. The answer for all measurements is given in the **Result:** box found in the

Instant Calculation window. Due to human error in accurately locating markers, it is standard procedure to average at least three answers for each required measurement.

Procedure details: (AN OVERVIEW - DO NOT EXECUTE INSTRUCTIONS AT THIS TIME)

1. Distance, length and displacement

Procedures:
- select **[Distance]** measure.
- click on one end of desired distance or length.
- click on other end of distance or length.
- the results include the distance or length and, in addition, the **X** and **Y** displacements between the first and second selected points.

An identical process can be applied between different frames, as long as there is no video frame movement (e.g. camera panning). There is a process for measuring distance, while panning, but it will not be covered here.

2. Linear velocity
- the rate of change of displacement.
- uses the method of simple finite differences.

Equations for linear velocities and resultant speed.

$$v_x = \frac{(x_2 - x_1)}{\Delta t} \qquad v_y = \frac{(y_2 - y_1)}{\Delta t}$$

$$v_r = \sqrt{v_x^2 + v_y^2}$$

Dt - the time interval between measurements.

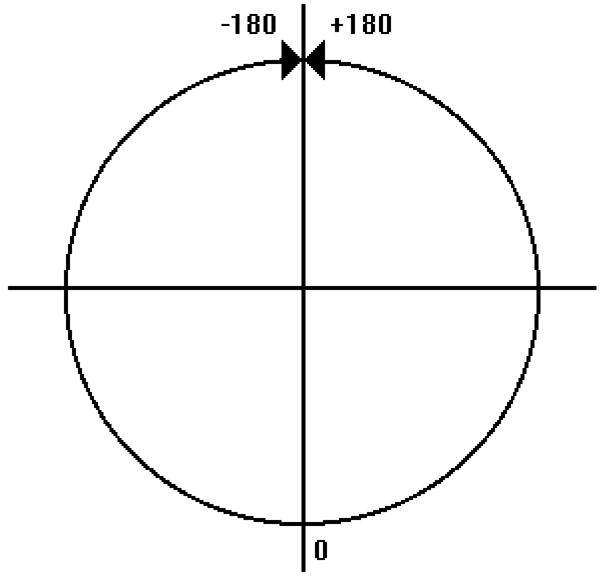
Procedures:
- select **[Linear Velocity]** measure.
- click first marker for desired linear velocity.
- move to next desired frame.
- click the same marker a second time.

Note that this procedure calculates either **average** or **instantaneous** velocity, depending on the time interval.

3. Absolute angle
- the angle between a selected segment (or line) and the vertical.

The absolute angle is calculated with respect to a vertical drawn through one end of the identified segment (or line), where the first selected end is identified as the angle **vertex**. Hu-m-an conventions are to measure the absolute angle using -180 and +180 degree arcs.

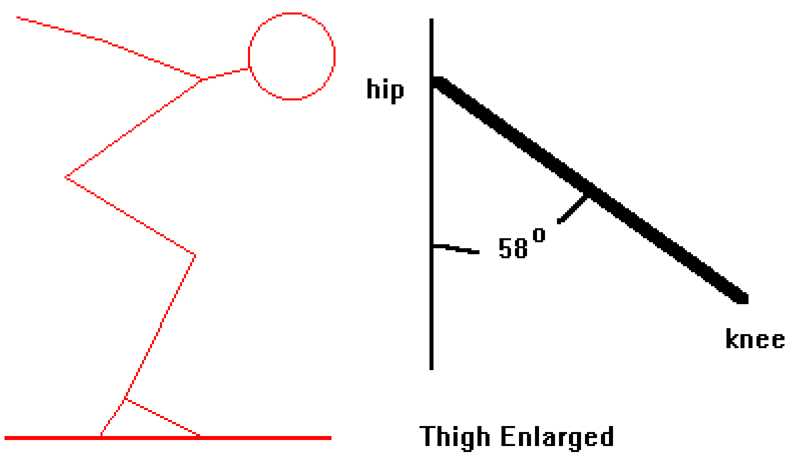
Absolute Angle Conventions



Absolute Angle Conventions

The example below illustrates identifying the absolute angle of the thigh with respect to the hip.

Absolute Angle Example



Absolute Angle of the Thigh with repect to the Hip

Procedures:

- select the **[Absolute Angle]** measure.
- click on a mark identifying the vertex (Vertex Coord #1) of the desired absolute angle (the point through which the vertical line is to be drawn).
- click on a mark identifying the distal end (Distal Coord #1) of the desired absolute angle.

4. Absolute angular velocity

- uses the simple finite difference method to find the angular velocity of an absolute angle change.

Angular velocity

$$\omega = \frac{(\theta_2 - \theta_1)}{\Delta t}$$

Procedures:

- select the **[Abs. Angular Velocity]** measure.
- identify the first absolute angle as described above.
- advance to next desired frame.
- identify second absolute angle as described above.

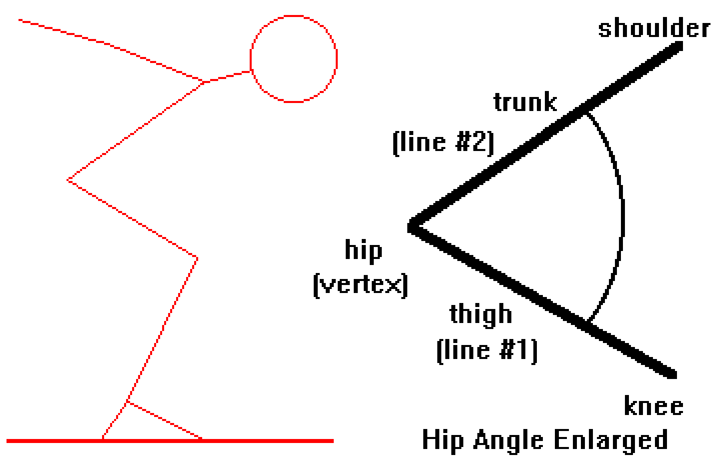
Note that this procedure calculates either **average** or **instantaneous** velocity depending on the time interval. For interpretation, a positive angular velocity means that the segment or line is rotating in a counter-clockwise direction, while a negative angular velocity indicates a clockwise rotation.

5. Relative angle

- the angle between two segment (or intersecting lines).

The desired angle is identified by visualizing the angle drawn in a counter-clockwise direction with the initiating line defined as line #1, and the ending line defined as line #2. For the example hip angle shown below, the thigh would, therefore, be line #1 and the trunk, line #2. Note that, if the subject was facing left, then lines #1 and #2 would be reversed. These conventions enable the computer to interpret correctly the user identified angle.

Relative Angle example.



Relative Angle of the Hip

Procedures:

- select the **[Relative Angle]** measure.
- identify the desired angle and locate line #1 and line #2 as described above (using counter-clockwise convention).
- click on a mark on line #1 (Vertex Coord #1) closest to the desired vertex of the identified relative angle. Note that the mark does not need to be directly on the vertex

since the program will determine the precise vertex of the two identified straight lines.
- click on a mark on line #1 identifying the distal end (Distal Coord #1).
- repeat the procedure for Vertex Coord #2 and Distal Coord #2.

The program visually draws the angle, so that correct selection can be confirmed.

6. Relative angular velocity

- uses the simple finite difference method to find the angular velocity of a relative angle change.

Relative angular velocity

$$\omega = \frac{(\theta_2 - \theta_1)}{\Delta t}$$

Procedures:
- select the **[Rel. Angular Velocity]** measure.
- identify the first relative angle, as described above.
- advance to next desired frame.
- identify the second relative angle, as described above.

Note that this procedure calculates either **average** or **instantaneous** velocity depending on the time interval. For interpretation, a positive angular velocity means that the angle is increasing in size, while a negative angular velocity means that the angle is decreasing in size.

End of overview.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

Procedures:

1. Activate the **[File], [Load Trial]** menu item. Single click the **sprinta.ht1** file and then click **[OK]**.

2. To print a blank data sheet (After loading video file):

- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Blank Data Sheet** item and click the **[Execute]** button responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in **the Optional Header** text box. Click **[Proceed with Printing]** when ready. Retrieve the blank data sheet from the printer.

3. Select the **[Options], [Instant Calculation]** menu item to display the enlarged video picture

and the **Instant Calculation** control window.

4. Select the **[View][Quiz]** menu item to display the **Quiz** window. **The Quiz window can be moved or minimized when not in use, to better access the scroll bars on the video screen.**

5. Click the **[Scale]** button. For this video capture process, it is known that the aspect ratio is 1.0 and, therefore, respond **[OK]** to the Caution window query and move directly on to calculating the scaling factor. Remember that the scaling rod is 1.800 meters long. In this particular case the scaling rod is held horizontally, however, the end points of the rod (either order) can be selected as the **top** and **bottom**. Move windows, where necessary, to see the scaling rod and use the scroll buttons at the bottom of the video window, if necessary. See the figure below for identification of correct end points.

After selecting **meters** and entering the **1.800** for rod length, digitize the ends of the scaling rod. The new scaling factor should be in the range of 0.00195 to 0.00200 m/screen unit. To complete the scaling process, click the **[Apply New Scale]** button.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

Procedures continued.

6. Make and record the following measurements.
   NOTES:
   - Yellow markers have been added to enable consistent measurement. Three measures and an average should be determined for each result.
   - In the **Instant Calculation** window, you can **optionally** click the **<Zoom> <4x>** button. This magnifies the size of the image and enables more accurate location of the cursor in the center of the yellow markers. The scroll bars on the side and bottom of the **Video** window can be used to reposition the pictures if the markers are not visible. If necessary, move to **Instant Calculation** window to access the scroll bars.
   - Remember that the correct **<Measure>** must be selected prior to initiating each process.

a) **The distance the right foot is from the starting line (**frame **0)**. This is determined by measuring the horizontal distance from the back edge of the starting line to the tip of the right toe at the ground (use marks in the same plane). Show quiz question #1, enter your result, and click the **[Check]** button to test result.

b) **The length of the first stride.** Calculate this by measuring the horizontal distance from the tip of the left toe in frame **22** to the tip of the right toe in frame **25**. Show quiz question #2, enter your result, and click the **[Check]** button to test result.

c) **An estimate of the horizontal velocity after the first step**. Calculate this by measuring the horizontal velocity of a point in the center of the head between frames **25** and **26**. Show quiz question #3, enter your result, and click the **[Check]** button to test result.

d) **The absolute angle of the trunk with respect to the hip at the start** (frame **0**). Show quiz question #4, enter your result, and click the **[Check]** button to test result.

e) **The absolute angular velocity of the thigh during swing leg drive** (between frame **19** and **20**). Show quiz question #5, enter your result, and click the **[Check]** button to test result.

f) **The relative angle of the right knee at the start** (frame **0**). Show quiz question #6, enter your result, and click the **[Check]** button to test result.

g) **The relative angular velocity of the knee during swing phase** (between frame **22** and **23**). Show quiz question #7, enter your result, and click the **[Check]** button to test result.

Click the **[Print]** button in the **Quiz** window. In the displayed **Print Options** window, enter your name in the **Optional Header** text box, select the appropriate printer and click the **[Proceed with Printing]** button.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Back

Completing the laboratory.

The **Instant Calculation Laboratory** is now complete.

Complete all the questions on the **Print out**.

Click **[Exit]** in the Quiz window.

Click **[Exit]** in the **INSTANT CALCULATION** window .

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is also available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this Laboratory** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A

Print Option screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

Follow the normal procedures for exiting the **Hu-m-an** program, that is:
Select the **[File], [Exit]** menu item.
Respond **[Yes]** to the query about exiting without saving data.

Back

24 . CENTER OF GRAVITY

HU-M-AN
Forward

CENTER OF GRAVITY

Purpose
1. To introduce the segmental method for calculating the center of gravity.
2. To practice the estimation of the center of gravity for selected figures.

Notebook:
1. Tables I, II, and III (complete) for the segmental method.
2. Print out of Quiz results (C. of G. estimation).

Video Sequence
The video provided contains 12 different figures.

For this laboratory it is assumed that the aspect ratio is 1.0 and it is not necessary to calculate or apply a scaling factor. All calculations are made using video units (not scaled).

Remember that this Instruction Window can be moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components.

Click **[Forward]** to continue.

Forward

HU-M-AN
Forward **Back**

Part I - Calculating the Center of Gravity Using the Segmental Method.

Overview
Center of Gravity definition is the concept in which all the weight of a body is assumed to be concentrated at a single point and acts downwards from that point.

The segmental method is a mathematical procedure for calculating the center of gravity of a multi-segment human body utilizing anthropometric standardized data and fundamental mechanics theory.

The fundamental theory is based on moments and focuses on the concept that the sum of segment moments about the center of gravity equals zero. A corollary is that the moment (turning effect) of the human body considered as a single unit (i.e. system center of gravity), must have the same moment as the system considered as a series of rigid segments.

An 8 segment symmetric model is used for the required manual calculation consisting of:

1. Forearms and hands (elbow axis / wrist axis)
2. Upper arms (glenohumeral axis / elbow axis)
3. Head (center, ear canal)
4. Upper trunk (glenohumeral axis / T12-L1)
5. Lower trunk (hip axis / T12-L1)
6. Thighs (hip axis / knee axis)
7. Shanks (knee axis / ankle axis)
8. Feet (ankle axis / metatarsal II)

The specific procedure involves three phases:

1. Locating and digitizing (locating) the segment end points. (See Example .Table I)
2. Determining contributing segment weight ratios and calculating the segment center of gravity using the appropriate equations (See Example .Table II and Equations (3) and (4) in the fundamental theory)
3. Applying the moment equations to calculate the system center of gravity. (See Example .-Table III and Equations (1) and (2) in the fundamental theory.)

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

EXAMPLE

EXAMPLE SYSTEM CENTER OF GRAVITY CALCULATION

TABLE I
SEGMENT END COORDINATES

a.	Head	Xa= 714	Ya= 634
b.	Wrist	Xb= 476	Yb= 672
c.	Elbow	Xc= 548	Yc= 658
d.	Shoulder	Xd= 636	Yd= 614
e.	Mid-trunk	Xe= 560	Ye= 566
f.	Hip	Xf= 512	Yf= 538
g.	Knee	Xg= 634	Yg= 472
h.	Ankle	Xh= 564	Yh= 352
i.	Toe	Xi= 610	Yi= 334

TABLE II

SEGMENT CENTER OF GRAVITY

```
------------------------------------------------------------
1.  Head
  X1 = Xa                                       X1= 714.000

  Y1 = Ya                                       Y1= 634.000
------------------------------------------------------------
2.  Forearms and Hands
  X2 = Xc+0.682(Xb-Xc)= 548 + 0.682( 476  - 548   )= 498.896

  Y2 = Yc+0.682(Yb-Yc)= 658 + 0.682( 672  - 658   )= 667.548
------------------------------------------------------------
3.  Upper Arms
  X3 = Xd+0.436(Xc-Xd)= 636 + 0.436( 548  - 636   )= 597.632

  Y3 = Yd+0.436(Yc-Yd)= 614 + 0.436( 658  - 614   )= 633.184
------------------------------------------------------------
4.  Upper Trunk
  X4 = Xd+0.360(Xe-Xd)= 636 + 0.360( 560  - 636   )= 608.640

  Y4 = Yd+0.360(Ye-Yd)= 614 + 0.360( 566  - 614   )= 596.720
------------------------------------------------------------
5.  Lower Trunk
  X5 = Xf+0.540(Xe-Xf)= 512 + 0.540( 560  - 512   )= 537.920

  Y5 = Yf+0.540(Ye-Yf)= 538 + 0.540( 566  - 538   )= 553.120
------------------------------------------------------------
6.  Thighs
  X6 = Xf+0.433(Xg-Xf)= 512 + 0.433( 634  - 512   )= 564.826

  Y6 = Yf+0.433(Yg-Yf)= 538 + 0.433( 472  - 538   )= 509.422
------------------------------------------------------------
7.  Shanks
  X7 = Xg+0.433(Xh-Xg)= 634 + 0.433( 564  - 634   )= 603.690

  Y7 = Yg+0.433(Yh-Yg)= 472 + 0.433( 352  - 472   )= 420.040
------------------------------------------------------------
8.  Feet
  X8 = Xh+0.500(Xi-Xh)= 564 + 0.500( 610  - 564   )= 587.000

  Y8 = Yh+0.500(Yi-Yh)= 352 + 0.500( 334  - 352   )= 343.000
------------------------------------------------------------
```

TABLE III
SYSTEM CENTER OF GRAVITY

Segment	Weight Ratio	X	Moment X	Y	Moment Y
Head	0.081	714.000	57.834	634.000	51.354
Forearms/Hands	0.044	498.896	21.951	667.548	29.372
Upper Arms	0.056	597.632	33.467	633.184	35.458
Upper Trunk	0.216	608.640	131.466	596.720	128.892
Lower Trunk	0.281	537.920	151.156	553.120	155.427
Thighs	0.200	564.826	112.965	509.422	101.884
Shanks	0.093	603.690	56.143	420.040	39.064
Feet	0.029	587.000	17.023	343.000	9.947
	1.000	X =	582.005	Y =	551.398

Therefore the system center of gravity = (582.005,551.398)

Back

HU-M-AN

Back

FUNDAMENTAL THEORY

The moment equations for calculating the (x,y) center of gravity coordinates are:

$$x_s = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \quad (1) \qquad y_s = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i} \quad (2)$$

x_s , y_s - system center of gravity

n - number of segments in system

w_i - weight ratio for **i** th segment (ratio of segment weight to system weight)

x_i , y_i - center of gravity for **i** th segment

To operationalize the procedure, it is necessary to know the contributing segment weight ratio and center of gravity. The weight ratio is obtained from published anthropometric data. The segment center of gravity is calculated using appropriate standardized data and the following equations:

$$x_i = x_p + r_{pi}(x_d - x_p) \quad (3)$$

$$y_i = y_p + r_{pi}(y_d - y_p) \quad (4)$$

x_i, y_i - center of gravity for **i** th segment
x_p, y_p - proximal coordinate for **i** th segment
x_d, y_d - distal coordinate for **i** th segment
r_{pi} - ratio of segment length to center of gravity from the proximal end for the **i** th segment.

Click **[Back]** to return.
Back

HU-M-AN

Forward **Back**

Procedures:

1. Activate the **[File]**, **[Load Trial]** menu item. Single click the **cofg.ht1** file and then click **[OK]**.

Print hard copies of Tables I, II and III with the following procedures:

a) Select the **[View], [Macros]** menu item (from the main window menu bar).
b) Select the **Print Blank Tables** item from the list.
c) Click the **[Execute]** button.
d) Ensure that the correct printer is identified, enter the user's name in the **Optional Header** text box and click the **[Proceed with Printing]** button. Retrieve the hard copy from the printer.

2. Select the **[Options], [Instant Calculation]** menu item and following the display of the **Instant Calculation** window, click the **[Digitize Sample Points]** option listed under **Measures**.

Note that there are forward play, backward play, stop, single frame forward and single frame backward buttons for video control.
Use the VCR **single frame** controls to review the video pictures one frame at a time.

3. Frames 1 to 4 are symmetric, while figures 5-12 are non-symmetric. Select one of the symmetric figures for the segmental method calculation.

After placing the arrow tip on the **nine** required segment locations and clicking the left hand mouse button, the resulting (x,y) coordinates, using basic video units, are displayed in the **Instant Calculation** window. **When recording displayed coordinates, do not include decimals.** The nine coordinate locations include:

1. Head
2. Wrist
3. Elbow
4. Shoulder
5. Mid trunk

6. Hip
7. Knee
8. Ankle
9. Toe

Record (x,y) coordinates of the segment end points and complete Table I (Segment End Coordinates).

Note that the scroll bars on the bottom and right side of the <u>Video</u> window can be used to move the figure, if it is covered by other windows during digitizing.

Table II and Table III can be completed after finishing the computer part of the laboratory.

4. Complete Table II to calculate the center of gravity of each segment. Note that the center of gravity of the head is digitized directly and, therefore, no computation is necessary.

5. Complete Table III to calculate the system center of gravity.

This completes Part I. The user's answer can be confirmed during Part II of this laboratory.

Click **[Forward]** to continue.
<u>Forward</u> **<u>Back</u>**

HU-M-AN

<u>Forward</u> **<u>Back</u>**

Part II - Estimating system center of gravity.

Overview

The object for Part II is to estimate the location of the center of gravity for a number of figures.

Procedures:

The **Instant Calculation** window should still be active and the **[Digitize Sample Points]** measure should also remain activated.

1. Click the **[View], [Quiz]** menu item to activate the **Quiz** window.

2. Use the VCR style **single frame** controls and move the video to frame #1 . Note that frame **0** is the title for the video, '**Center of Gravity**', and frame **1** is the first picture. Check to see if the display question in the **Quiz** window identifies the correct picture. Make sure that the VCR video controls in the **Instant Calculation** window and not those in the **Video-Model Control** are used for advancing the video. Also, if the colors of the picture are not correct the **[Re-Display]** button at the bottom of the **Instant Calculation** window can be used for updating the video. **Now move the arrow tip to the estimated center of gravity** and click the left hand mouse button (cross hairs are drawn). The selected coordinates will appear in both the **Instant Calculation** window and the **Quiz** window. Click the **[Check]** button in the **Quiz** window to see if the answer is acceptable.

If not correct, repeat the selection and **[Check**] procedure. Note that the **Response/Directions** area in the **Quiz Window** provides hints for where to move the cursor if your answer is incorrect. The acceptable error range is quite small for this exercise. During an evaluation session the error range is less stringent and has more than one level.

3. Continue by advancing the video to the next frame. The **Quiz** window will also automatically advance. If it does not, then selecting the button number (in the Quiz window) corresponding to the displayed picture can manually advance it. Again locate and **[Check]** your estimate for the center of gravity. Complete all 12 figures.

4. Print a summary of the results. Click the **[Print]** button in the **Quiz** window. **A Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready.

Part II of the laboratory exercise has now been completed.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Back

Exit Center of Gravity Laboratory.

The Center of Gravity Laboratory is now complete.

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is also available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this Laboratory** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

To Exit:

1. Click **[Exit]** in the **[Quiz]** window.
2. Click **[Exit]** in the **Instant Calculation** window.
3. Select the **[File], [Exit]** menu item.

Back

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25 . KINEMATIC QUIZ

HU-M-AN

Forward

KINEMATIC QUIZ

Purpose

1. To introduce kinematic analysis using previously digitized and analyzed video based data.
2. To analyze selected general movement skills.
3. To identify patterns of coordination for displacement and velocity.
4. To test understanding of basic kinematic measurements.

Notebook:

1. Print out of **Quiz** results.

Data sequences.

The data for this analysis include three vertical jumps and one standing long jump and incorporates model files together with a prepared analysis from the database.

Remember that this Instruction Window can be moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components.

Click **[Forward]** to continue.

Forward

HU-M-AN

Forward Back

Overview

Previously digitized and analyzed data for three subjects performing a vertical jump and one subject performing a standing long jump are available for analysis. Each file can be loaded by selecting the **[File], [Load Trial]** menu item, followed by selecting the desired file and clicking the **[OK]** button in the **Load Trial** window (or by double clicking the desired file).

To speed up the process, click the **[Load without video]** checkbox. Although this is strictly optional, it does minimize the loading time when files are accessed many times and video viewing is not critical.

Note that the **Viewing Analyzed Data** demonstration illustrates the techniques that are available for displaying and analyzing the data. Review this demonstration, if necessary.

Graph and Model display options available:

- display stick figures in a variety of forms.

- create graphs of desired data.
- display figures and graphs together to review coordination.
- locate specific values from displayed graph data.
- locate maximum or minimum values.

A quiz of 12 questions has been prepared to test your understanding of basic kinematic analysis. Two approaches will be used to evaluate jump coordination

Displacement Pattern Coordination for Contributing Joints

The coordination of joints contributing to a motion can be assessed in many ways. In the vertical jump one approach is to identify the order of the initiation of extension (plantar-flexion) for the hip, knee and ankle joints (proximal to distal), to determine if they are acting in sequence (in order) or simultaneously. Since many variations of jumping initiation occur, it is often necessary to distinguish between incidental extension (or plantar-flexion), and the true power extension (or plantar-flexion) phase.

If there is an identifiable proximal to distal (hip, knee, ankle) order, then evidence exists that the displacement coordination is sequenced, while, if the initiation of motion occurs at the same time, then evidence points to simultaneous coordination.

Figure 1 below shows the hip, knee and ankle joint displacement for a vertical jump. The **initiation** of extension (plantar-flexion) is identified (1,2 and 3), indicating evidence of sequenced coordination, since the hip initiates extension first, followed in time order by the knee and then the ankle.

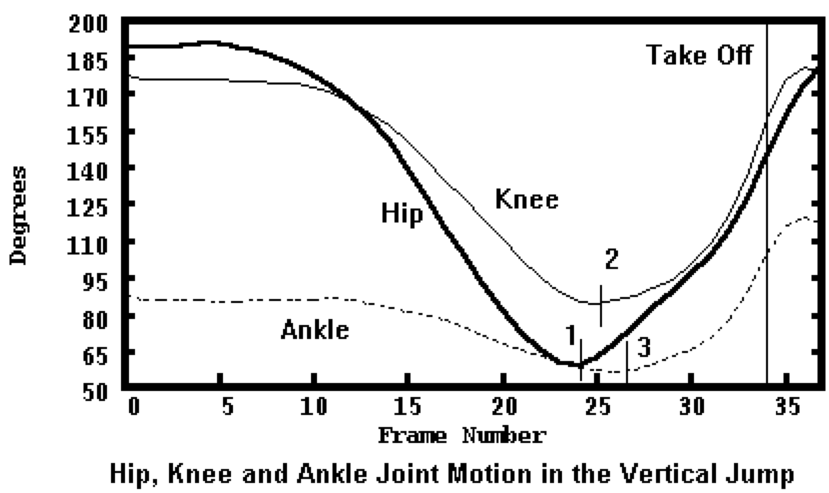


Figure 1

Velocity Pattern Coordination for Contributing Joints

A similar approach can be used to evaluate the velocity patterns of contributing joints.

One aspect of coordination for angular velocities can be identified by examining the timing of maximum angular velocities for the contributing joints under investigation (hip, knee and ankle). Invariably, simultaneous coordination would typically break down, if an infinitesimally small time difference was required and, therefore, an arbitrary standard must be established. Since the standard video speed is at the relatively slow rate of 25-30 frames per second, it will be assumed that simultaneous coordination occurs only when all three joints reach their maximum angular velocity at the same frame.

Figure 2 below shows the pattern of hip, knee and ankle velocities during the vertical jump for one selected subject. The points of maximum extension (or plantar-flexion) angular velocity have been identified. Since they do not occur at the same frame, and are also not maximized in order, it is concluded that evidence of neither simultaneous nor sequential coordination exists in this case. Note that it is also possible to determine evidence of displacement coordination from this graph. (Hint: review and understand maximum and minimum displacement values and their resulting velocity relationship.)

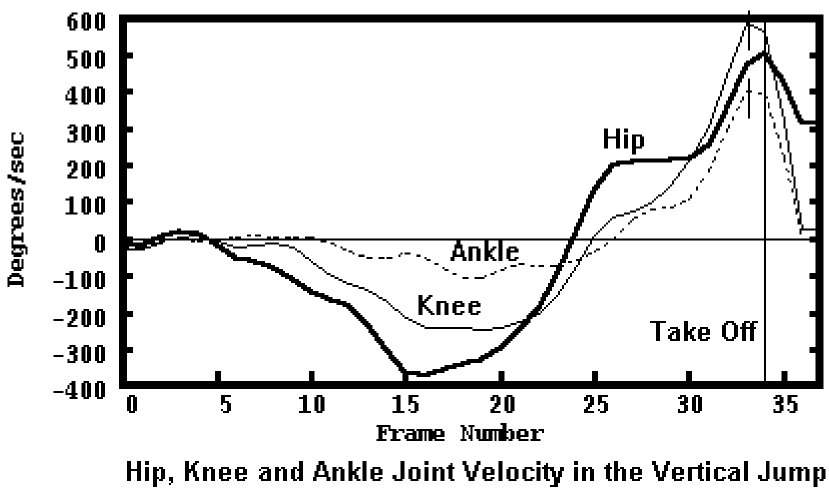


Figure 2

Coordinated initiation of contributing joints, while reaching maximum linear velocity and culminating in a vertical jump, requires skilled coordination and balanced muscular development. Coordination changes as small as 3/100th of a second have been shown to change a vertical jump into a standing long jump! The results of lack of effective coordination for both displacements and velocities are reduced jumping height, traveling, and unwanted rotation while in the air.

Click **[Forward]** to continue.

Forward Back

Procedures:
1. Activate the **[View], [Quiz]** menu item showing the **Quiz** window. The first question is automatically displayed. To answer the question, analyze one or more data files, and make specific value readings from graphs, as needed. Remember that the **Quiz** window can be moved, if desired.

2. Read the question carefully and then load the appropriate data file for analysis. To load data, click the **[File], [Load Trial]** menu item, select the desired file and then click **[OK].**

Success in answering the questions primarily depends on the ability to determine which variable(s) should be analyzed, and understanding the measurement requested. Consider your choices carefully.

Note:
- The **[Auxiliary Graph Data]** window (found under the **[View]** menu item) can be used to save a specific graph, when different subjects are to be compared.
- It is helpful to **minimize** the instruction window to give easy access to the entire screen.
- The vertical lines on the graph represent the **Take Off** and for the long jump, also **Landing**.

After the answer to the question has been determined, select the letter button for responses to multiple choice questions or enter the number answer and click **[Check],** to determine if the response is correct.

Continue on with all the questions by clicking the number of the question to be displayed.

Some questions will require calculations. Always carefully consider what data should be displayed to best answer a particular question. Remember that values for a specific time or maximum/minimum, values can be displayed by appropriate clicking of the mouse button over the **Graph-Data** window. In particular, it is important to use the **Click [High]** and **[Low]** functions to accurately determine maximum or minimum values.

3. After all questions have been completed, print a summary of the results. Click the **[Print]** button in the **[Quiz]** window. A **[Print Option]** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing]**, when ready.

Click **[Next]** to continue.
Forward Back

HU-M-AN
Back

Completing the laboratory.

The **Kinematic Quiz** Laboratory is now complete.

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is also available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this**

Laboratory item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

Select the **[File], [Exit]** menu item to exit the program.

Back

26 . GAIT ANALYSIS
- KNEE AND ANKLE JOINT MOTION DURING WALKING AND RUNNING

HU-M-AN
Forward

GAIT ANALYSIS - KNEE AND ANKLE JOINT MOTION DURING WALKING AND RUNNING

Purpose
1. To practice analysis from digitizing to activating macros.
2. To introduce movement pattern analysis in biomechanics.
3. To digitize and analyze the specific movement pattern of the knee and ankle joint in walking.
4. To compare knee and ankle joint motion in walking, to level and uphill running.

Notebook:
1. Printed output from a **macro** analysis of your walk and a **macro** directed comparison with running. Answer questions as required.

Video Sequence
For this laboratory, a video that captures at least one complete walking cycle is provided for digitizing and analysis, titled, **walk.avi**. Video and completed analysis files for level treadmill running (**runa.ht1**) and uphill running (**uphilla.ht1**) are provided for review.

Remember that this Instruction Window can be moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components.

Click **[Forward]** to continue.

Forward

HU-M-AN
Forward **Back**

Overview

Part I
In this exercise the movement pattern of the knee and ankle angle for the right leg will be analyzed from right heel contact through one complete step to the next right heel contact.

Figure 1 identifies on a schematic, the knee and ankle angles measured as the relative angle between adjacent segments. **Figures 2** and **3** show typical displacement patterns for one complete step.

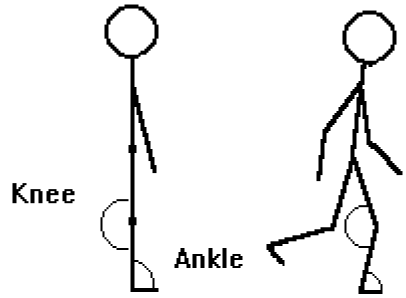
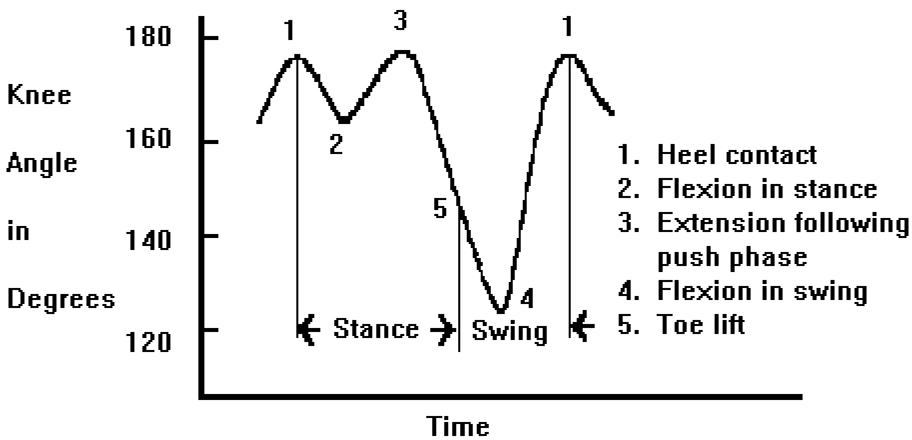
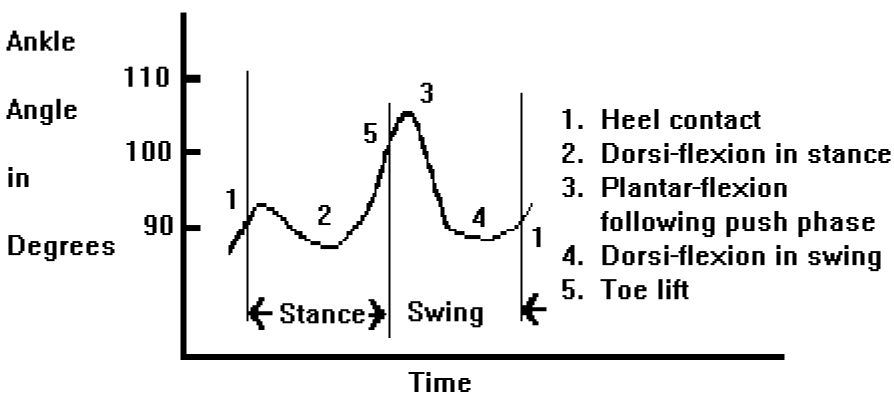


Figure 1



Knee Joint Action in Walking

Figure 2

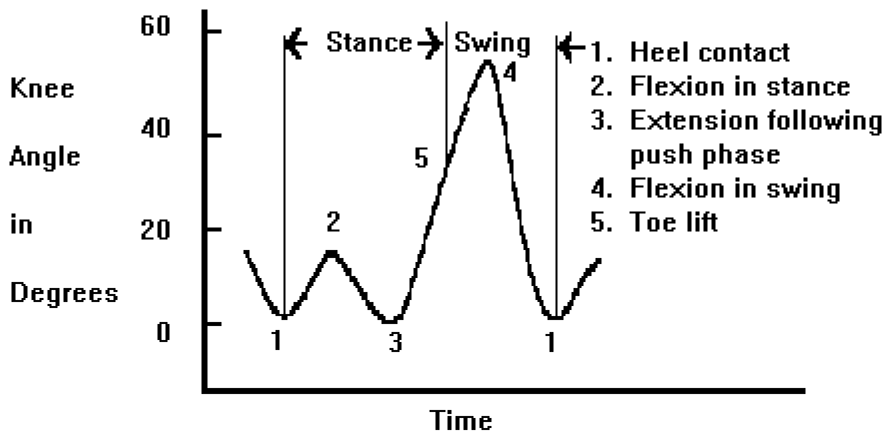


Ankle Action During Walking

Figure 3

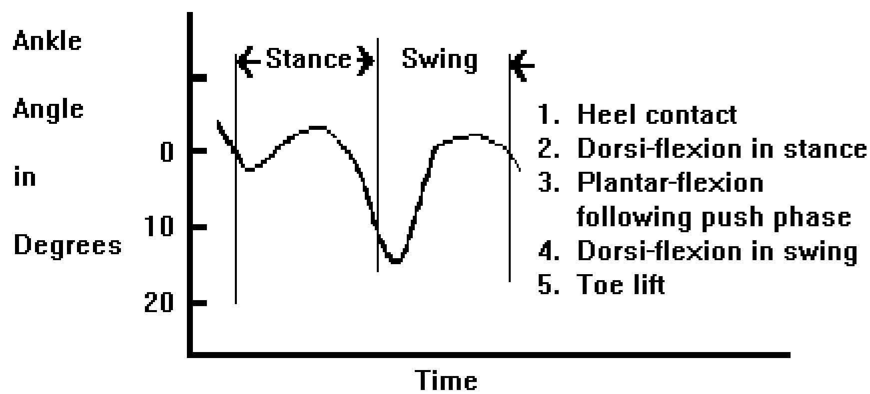
An Alternate Form of Presentation - Zero Base Angles

A second measurement basis defines the knee and ankle angles as zero during erect standing. Flexion/extension and dorsi-flexion/plantar flexion directions are also often reversed for graphic presentation. **Figures 4** and **5** reproduce the typical movement patterns using **zero base** format.



Knee Joint Action in Walking

Figure 4



Ankle Action During Walking

Figure 5

The collection points used to identify the appropriate angle consist of:

1. Hip axis
2. Knee axis
3. Ankle axis
4. Back of heel at the bottom of the foot
5. Under ball of foot at the bottom of the foot

Figure 6 identifies the collection points on a sample video picture.

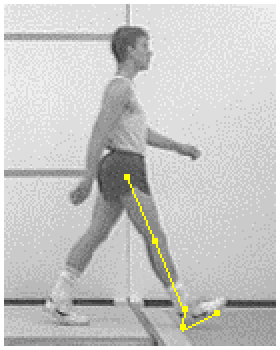


Figure 6

Part II
A previously prepared **project file** is used for comparison of knee and ankle motion during walking and running.

Click **[Forward]** to continue.
Forward Back

HU-M-AN

Forward Back

Procedures:

Part I Digitizing and Analysis of Knee and Ankle Motion in Walking

1. Activate the **[File], [Load Trial]** menu item. Now single click the listed **walk.avi** file and again click **[OK].**

2. Use the VCR controls to review the full video. Use single frame forward and backward to identify the third frame **before** first right heel contact and the third frame **following** the next right heel contact of one complete step. Enter these frame numbers as the **Start** and **End** frames at the top of the **Video-Model Control** window. Now select the **[Utilities], [Set a New Trial Sub-Sequence]** menu item and respond **[Yes]** to the caution query.

The video should now consist of three frames, followed by right heel contact, continuing through to the second right heel contact, followed by three frames to complete the sequence. If a mistake is made, the process can be repeated following procedures 1 and 2, (Re-loading the original **.avi** file).

Suitable default **Trial Set Up** files (Collection Model, Display Model, etc.) are already established, so video digitizing can begin immediately.

Forward Back

HU-M-AN

Forward **Back**

Procedures continued.

3. Select the **[Options], [Digitize]** menu item to display the video picture and the **Digitizing** control window. Note that a Zoom option is available to increase the size of the video displayed, as desired, and that the video can be scrolled, if necessary.

4. Click the **[Scale]** button. Since the aspect ratio is known to be 1.0, respond **[Yes]** to the Caution and proceed directly to the scaling calculation. Complete the scaling factor computation process, **as previously demonstrated**. The scaling rod is 1.80 meters long.

5. Starting with frame **0**, digitize the frame by placing the arrow tip over the appropriate location and clicking the left hand mouse button for:

1. Hip
2. Knee
3. Ankle
4. Back of heel at the bottom of the foot
5. Under Ball of foot at the bottom of the foot

See the picture provided in the **Overview**, if a review of digitizing locations is required.

If errors are present, it is easiest to correct them before proceeding to the next frame. Use either **[Replacement Mode]** or **[Re-collect Frame]** to replace faulty data.

At the end of each frame collection, if a correct stick figure is displayed, then simply re-**click the left hand mouse button with the arrow over the digitizing screen** to advance to the next frame.

6. Continue the digitizing process until all frames have been completed. Note again that the scroll bar at the bottom of the **Digitizing Screen** can be used to move the video figure, if necessary.

7. Click the **[Exit]** button at the bottom of the **Digitizing** control window.

Click **[Forward]** to continue.

Forward **Back**

HU-M-AN

Forward **Back**

Procedures continued.

8. Activate the **[Model], [Video]** and **[+ Model]** check boxes in **the Video-Model Control** window and click the **run** button **[>]** to review the video and digitizing.

9. **BEFORE ANALYZING THE DATA USING THE PREPARED MACRO FILE, THE APPROPRIATE CRITICAL POINTS FOR YOUR PARTICULAR SUBJECT MUST BE ESTABLISHED**. Select the **[Edit], [Trial Set Up]** menu item. Click the **[Subject - Trial Data]** button. At this time there will be no **critical points** listed. Click the **[Add]** button. Replace the **1** in the presented text field with the title, **Right heel contact,** and then replace the **0** with the

correct frame number for this point. NOW CLICK THE **ACTIVATE** CHECK BOX. Note that the video frames can be changed, to view the video, while this window is active. Also **the Subject - Trial Data** window can be moved, if it covers the video.

10. Next click the **[Add]** button again and this time replace the **2** in the text field with the title, **Right toe off.** Replace the **0** with the frame number identifying the right toe first leaving the ground, after stance (support). Again click the **Activate** check box.

11. Repeat the process adding a third critical point using the **Right heel contact** title for the second time. (Add the correct frame number and click the **Activate** check box.)

12. **[Exit]** the **Subject - Trial Data** window and then **[Exit]** the **Trial Set Up** window.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

Procedures continued.

13. The data set is now ready for processing. A macro has been prepared to perform a basic gait analysis. Select the **[View], [Macros]** menu item. From the macro list presented select the **Simple Walking Analysis** item and click **[Execute]** answering **[Yes]** to the caution query.

Note that if an error has been made in the number of critical points or digitized points, a warning message will be displayed. If this is the case, it is better not to execute the macro until the errors have been corrected.

14. When the **Print Options** window is displayed, ensure that the correct printer is identified, enter your name in the **Optional Header** text box, and click **[Proceed with Printing].**

15. Read the printed results carefully. Answer the questions based on your knowledge of gait analysis, as explained in the overview and covered in class.

Click [Forward] **to continue.** **Forward Back**

HU-M-AN

Forward **Back**

Procedures continued:

Part II Comparison of Knee and Ankle Motion in Walking and Running

1. The knee and ankle motion in walking will now be compared with previously digitized and analyzed data for level running on a treadmill, and uphill running on a treadmill. The data are made available in the form of **Project Data**, a format where similar data from a large number of trials can be stored for comparison with current data.

2. Activate the **[File], [Load Project Data]** menu item. Now click the **[CD/Server Project Data]** button in the bottom left corner of the displayed window. From the list of project files **(*.hp?)** presented, mark (click) the **gait01.hp1** file and then click **[OK]**. Note that the **Project Data** window contains three lists:

- trials available
- variables calculated
- critical points for synchronization

The two trials available are from level and uphill running. The variables include the knee and ankle angle. Same critical points must exist for all data sets. Since it is normal for different trials to be of different lengths, it is often advantageous to synchronize the data to the critical points. In this presentation, the data will be left with their original time base.

3. Review the data by marking the two trials and then selecting first the knee, and then the ankle variables. The knee and ankle variables for the current walker can be super-imposed over the **Project Data**.

Forward **Back**

HU-M-AN

Forward **Back**

Procedures continued:

4. The data set is now ready for processing. A macro has been prepared to perform a basic gait analysis. Select the **[View], [Macros]** menu item. From the macro list presented select the **Walking and Running** item and click **[Execute]** answering **[Yes]** to the caution query.

Note that if an error has been made in the number of critical points or digitized points, a warning message will be displayed. If this is the case, it is better not to execute the macro until the errors have been corrected.

5. When the **Print Options** window is displayed, ensure that the correct printer is identified, enter your name in the **Optional Header** text box, and click **[Proceed with Printing].**

6. Study the printed results carefully. Identify for yourself the changes in knee and ankle motion that occur when going from walking to level and uphill treadmill running. Note that the "run" is

more like a jog since it is performed at a relatively low speed. Complete the questions based on your knowledge of gait analysis, as explained in the overview and covered in class.

Tables I and II combine data from the walk just digitized in this exercise, and the level and uphill run, which are parts of the **Project Data**. Note, in particular, Tables III and IV on page 6 of the hard copy printout, which require an analysis of the combined data, to rank order the results.

Forward Back

HU-M-AN

Forward Back

Further review of treadmill running:

The source files for the level and uphill treadmill running are also available with their respective videos for review. Do not load these files until you have successfully retrieved the printed copy, as your walking results are not saved. If you wish to save the data, follow these procedures:

To save the data: (Optional)

1. Select the **[File], [Save Trial As]** menu item. The original drive will automatically be accessed. If this is a CD or server the data are to be saved to a different drive (e.g. **[Local Data Area]**), then locate that drive and sub-directory. **The data collection can also be saved to a floppy disk, if preferred.** In the title field a default title, **walk.ht**, will appear. Complete the three letter extension with a letter or number. Since this is a basic collection, a title like **walk.ht0** is appropriate.

2. Click **[Save]** to activate the saving process.

Forward Back

HU-M-AN

Back

Completing the laboratory.

The **Gait Analysis Laboratory** is now complete.

If the data collection is not to be saved, then while exiting, respond **[Yes]** to the **exit without saving the data** caution message.

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this Laboratory** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name

in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

Follow the normal procedures for exiting the **Hu-m-an** program, that is, select the **[File], [Exit]** menu item.

Back

27 . VERTICAL JUMP ANALYSIS

HU-M-AN
Forward

VERTICAL JUMP ANALYSIS

Purpose
1. To practice analysis from digitizing to signal processing.
2. To introduce sport skill analysis in biomechanics.
3. To analyze the movement patterns associated with the shoulder, hip, knee and ankle joint in vertical jumping.
4. To practice the use of **Macros** used in **Hu-m-an** program analysis.
5. To understand and interpret basic kinematic measurements.

Notebook
1. Four page Basic Vertical Jump Analysis print out. Complete the questions as required.

Video Sequence

For this laboratory, a video that captures one complete vertical jump is provided and is titled, **jump.avi**.

Remember that this Instruction Window can be moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components.

Click **[Forward]** to continue.

Forward Back

HU-M-AN
Forward Back

Overview

A basic kinematic analysis of the vertical jump is executed using a previously prepared **macro** file. In addition to basic kinematic analysis, an assessment of coordination will be applied, as introduced in the **Kinematic Quiz** laboratory.

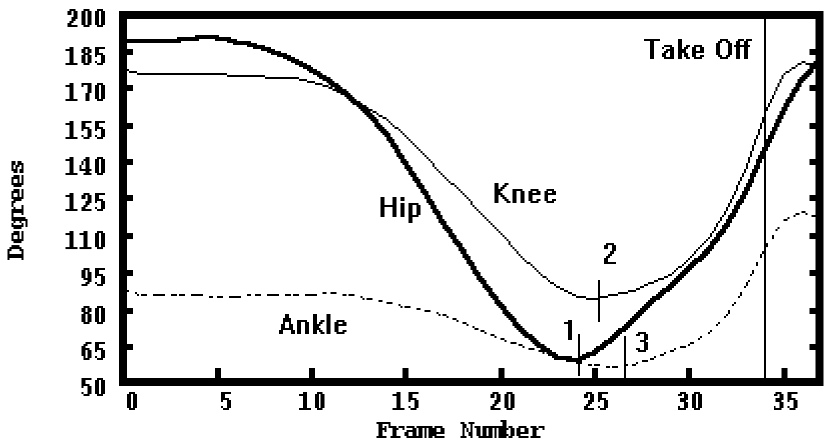
Review of Coordination Analysis

Displacement Pattern Coordination for Contributing Joints

The vertical jump can be monitored through kinematic measurement of selected elements. A complementary approach is to analyze the coordination of joints and this can be evaluated in different ways. In the vertical jump one approach is to identify the order of the initiation of extension (plantar-flexion) for the hip, knee and ankle joints, to determine if they are acting sequentially (in order), or simultaneously. Since many variations of jumping initiation occur, it is often necessary to distinguish between incidental extension (or plantar-flexion), and the true power extension (or plantar-flexion) phase.

If there is an identifiable hip, knee, ankle order (normally assumed to be proximal to distal unless otherwise indicated), then evidence exists that the displacement coordination is **sequenced,** while, if the initiation of motion occurs at the same time, then evidence points to **simultaneous** coordination.

Figure 1 below shows the hip, knee and ankle joint displacement for a vertical jump. The **initiation** of extension (plantar-flexion) is identified (1,2 and 3) showing that evidence of sequenced coordination exists, since the hip initiates extension first, followed in time order by the knee and then the ankle.



Hip, Knee and Ankle Joint Motion in the Vertical Jump

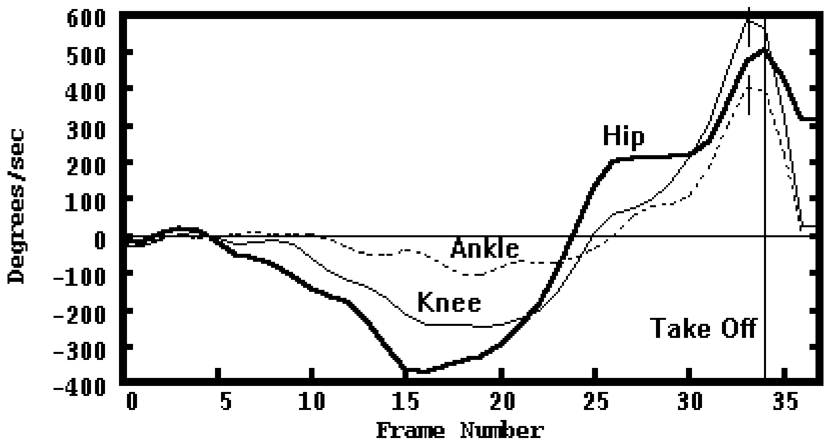
Figure 1

Velocity Pattern Coordination for Contributing Joints

A similar approach can be used to evaluate the velocity patterns of contributing joints.

One aspect of coordination for angular velocities can be identified by examining the timing of maximum angular velocities for the contributing joints under investigation (hip, knee and ankle). Simultaneous coordination would typically break down, if an infinitesimally small time difference was required, and, therefore, an arbitrary standard must be established. Since the standard video speed is at the relatively slow rate of 25-30 frames per second, it will be assumed that simultaneous coordination occurs only when all three joints reach their maximum angular velocity at the same frame.

Figure 2 below shows the pattern of hip, knee and ankle velocities during the vertical jump for one selected subject. The points of maximum extension (or plantar-flexion) angular velocity have been identified. Since they do not occur at the same frame, and are also not maximized in order, it is concluded that evidence of neither simultaneous nor sequential coordination exists in this case. Note that it is also possible to determine evidence of displacement coordination from this graph. (Hint: review your understanding of maximum and minimum displacement values and their resulting velocity relationship.)



Hip, Knee and Ankle Joint Velocity in the Vertical Jump

Figure 2

Jumpers often appear to exhibit sequential initiation of contributing joints while reaching maximum velocity simultaneously. To accomplish this while culminating in a vertical jump with little or no horizontal travel requires skilled coordination and balanced muscular contribution. Coordination changes as small as 3/100th of a second have been shown to change a vertical jump into a standing long jump! The results of lack of effective coordination for both displacements and velocities are, reduced jumping height, traveling, and unwanted rotation while in the air.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

Procedures:

1. Activate the **[File], [Load Trial]** menu item. Now single click the listed **jump.avi** file and again click **[OK].**

2. Use the VCR controls to review the full video. Use single frame forward and backward to identify the **third frame before** the first detectable motion of either the hip or knee joint and the **third frame following** last ground contact at the point of take off. Enter these frame numbers as the **Start** and **End** frames at the top of the **Video-Model Control** window. Now select the **[Utilities], [Set a New Trial Sub-Sequence]** menu item and respond **[Yes]** to the caution query.

The video should now consist of three frames, followed by a vertical jump until take off, followed by three frames to complete the sequence. If a mistake is made, re-load the **jump.avi** file and repeat the process following procedures 1 and 2.

Suitable default **Trial Set Up** files are already established, so video digitizing can begin immediately.

Forward Back

HU-M-AN

Forward Back

Procedures continued.

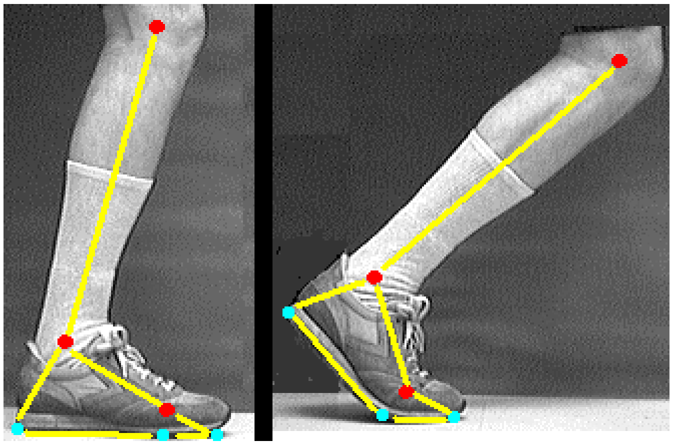
3. Select the **[Options], [Digitize]** menu item to display the video picture and the **Digitizing** control window.

4. Click the **[Scale]** button. Since the aspect ratio is known to be 1.0, respond **[OK]** to the Caution and proceed directly to the scaling factor calculation. **Complete the scaling factor computation process, as previously introduced.** The scaling rod is 1.800 meters long. (This ends with activating the **[Apply New Scale]** button!)

5. Starting with frame **0**, digitize the frame by placing the arrow tip over the appropriate location and clicking the left hand mouse button for:

1. Center of head
2. Wrist
3. Elbow
4. Shoulder
5. Hip
6. Knee
7. Ankle
8. Toe (lateral aspect of 5th metatarsal)
9. Tip toe (front edge of toe at the bottom of the foot
10. Under Ball of foot at the bottom of the foot)
11. Back of heel at the bottom of the foot

Figure 3 identifies the collection points in a sample video.



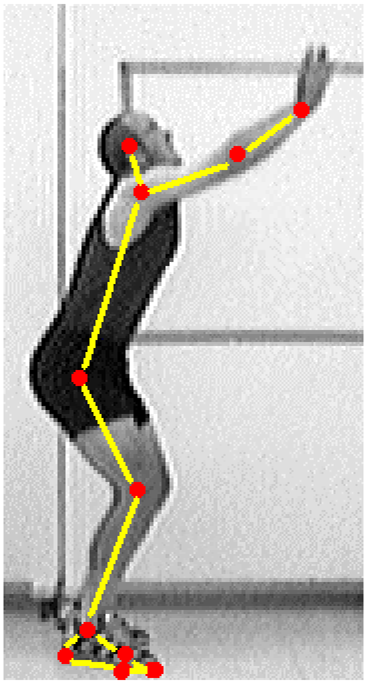


Figure 3 Vertical Jump Collection Points and Foot Details.

If errors are present, it is easiest to correct them before proceeding to the next frame. Use either **[Replacement Mode]** or **[Re-collect Frame]** to replace faulty data.

If a correct stick figure is displayed, then simply re-click the left hand mouse button with the arrow over the digitizing screen to advance to the next frame.

The movement is assumed to be symmetric, therefore, if the arms separate, continue to collect the near side.

6. Continue the digitizing process until all frames have been completed.

7. Click the **[Exit]** button at the bottom of the **Digitizing** control window.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

Procedures continued.

8. Activate the **[Model], [Video]** and **[+ Model]** check boxes in the **Video-Model Control** window and click the **run** button **[>]** to review the video and digitizing.

9. **BEFORE ANALYZING THE DATA USING THE PREPARED MACRO FILE, THE**

APPROPRIATE CRITICAL POINT FOR YOUR PARTICULAR SUBJECT MUST BE ENTERED. Select the **[Edit], [Trial Set Up]** menu item. Click the **[Subject - Trial Data]** button. At this time there will be no **critical points** listed. Click the **[Add]** button. Replace the **1** in the presented text field with the title, **Take off,** and then replace the **0** with the correct frame number for the point of last ground contact. CLICK THE **[ACTIVATE]** CHECK BUTTON. Note that the video frames can be advanced to view the video, while this window is active. Also the **Subject - Trial Data** window can be moved, if it covers the video.

10. **[Exit]** the **Subject - Trial Data** window and then **[Exit]** the **Trial Set Up** window.

Click **[Forward]** to continue.

Forward Back

HU-M-AN
Forward Back

Procedures continued.

11. The data set is now ready for processing. A macro has been prepared to perform a basic vertical jump analysis. Select the **[View], [Macros]** menu item. From the **macro** list presented select the **Basic Vertical Jump Analysis** item and click **[Execute]** answering **[Yes]** to the caution query.

12. When the **Print Options** window is displayed, ensure that the correct printer is identified, enter your name in the **Optional Header** text box, and click **[Proceed with Printing].**

13. Read the printed results carefully. Answer the questions included on the printed results, based on your knowledge of kinematics and the vertical jump. For details on the question about estimating the maximum shoulder velocity during propulsion, see **The Graphic Tangent Method for Estimating Velocity**

Click **[Forward]** to continue.

Forward Back

HU-M-AN
Back

Completing the laboratory.

The **Vertical Jump Analysis Laboratory** is now complete.

To save the data (optional):

1. Select the **[File], [Save Trial As]** menu item. The original drive will automatically be accessed. If this is a CD or server and the data are to be saved to a different drive (e.g. **[Local Data Area]**), then locate the appropriate drive and sub-directory. The data collection can also be saved to a floppy disk, if preferred. In the title field a default title, **jump.ht,** will appear.

Complete the three letter extension with a letter or number. Since this is a basic collection, a title like **jump.ht0** is appropriate.

2. Click **[Save]** to activate the saving process.

If the data material is not to be saved, then, while exiting, respond **[Yes]** to the **exit without saving the data** caution message.

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is also available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this Laboratory** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

Follow the normal procedures for exiting the **Hu-m-an** program, that is, select the **[File], [Exit]** menu item.

Back

28 . KINETIC QUIZ

HU-M-AN
Forward

KINETIC QUIZ

Purpose
1. To introduce kinetic analysis using digitized and analyzed video based data.
2. To analyze selected jumping skills.
3. To quiz understanding of basic kinetics.

Notebook:

1. Print out of the **Quiz** results.

Remember that this Instruction Window can be moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components.

Click **[Forward]** to continue.

Forward

HU-M-AN
Forward **Back**

Overview
Previously digitized and analyzed data for three subjects performing a vertical jump and one subject performing a standing long jump are available for analysis. Note that the listed files include **.ht1** and **.ht2** files for the 3 vertical jumpers and the long jumper. The **.ht1** files are the same as those viewed for the **Kinematic Quiz,** while the **.ht2** files include new kinetic data. The **.ht2** files should be used to answer the questions in this **Kinetic Quiz** laboratory.

Each file can be loaded by selecting the **[File], [Load Trial]** menu item and then by selecting the desired file and clicking the **[OK]** button in the **Load Trial** window (or double clicking the desired file).

To speed up the process, click the **[Load without video]** checkbox. Although this is strictly optional, it does minimize the loading time when files are accessed many times and video viewing is not critical.

Review, if necessary, the various options that are provided to display and analyze the data:

You can:

- display stick figures in a variety of forms.
- create graphs of desired data.
- display figures and graphs together to review coordination.
- locate specific values from displayed graph data.
- locate maximum or minimum values.

A quiz of 12 questions has been prepared to test your understanding of basic kinetic analysis.

In review:

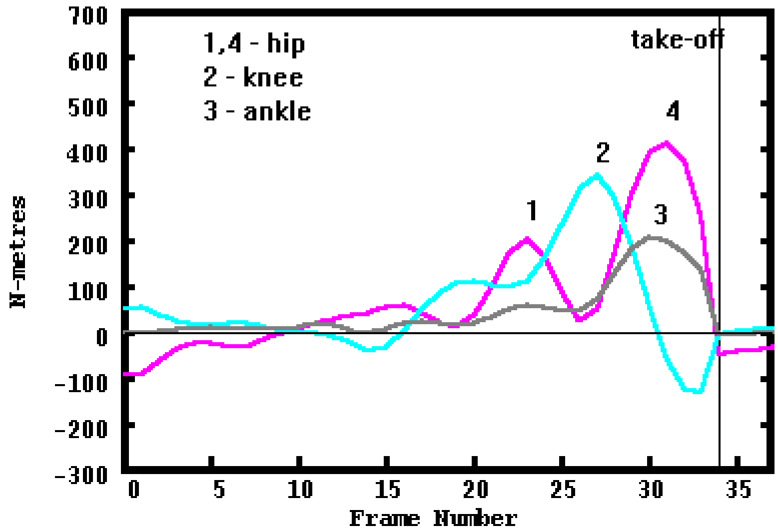
Coordination of Joint Torque Patterns

The concept of assessment of joint coordination through displacement and velocity patterns was introduced earlier, in the context of kinematic analysis of jumping by investigating the initiation of joint extension and joint angular velocities.

Evidence of **coordination** can also be identified in vertical jumping by analyzing the joint torque produced by the hip, knee and ankle. In particular, the initiation of the powerful thrust phase of the jump will be investigated by identifying the time when the hip, knee and ankle joints reach their maximum torque. As a result of the interaction between segments, joint torque patterns often display unexpected patterns and illustrate the complex requirements for skilled performance.

Since many variations of jump initiation occur, it is often necessary to interpret torque patterns in an attempt to identify true power phases.

Figure 1 below shows the hip, knee and ankle joint torque patterns for a vertical jump. Note that the hip demonstrates two distinct peaks (1 and 4) with the first peak appearing to initiate hip extension. If this peak is considered, then the motion does illustrate sequenced coordination of the hip, knee and ankle (1, 2 and 3). It is evident that the second dominant hip torque is also very important to overall power.



Hip, Knee and Ankle Net Moments During the Vertical Jump

Figure 1

Evidence of Eccentric and Concentric Contractions

Muscular contractions:

Isometric - Muscle under tension and not changing length.

Concentric - Muscle under tension while shortening in length

Eccentric - Muscle under tension while lengthening.

It is possible to suggest the type of contraction for the dominant muscle group in kinetic analysis. In this data analysis, a positive torque represents extensor (or plantar flexor) dominance while a negative torque represents flexor (or dorsi-flexor) dominance for the muscle group under investigation. If the physical action of the muscle is determined, then the user can suggest whether the dominant muscle action is concentric or eccentric. "Suggest" is used in interpreting net moments, particularly when they are not large, since other factors, such as segment weights, can influence the results.

For example, if the flexors are dominant during flexion, then the contraction for this muscle group is concentric, and if the flexors are dominant during extension, then the contraction for this muscle group is eccentric.

Figure 2 below shows the displacement and net moment patterns for the knee flexors/extensors. Using the above analysis, the numbered shaded sections of the graph represent:

1. Flexors dominant during flexion - a concentric contraction of the flexors.
2. Extensors dominant during flexion - an eccentric contraction of the extensors.
3. Extensors dominant during extension - a concentric contraction of the extensors.
4. Flexors dominant during extension - an eccentric contraction of the flexors.

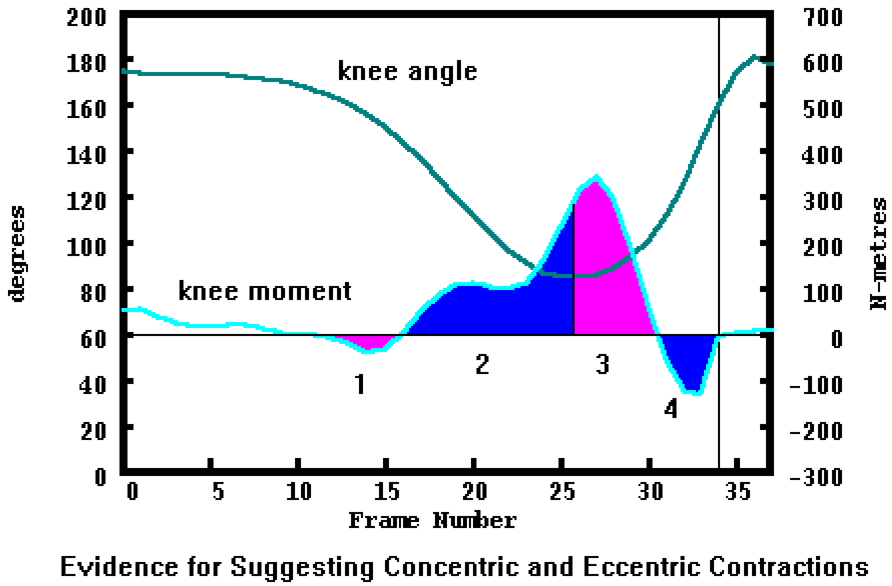


Figure 2

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

Procedures:

1. Activate the **[View], [Quiz]** menu item showing the **Quiz** window. The first question will be automatically displayed. To answer load one or more data files, and make specific value readings from graphs, as needed.

2. To load data activate the **[File], [Load Trial]** menu item, select the desired file and then click **[OK].**

Note that the **Auxiliary Graph Data** window (found under the **[View][Auxiliary]** menu item) can be used to save a specific graph, when different subjects are to be compared.

After determining the answer to the question, select the **letter button** for responses to multiple choice questions or enter the number answer and click **[Check]** to determine if the response is correct.

Continue on with all questions by clicking the number of the question to be displayed.

Some questions will require calculations. Always carefully consider what data should be displayed to best answer a particular question.

Remember that the **Click** **[High]** and **[Low]** functions are valuable tools to accurately identify maximum and minimum values.

3. Print a summary of the results. Click the **[Print]** button in the **Quiz** window. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready.

Click [Forward] to continue.

Forward Back

HU-M-AN

Back

Completing the laboratory.

The **Kinetic Quiz** Laboratory is now complete.

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is also available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this Laboratory** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

Select the **[File], [Exit]** menu item to exit the **Hu-m-an** program.

Back

29 . CONSERVATION OF ANGULAR MOMENTUM

HU-M-AN

Forward

CONSERVATION OF ANGULAR MOMENTUM

Purpose

1. To demonstrate the principle of conservation of angular momentum in a closed system.
2. Specifically, using a forward solution dynamics simulation of a diver, the objectives are:
   a) To determine, for selected fixed positions, the moment of inertia of the body with respect to an axis through the center of gravity in sagittal view.
   b) To determine the angular velocity of a diver in selected positions, given an initial angular momentum.
   c) To investigate the relationship between angular velocity, moment of inertia and angular momentum.
   d) To demonstrate the principle of conservation of angular momentum while changing body position during diving.

Notebook:

1. Complete print outs from **macros** **Angular Momentum Analysis - Part I** and **Angular Momentum Analysis - Part II**.

Remember that this Instruction Window can be closed, moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components.

Click **[Forward]** to continue.

Forward

HU-M-AN

Forward **Back**

Overview

The **Principle of Conservation of Angular Momentum** states that:
In a closed system, the angular momentum is constant regardless of any interactions between parts of the system.

A **Closed System** is a system isolated from all external contacts. In terms of angular motion, systems in flight (e.g. divers) act as closed systems since the only external force is gravitational attraction, assumed to be directed through the center of mass which is also the center of rotation.

Moment of Inertia is the body or systems resistance to change in angular motion.

In its simplest form, for a rigid system **the Principle of Conservation of Angular Momentum** in equation form is:

$$H = I_g \omega \qquad (1)$$

Where
H = system angular momentum
I_g = system moment of inertia
ω = system angular velocity

In other words, angular momentum is the product of system moment of inertia and system angular velocity.

PART I

In **Part I** of the laboratory, a simple full layout dive is simulated, and then body positions are successively altered while maintaining the same angular momentum, in order to investigate changes in system moment of inertia and angular velocity. Since in the final phase of the dive the body is held rigid, its angular velocity can be determined by measuring the angular velocity of any segment. In this experiment, the angular velocity of the trunk is measured.

Personal experience and observation indicates that as the body tucks the angular velocity of the system increases. The objective of this experiment is to investigate how changes in body position affect the size of its moment of inertia, and hence the resulting angular velocity in a closed system. Another important objective is to gain a visual sense of the relationship between body position, moment of inertia and angular velocity.

From the produced table of results, a graph is developed illustrating the relationship between angular velocity and moment of inertia. Simple review of the rigid system equation for conservation of angular momentum (above), illustrates that, if the moment of inertia is halved then the angular velocity must double if the angular momentum is to remain constant.

It is often thought that there is an inverse **linear** relationship between the moment of inertia and angular momentum, but in fact the mathematical relationship is described by a rectangular hyperbola with the coordinate axes as the asymptotes. While interpreting the graph, think of what this might mean in terms of performance quality.

The objective is to link physical observation and theoretical understanding.

PART II

Part II of the laboratory will investigate the **Principle of Conservation of Angular Momentum** for a changing system. Again the angular momentum must remain constant even though there is an interaction between parts of the system. In this case the simple rigid body equation does not suffice and the system angular momentum is described by the general equation:

$$H = \Sigma(I_g\omega + mvr) \qquad (2)$$

Where

$I_g\omega$ = local term

mvr = transfer term

Σ = sum for each segment relative to system C. of G.

In this case the first term is known as the local term, or the angular momentum of a segment about its own center of gravity. The second term is known as the transfer term, and is each segments angular momentum about the system center of gravity. This is more complex calculation and the details will not be dealt with in this introductory laboratory.

For this investigation the moment of inertia for each body position (frame by frame), will be calculated (a relatively straight forward calculation), while the measured angular velocity of the trunk will be assumed to best represent the angular velocity of the system.

The resulting graph will super-impose an idealized curve on the measured curve showing the relationship between the moment of inertia and the system angular velocity. The results are similar to those in Part I which suggests that for general purposes our angular velocity-moment of inertia relationship holds true.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward **Back**

Procedures:

PART I

1. Activate the **[File], [Load Trial]** menu item. Single click the **diver01a.ht1** file and then click **[OK].**

2. View the model simulation of the diver performing a rigid full layout backward somersault:
   - Click the **[C]** button to center the model.
   - Click the **run [>]** button to view the model.
   - Repeat as necessary to become familiar with the first dive.

3. For this investigation, a series of **macros** have been prepared. To print out a blank data sheet and working graph, execute the first **macro** as follows:
   - Click the **[View], [Macros]** main bar menu item.
   - From the **Macro** window presented click the **Print Table I and Figure I** item and then click **[Execute].**
   - Click **[Yes]** to the caution query.
   - The **Print Options** window is then presented.
   - ■ Ensure that the correct printer has been selected, enter your name in the **Optional**

Header text box and click **[Proceed with Printing].**
A blank table and a working graph of the idealized model will be printed.

4. To analyze the first diver:
   - Click the **[View], [Macros]** main bar menu item.
   - From the **Macro** window presented click the **Angular Momentum Analysis - Part I** item and then click **[Execute].**
   - Click **[Yes]** to the caution query.

5. Three new variables will now appear at the bottom of the **<Graph-Data Control>** window, namely:
   Angular velocity (Trunk)
   Moment of Inertia: Full Body
   Angular Momentum: Full Body

   Click on the **Moment of Inertia (Full Body)** item to graph this variable. Using the left mouse button click on the plotted graph at a point during the dive where the moment of inertia is constant during flight to display this value. Enter this value in the appropriate row [e.g. **a)** for the first trial], and column (**I**) of the blank table.

   Click on the **Angular velocity (Trunk)** item to graph this variable. Using the left mouse button click on the plotted graph at a point during the dive where the angular velocity is constant during flight to display this value. Enter this value in the appropriate column (**w** intended to represent omega, the angular velocity) of the blank table. (Skip the **I'** column for now)

   The remaining columns (**w'**) and (**H**) can be completed now or later. (**w'**) is the angular velocity in radians/second (**w** / 57.296 - 1 radian equals approximately 57.296 degrees). (**H**) is the angular momentum and is the product of (**I**) and (**w'**). For this operation the angular velocity must be expressed in radians. You should also note the units associated with the other measures, in particular, for angular momentum.

   Finally, make a simple sketch of the body under the column titled **Position Diagram**.

6. Activate the **[File], [Load Trial]** menu item. Single click the **<u>diver01b.ht1</u>** file and then click **[OK**]. Respond **[Yes]** to the load without saving question. View the model simulation of the diver performing a rigid full layout backward somersault:
   - Click the **[C]** button to center the model.
   - Click the **run [>]** button to view the model.
   - Repeat as necessary to become familiar with the dive.

   Analyze this diver and record the results by repeating steps 4 and 5 above.

7. Repeat step 6 for **<u>diver01c.ht1</u>**, **<u>diver01d.ht1</u>**, and **<u>diver01e.ht1</u>**.

8. The **I'** column can now be completed. In order to more effectively compare the sizes, the moments of inertia will be normalized to the tuck position. To accomplish this, the final tuck position (**diver01e.ht1**) moment of inertia **I'** is set to one (1) by dividing **I** by itself. The other values of **I** are then divided by this same **I** (for the tuck position of **diver01e.ht1**), which then expresses all moments of inertia relative to the tuck position. Note that these results show that the moment of inertia in the full layout position is more than 3 times greater than that in the tuck position.

9. Using the data from **Table I**, clearly plot the individual values for (**w)** vs. (I) on the printed working graph using crosses (on **Figure 1**). Review your results with respect to what was introduced in the overview and with what may have been covered in class. Comment in the space at the bottom of this page any comments you might have about your results, for example, are they what you expected?

PART II

1. Activate the **[File], [Load Trial]** menu item. Single click the **diver02a.ht1** file and then click **[OK].** Respond **[Yes]** to the load without saving question.

2. View the model simulation of the diver performing a 2 1/2 backward tuck somersault:
   - Click the **[C]** button to center the model.
   - Click the **run [>]** button to view the video model.
   - Repeat as necessary to become familiar with the dive.

3. To analyze the diver:
   - Click the **[View], [Macros]** main bar menu item.
   - From the **Macro** window presented click the **Angular Momentum Analysis - Part II** item and then click **[Execute].**
   - Click **[Yes]** to the caution query.
   - The **Print Options** window is then presented.
   - Ensure that the correct printer has been selected, enter your name in the **Optional Header** text box and click **[Proceed with Printing].**

4. Again, three new variables appear at the bottom of the **<Graph-Data Control>** window, namely:

   Angular velocity (Trunk)
   Moment of Inertia: Full Body
   Angular Momentum: Full Body

   In addition, a graph will be printed plotting the relationship between the system angular velocity and the moment of inertia for both an idealized diver and for the actual diver viewed in this experiment. Note again that for the actual measured value, the angular velocity of the trunk is used.

   Complete the questions included with the printout.

   Discrepancies between the idealized and measured relationships are related to the above trunk angular velocity assumption as well as limitations of the original modeling and simulation. Although it is an effective model as evidenced by the data and visual observation, additional improvement and specific validation are required before this model can be used for research purposes.

Note that the <Twovars> display function is now active (found at the bottom right of the <Graph-Data Control> window. In order to observe normal variable vs. frame graphs you will need to turn off (re-toggle) this option.

Also, the display has been limited to the flight portion of the dive. Click the <R1> button at the bottom right of the <Video-Model Control> window to reset the display to the original complete sequence.

Forward Back

HU-M-AN

Back

The **Principle of Conservation of Angular Momentum Laboratory** is now complete.

Consider the importance of the results, in relation to overview information and class instruction..

As well as being familiar with the overview theory and investigation procedures, you should be able to answer questions such as:

1. What is the range of moment of inertia when moving from tuck position to full layout position?
2. In a closed system what is the relationship between moment of inertia and angular velocity?
3. Does angular momentum change with body position while in flight?
4. What units are associated with each of the measures?

Etc.

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is also available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this Laboratory** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

Use normal procedures for exiting the **Hu-m-an** program:

Click the **[File],[Exit]** menu item. Answer **[Yes]** to the query about exiting the program without saving the results, since the results can easily be re-constituted by re-running the **macros** again at any future time.

Back

30 . ANALYSIS OF LIFTING

HU-M-AN
Back

ANALYSIS OF LIFTING
Calculating Net Joint Moments

Purpose
1. To introduce static and dynamic analysis of lifting techniques.
2. Specifically to analyze net hip moments during two simple lifts.

Notebook:
1. Completed print outs for **Lift (a)** and **Lift (b)**.

Remember that this Instruction Window can be moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components.

Click **[Forward]** to continue.

Forward

HU-M-AN
Forward **Back**

Overview

The object of this laboratory is to biomechanically analyze two lifting techniques. A subject lifts a weight from the floor:

1. using flexed knees and a relative erect trunk. (leg dominant lift)
2. using almost straight legs and flexed hips. (back dominant lift)

One of the most common causes of low back injuries is the use of poor lifting technique. Net hip moments are a good indicator of the torques present in the low back. Subject weight, lifting weight, speed of motion and technique all contribute to hip (and therefore low back) moment forces, which, in turn, create spinal compression forces. These forces, if excessive, can cause injury.

This laboratory will determine the net hip moments during the two lifting techniques.

Static Simulation Analysis.
The first calculation will be based on the assumption that for slow lifting the results can be simulated assuming static conditions. This means that, for each position measured, the subject is assumed to be in a stationary position.

Figure 1 below shows the subject (assumed static), holding the weight and a free body diagram isolating the trunk, head and arms.

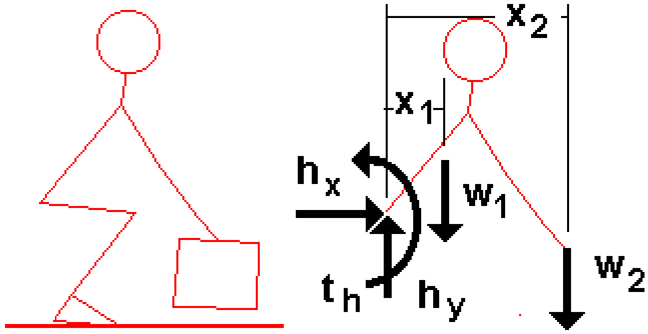


Figure 1

t_h = net hip moment

h_x = net horizontal reaction force

h_y = net vertical; reaction force

w_1 = weight of trunk, head and arms

w_2 = weight of object lifted

$x_{1'}$ = perpendicular distance from the center of gravity of the trunk, head and arms to the hip joint

x_2 = perpendicular distance from the lifted weight to the hip joint

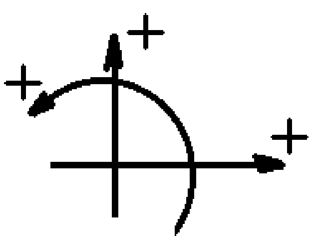


Figure 2 - Direction Conventions

Illustrated below is the derivation of the equations (based on Newton's equations for equilibrium) for calculating net joint hip moments and forces assuming a static simulation. (See **Figure 2** for direction conventions). **Equation 3** is the specific equation that will be required to complete the laboratory requirement of a demonstration manual calculation.

$$\Sigma F_x = 0 \quad h_x = 0 \qquad (1)$$

$$\Sigma F_y = 0 \quad h_y - w_1 - w_2 = 0$$

$$h_y = w_1 + w_2 \qquad (2)$$

$$\Sigma T_z = 0 \quad t_h - w_1 x_1 - w_2 x_2 = 0$$

$$t_h = w_1 x_1 + w_2 x_2 \qquad (3)$$

Dynamic Analysis
As a part of the prepared **Macro File** analyses, **'Lifting Analysis - Lift-(a)'** and **'Lifting Analysis - Lift-(b)'**, a dynamic analysis is also completed. The theory for this calculation is not covered here, but dynamic analysis takes into account the effect of accelerated motion during the lift.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward **Back**

Procedures:

Analysis of Lift (a)

1. Activate the **[File], [Load Trial]** menu item. Single click the **lifta.ht0** file and then click **[OK].**

2. Review the video and model collection:
   - Click the **[Model]** radio button in the **Video-Model Control** window.
   - Click the **[C]** button to center the model.
   - Click the **run [>]** button to view the video and model.

3. To analyze the lift, a **macro** has been prepared. To Execute the **macro:**
   - Click the **[View], [Macros]** main bar menu item.
   - From the **Macro** window presented click the **Lifting Analysis - Lift-(a)** item and then click **[Execute].**
   - Click **[Yes]** to the caution query.
   - The **Print Options** window is then presented.
   - Ensure that the correct printer has been selected, enter your name in the **Optional Header** text box and click **[Proceed with Printing].**

4. Complete **Part I** of the print out.

The vertical line in the graph represents the first point where the weight is clear of the ground and, therefore, when the theoretical model applies. Frame 10 (one frame after the vertical line) will be analyzed as representing an initiating position, where low back forces are likely high.

Completing **Part I** will require the retrieval of some data values after plotting variables in graph form. Remember that by clicking the arrow tip on the **frame 10** marker at the bottom of the graph, the value of the **active plot** (indicated in the window title bar), can be retrieved. The **active plot** can be changed by clicking the desired variable in the **Graph-Data Control** window.

5. The remaining **Part II** questions can be completed after the active computer part of the laboratory is finished.

Analysis of Lift (b)

1. Activate the **[File], [Load Trial]** menu item. Single click the **liftb.ht0** file and then click **[OK].**

2. Review the video and model collection:
   - Click the **[Model]** radio button in the **Video-Model Control** window.
   - Click the **[C]** button to center the model.
   - Click the **run [>]** button to view the video and model.

3. To analyze the lift, a second **macro** has been prepared. To Execute the **macro:**
   - Click the **[View], [Macros]** main bar menu item.
   - From the **Macro** window presented click the **Lifting Analysis - Lift-(b)** item and then click **[Execute].**
   - Click **[Yes]** to the caution query.
   - The **Print Options** window is then presented.
   - Ensure that the correct printer has been selected, enter your name in the **Optional Header** text box and click **[Proceed with Printing].**

4. Complete **Part I** of the print out.

The vertical line in the graph represents the first point where the weight is clear of the ground and, therefore, when the theoretical model applies. **Frame 10** (one frame after the vertical line) will be analyzed as representing an initiating position, where low back forces are likely high.

Completing **Part I** will require retrieval of some data values, after plotting variables in graph form. Remember that by clicking the arrow tip on the frame 10 marker at the bottom of the graph the value of the **active plot,** as indicated in the window title bar, can be retrieved, and that the active plot can be changed by clicking the desired variable in the **Graph-Data Control** window.

5. The remaining **Part II** questions can be completed after the active computer part of the lab is finished.

Some **Part II** questions require a comparative analysis of the lifting technique. which is, of course, central to this laboratory.

Forward Back

HU-M-AN

Back

The **Analysis of Lifting Laboratory** is now complete.

Ensure that all questions on the print outs are completed.

Consider the importance of the results, since low back injury, as a result of poor lifting technique, is extremely common.

In addition consider the following factors:

1. How would speed of motion affect hip (and therefore low back) net moments?
2. How would holding the weight closer to the body affect the results?
3. How would body weight and size affect the results?

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is also available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.
- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this Laboratory** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

Use normal procedures for exiting the **Hu-m-an** program:

Click the **[File],[Exit]** menu item. Answer **[Yes]** to the query about exiting the program without saving the results, since the results can easily be re-constituted by re-running the **macros** again at any future time.

Back

31 . ORIGINAL KINEMATIC ANALYSIS

HU-M-AN

Forward

Original Kinematic Analysis

Purpose

1. To demonstrate the processes involved in an original kinematic analysis.
2. Specifically, using a provided source data collection for a standing back somersault, the objectives are:
   a) To determine the horizontal and vertical displacement, velocity and acceleration patterns for the subject's center of gravity.
   b) To process this data for appropriate graphic presentation.
   c) Based on an understanding of projectile dynamics, present a **limited empirical** view of accuracy for fundamental video based analysis.
   d) To determine the angular displacement and velocities for the hip, knee and ankle relative angles as a basis for analyzing the coordination present in executing a standing back somersault.

Notebook:
1. Four graphs (each on a separate page) illustrating selected results of the processes in kinematic analysis**.**

Remember that this Instruction Window can be closed, moved, maximized, minimized or re-sized, as desired, during the execution of the laboratory components. It is often preferable to complete labs using a hard copy print out instead of from on the screen windows, and in this case the Instruction Window should be closed.

Click **[Forward]** to continue.

Forward

HU-M-AN

Forward Back

Overview

To be successful in this laboratory, the demonstrations leading up to and in particular the **<Starting Original Calculations>** demonstration must be fully understood. Many of the instructions are intentionally brief, requiring the user to complete the operation based on knowledge gained in the previous demonstrations and laboratories.

Smoothing of data is kept to a minimum. The theory and application of advanced data smoothing and enhancement is beyond the scope of this introductory laboratory, while an emphasis is placed on empirically investigating data accuracy where feasible. The question that should always be asked is: **'do the results of the analysis make sense'**. Far too often, computer results are accepted by novice analysts as being beyond question, a fatal error. Data smoothing and enhancement is in part differentiating between eliminating noise or error on one hand, and distorting the real movement pattern on the other.

The objective of kinematic analysis is to monitor how a skill is performed in order:

1. To improve one's objective view of the performance. After a skill has been analyzed, viewing of live performance becomes more objective and focused, based on knowledge and understanding of the skill.
2. To develop a baseline for comparison between different levels of performance. What are the key differences between successful and unsuccessful skill execution? What are the common components of skilled performance?
3. To corroborate known mechanics about the performance, either the reflections of basic physics or the results of previously accepted empirical skill execution theories.
4. To accurately identify the performance characteristics of an individual as a basis for skill execution improvement.

For novice analysts, a major problem is often identifying what should be measured. This is where the assistance of a experienced coach, teacher, or athlete is invaluable.

A **Check Procedure** has been established to enable the user to periodically confirm the correctness of the results. The confirmation file is in the form of a **Project File**. Details will be introduced at the appropriate time during the laboratory.

This is a fairly lengthy laboratory. It is possible to interrupt the laboratory at a convenient location, save the data, and then re-load this data and continue the laboratory at a future time.

To save the data (optional):

1. Select the **[File], [Save Trial As]** menu item. The original drive will automatically be accessed. If this is a CD or server (you cannot write to the CD or server), and the data are to be saved to a different drive (e.g. **[Local Data Area]**), then locate the appropriate drive and sub-directory. **The data collection can also be saved to a floppy disk, if preferred.** In the **File Name** field the title of the source data, **jump.ht0,** will appear. The **.ht0** should be changed to an **.ht1** so that this data set is separate and not confused with the original data. If a **jump.ht1** file already exists, then respond **[Yes]** to the replacement question.

Click **[Forward]** to continue.

Forward Back

HU-M-AN

Forward Back

PART I

1. Loading the source Data.

Activate the **[File], [Load Trial]** menu item and load the **backs01.ht0** source data. View the model, video, and model with video to become familiar with the performance. Frame 47 has been identified as the point of take-off (the instant the subject leaves the ground) and appears to have captured this critical point accurately. However, frame 65, identified as landing is somewhat problematic since frame 65 appears to be before landing while frame 66 is after landing. The 30 frame/second collection frequency is likely not high enough for the inherent speed of this motion. A video captured at sixty fields/second (available in the **Hu-m-an\data** area) would be better, although 190 frames of data would be required instead on the current 95. Due to the inherent acceleration at landing, it is likely that not even this sampling frequency would be sufficient and therefore we will stay with the 30 frames/second collection, keeping these concerns in mind.

The source collection is based on the 11 point symmetric template and conveniently includes a pre-defined full body 6-segment center of gravity model, as well as pre-defined relative angles.

Forward Back

HU-M-AN

Forward Back

2. **Center of gravity displacement.**

Click the **[Calculate][System C. of G.][6 Segment Model]** main menu item. On display of the **System Center of Gravity** window, retain the default titles and then [**Calculate]** the system center of gravity. Note that for this laboratory, the default locations for the resulting data are used, although there is the option of directing them to different slot locations. View the results for both the horizontal and vertical displacement of the center of gravity carefully. Do the results make sense? Remember that the subject is moving from right to left. Note that the horizontal displacement of the center of gravity seems to be more irregular (contains more noise or error) than the vertical displacement pattern. This is somewhat misleading since the scale of the horizontal motion, by default, is much larger, tending to magnify small changes

To further process this data click the **[Edit][Calculated or Graph Data]** menu item to display the **Calculated-Graph Data** window. In this window click on **C of G Y: 6 Segment Model** to display the vertical center of gravity displacement data. These data represent the vertical displacement from an arbitrary origin base and it would make more sense to adjust these values to be relative to the ground. To accomplish this click the **[Normalize Data]** button, select the **Set Ground Line as Vertical Base** option and click **[Process and Exit]**. This procedure assumes, of course, that the ground line has been previously set. Now click the **[Scale-Decimals-Units]** button and from this window set the maximum value to 2.0, the minimum value to 0.0, the number of decimals to 2, and then click **[OK]**. All of these decisions, of course, need to be made by the user with the objective of presenting the data in the most effective fashion. These operations can be reversed using the **[Undo]** function, **but this must be applied before selecting and plotting a new data set**.

Now click on **C of G X: 6 Segment Model** to display the horizontal center of gravity displacement data. It makes sense to have these data start at zero for frame zero, rather than accept the arbitrary origin base. Click the **[Normalize Data]** button, select the **Set Frame ‘0’**

<u>Value to '0'</u> (the default) and click **[Process and Exit].** On your own, scale the data using a maximum of **1.0**, a minimum of **-1.0**, and specify **2** decimals. Note that a range of 2.0 meters was used for both the **X** and **Y** displacement data so as not to give a distorted picture of their relative movement. Finally, since we know from physics that in flight, a system's center of gravity must travel horizontally at a constant velocity (assuming air friction is negligible), a straight line (negative slope in this case), will be used to replace the current data. Click the **[Straight Line]** button to display the straight line window. The straight line should only replace the flight values, so select the **[Critical Points]** option, and from the two lists displayed (use down arrows), select the **Take-off** and **Landing** entries. Now select the **[First-last Points]** (default) option, and click the **[OK]** button.

[Exit] the **<u>Calculated-Graph Data</u>** window.

Using the <u>Check Procedure</u>.
A completed set of data has been saved as project data and this can be used to confirm the correctness of your results to date. Click the **[File][Load Project Data]** main menu item and in the displayed window click the **CD/Server Project Area** button in the bottom right. From the displayed list mark the **backs01.hp1** file, and click **[OK].** The **Project Data** window shows the **Trials** (in our case only one) and the **Variables** included. Mark the **backs01.ht1** trial and select the **C of G X: 6 Segment Model** variable. This displays the correct result for this data. Now click on the **C of G X: 6 Segment Model** item from your own **Graph-Data Control** window. This should exactly match (i.e. cover up) the first set of data if you followed procedures correctly. Now mark the **C of G Y: 6 Segment Model** variable to display this data and then confirm the correctness of your **Y** data. If your results do not match exactly you will need to re-do this section. **During a second (or subsequent!) attempts, you will need to take care in directing the new X and Y values to REPLACE the current entries or they will be added as additional entries. Alternately, you can use the [Delete] button found following the [Edit][Calculated or Graph Data] menu item to delete the incorrect variables and then re-calculate.**

[Exit] the **Project Data** window.

<u>Forward</u> **<u>Back</u>**

HU-M-AN

<u>Forward</u> **<u>Back</u>**

3. Center of gravity velocity.

Now calculate the horizontal velocity by initially selecting the **<Calculate><Velocity>** main menu item. Mark (select) the **C of G X: 6 Segment Model** item from the **Calculated Data** list (the default). This time replace the default title with the simpler **Horizontal Velocity** name(under the **Select Destination** heading), and then proceed to **<Calculate>** the velocity. Repeat a similar process to calculate the **Vertical Velocity**. Remember that the <u>method of first central finite differences</u> is used to determine the velocity from displacement. Since this procedure uses data from before and after the desired point, some inherent data smoothing is also included.

Using the **[Edit][Calculated or Graph Data]** do the following:

- Set the scales for both the horizontal and vertical velocity variables using a maximum of **5.0**, a minimum of -**5.0** and specify **2** decimals.
- Click the **Vertical Velocity** variable. Since we know that during flight the vertical velocity changes at a constant rate, Use the **[Straight Line]** function and replace the

segment from **Take-off** to **Landing** for the vertical velocity, using the **[First-Last Points]** option.

Remember, you can use the [Undo] function and re-process the data as long as this is done before displaying the next variable.

Click the **Horizontal Velocity** variable from the **Calculated Graph Data** list. Note that the **Horizontal Velocity** is not constant exactly from the precise point of **Take-off** to **Landing**. This results from the fact the method of first central finite differences is applied (using the points before and after the one for calculation), and this introduces a slight error. This should be corrected. Click the **[Edit Data Values]** button to show the frame by frame values. Scroll the table forward to display the values from frame 50-60 (during flight) and note the velocity is **-0.172** meters/second. **[Exit]** the View Data window. Now use the **[Straight Line]** function, identify the **Take-off** to **Landing** interval, select the **Set to '0'** option replacing the **'0'** with **-0.172** and click **[OK]**.

[Exit] the **Calculated-Graph Data** window**.**

Use the **Check Procedure** described at the end of section 2 to confirm the correctness of your results to date. Note: Always enter the **Project Data** variable first, followed by the **Graph-Data Control** variable. **Remember that the results must be correct before you proceed.**

[Exit] the Project Data window.
Forward Back

HU-M-AN
Forward Back

4. Center of gravity acceleration.

Now calculate the horizontal acceleration by initially selecting the **<Calculate><Acceleration>** main menu item. Mark (select) the **Horizontal Velocity** item from the **Calculated Data** list. Note that the **[Acceleration from Velocity]** option is automatically selected. There is an option to determine the acceleration directly from displacement data as well. The **[Acceleration from Velocity]** option is selected for this laboratory, in part to retain the inherent smoothing. This time replace the default title with the simpler **Horizontal Acceleration** name and then proceed to **<Calculate>** the acceleration. Repeat a similar process to calculate the **Vertical Acceleration**. Remember that the method of first central finite differences is used to determine the acceleration from velocity. Since this procedure uses data from before and after the desired point, additional inherent data smoothing is also included.

Using the **[Edit][Calculated or Graph Data]** do the following:

- Set the scales for both the horizontal and vertical acceleration using a maximum of **30.0**, a minimum of **-30.0** and specify **2** decimals.
- Mark the **Horizontal Acceleration** variable. We know that during flight the **horizontal acceleration** must be **zero**. The method of first central finite differences has introduced some minimal known error at the edges so use the **[Straight Line]** function and replace the segment from **Take-off** to **Landing** to **zero** using the **Set to '0'** option.
- Mark the Vertical Acceleration variable. We also know that during flight the vertical acceleration is -9.81 meters/sec/sec. Use the **[Edit Data Values]** function to find the current value of calculated acceleration (during flight, frames 50-60. It should be found as -8.711). **[Exit]** the **View Data** window. Remember this value for the coming

discussion on data validity. Now use the **[Straight Line]** function and the **Set to -9.81** option (you supply the -9.81) to replace the line segment from **Take-off** to **Landing**.

[Exit] the **Calculated-Graph Data** window**.**

Use the **Check Procedure** described at the end of section 2 to confirm the correctness of your results to date. . Note: Always enter the **Project Data** variable first, followed by the **Graph-Data Control** variable. **Remember that the results must be correct before you proceed.**

[Exit] the **Project Data** window.

Forward Back

HU-M-AN

Forward Back

5. An Empirical Look at Elements of Data Accuracy.

It is not the objective of this introductory laboratory to review in detail the theory and application of error analysis, but to introduce a practical sense of the accuracy of the current results.

Review the data by displaying the results in pairs, that is, the x-y displacement, then their velocities and then their accelerations. Use the **[Clear/Reset]** button between displaying each pair of variables. Visual inspection shows that the displacement data appear to be quite smooth or error free, but the possible error increases substantially as velocity and then acceleration are displayed.

Consider the following equations for velocity and acceleration using the method of first central finite differences.

$$v_{d_i} = \frac{d_{i+1} - d_{i-1}}{2(\Delta t)} \qquad a_{d_i} = \frac{v_{i+1} - v_{i-1}}{2(\Delta t)}$$

Assuming a sampling frequency of 30 frames/sec then the denominator in both cases would be 1/15.

If it is estimated that the possible error in calculating the center of gravity (d) is 0.5 cm and that in the worst case scenario the error is accumulated in the numerator, then the error in the resulting velocity would be (1 cm) / (1/15 second) = (+/-) 15 cm/second.

For acceleration, if this velocity error, in the worst case scenario, is accumulated in the numerator then the error in the resulting acceleration would be
(30 cm/second) / (1/15 second) = (+/-) 450 cm/sec/sec or (+/-) 4.5 m/sec/sec.

A visual inspection of the apparent noise or error component of the velocity and acceleration curves show that these estimates appear to be reasonable, as this data has not been smoothed.

The alternative is to smooth the data, which is the common practice in applied biomechanical analysis. This will be considered again in a few moments.

Since we have a flight portion in our skill performance, it is possible to sample current values to further assess accuracy. For example, the horizontal displacement during flight can be obtained from both the displacement curve itself and from taking the product of flight time and flight velocity. (Note that specific values used below were obtained from the **[Edit][Calculated or Graph Data]** and **[Edit Data]** function.)

Flight horizontal distance from measured displacement:

d = -0.165 - (-0.268) = 0.103 cm

Flight horizontal distance from measured velocity and air time:

d = 0.172 (18/30) = 0.103 cm

This seems to suggest that velocity calculations are far more accurate than at first thought, although caution is recommended in making this conclusion based on only one sample.

Another assessment can be made by measuring the rise in the center of gravity from take off to peak height directly and then using the vertical velocity of the center of gravity at take off and the projectile equation to predict the height.

Center of gravity rise measured directly:

d = 1.365 - 1.131 = 0.234 meters (23.4 cm)

Center of gravity rise from vertical velocity

$$d = \frac{V_y^2}{2g}$$

d = (2.182)(2.182) / 19.62 = 0.243 meters (24.3 cm)

As a final assessment, the acceleration of gravity can be calculated from the take-off and landing velocity and the flight time interval and compared with the known g= -9.81 m/sec/sec.

a = (-3.045 - 2.182) / (18/30) = -8.71 meters/sec/sec

These calculations seem to suggest that the results might be more accurate than indicated by our original analysis. Caution is recommended however and the original (+/-) 0.5 cm for displacement, (+/-) 15 cm/sec for velocity and (+/-) 4.5 meters/sec/sec for acceleration is likely still a good guideline for un-smoothed data of a similar nature.

Improving and enhancing data.

Data accuracy and integrity can be improved by a variety of means:

1. Improved source video.
   The initial image should be as large and as clear as possible. The fundamental accuracy of data can only be as good as the original source data. This is probably the single most common cause of inaccurate data.
2. Improved collection procedures.
   Joint center markings can be used to enhance collection consistency, remembering that the ultimate objective is to determine the appropriate joint center. At times the selected model is insufficient. For example, in the current back salto analysis, the assumption that the trunk and head constitute a single segment is likely only satisfactory during part of the skill execution.
3. Data smoothing and sampling frequency.

The accuracy of the kinematic analysis in this laboratory could very likely have been improved by data smoothing. The downside of data smoothing is potential data distortion and in particular the attenuation of peak values. This can in part be offset by increased sampling frequency. More powerful tools for data processing have yet to be introduced.

Conclusions

The data as calculated and presented show a good representation of the skill performance and can likely be left as is for the experienced analyst who can accurately assess and not misinterpret included noise (error). On the other hand, if the data were to be presented to a less experienced audience, then it is likely increased smoothing should be incorporated to guard against false interpretation, remembering that a potential side effect is data distortion and peak value attenuation. **Hu-m-an** keeps track of all data smoothing.

Forward Back

HU-M-AN

Forward Back

6. Hip, knee and ankle relative angles and velocities.

Calculate the relative angle of the hip by initially selecting the **<Calculate><Relative Angle>** menu item. Mark (select) the **Hip Angle** item from the **Pre-defined Angles** list and then proceed to **<Calculate>**. Repeat a similar process to calculate the knee and ankle relative angles.

Using the **[Edit][Calculated or Graph Data]** do the following:

- Set the scales for the three relative angles using a maximum of **220**, a minimum of **20** and specify **0** decimals.

[Exit] the **Calculated-Graph Data** window**.**

Now calculate the hip angular velocity by initially selecting the **<Calculate><Velocity>** menu item. Mark (select) the **Hip Angle** item from the **Calculated data** list. Replace the default title with the simpler **Hip Velocity** name and then proceed to **<Calculate>**. Repeat a similar process to calculate the knee and ankle angular velocities.

Using the **[Edit][Calculated or Graph Data]** do the following:

- Set the scales for the three angular velocities using a maximum of **1000**, a minimum of **-1000** and specify **0** decimals.

[Exit] the **Calculated-Graph Data** window**.**

Use the **Check Procedure** described at the end of section 2 to confirm the correctness of your results to date. **Remember that the results must be correct before you proceed.**

[Exit] the Project Data window.

Forward Back

HU-M-AN

Forward **Back**

7. Printing selected graphs of the results.

Four graphs will be prepared to demonstrate the results of this laboratory.

a) **[Clear/Reset]** the **Graphs** window. Plot the **C of G X: 6 Segment Model** using a wide line, the **Horizontal Velocity** using a narrow line, and the **Horizontal Acceleration** using a dashed line. Select the **[File][Print Models and/or Graphs]** menu item. Select the **[Graphs]** option and enter the title **Horizontal Center of Gravity Kinematics**. Click the **[Print]** button and on display of the **Print Options** window, enter your name in the **Optional Header** text box, select the correct printer and click **[Proceed with Printing].**

This is not a particularly effective graph and is produced as a record of the work accomplished. Note that since three different variable are plotted, not all three scales are printed with the graph.

b) Repeat the above process plotting the **C of G Y: 6 Segment Model** using a wide line, the **Vertical Velocity** using a narrow line, and the **Vertical Acceleration** using a dashed line.

c) Repeat the process a third time plotting the **Hip Angle** using a wide line, the **Knee Angle** using a narrow line, and the **Ankle Angle** using a dashed line. Modify the graph title appropriately before printing.

d) Finally, repeat the process a fourth time plotting the **Hip Velocity** using a wide line, the **Knee Velocity** using a narrow line, and the **Ankle Velocity** using a dashed line. Modify the graph title appropriately before printing.

Forward **Back**

HU-M-AN

Forward **Back**

8. Analysis and Interpretation of the results.

The user will be left to interpret and analyze the results but should consider, as a minimum. the following:

- the horizontal and vertical velocity of the center of gravity at take off.
- the amount of crouch (vertical center of gravity) during the jump preparation and during the landing.
- the height of the center of gravity during flight.
- the maximum vertical acceleration of the center of gravity during jump preparation and landing as being reflective of the vertical forces.
- the horizontal velocity of the center of gravity during flight and the distance of horizontal travel during flight.
- the sequencing of the hip, knee and ankle joint displacements during the jump preparation.
- the maximums, minimums, and ranges of joint displacement for the hip, knee and ankle during

various phases of the performance (preparation, flight, landing).
- the maximums, minimums, and ranges of joint velocity for the hip, knee and ankle during various phases of the performance(preparation, flight, landing).

There are, of course, other measures that are important to the understanding of the skill performance that have not been evaluated in this analysis, for example:

- the displacement and velocity of shoulder joint movement, in particular, how it is timed to create the required rotation for the performance.
- the absolute angle of the trunk, which describes the lean of the body in preparation for the rotation.

Undoubtedly, there are many other facets of the performance which can be analyzed and this is left to the skilled analyst with assistance from teachers, coaches and athletes.

Forward Back

HU-M-AN

Back

The **Original Kinematic Analysis** Laboratory is now complete.

The user should now be ready to attempt a completely original kinematic analysis, starting with a source .AVI file, selecting the digitizing model, digitizing the appropriate sequence, and then analyzing and interpreting the results.

Before proceeding, however, it is probably wise to complete all of the appropriate **Practice Exercises** to re-enforce the concepts covered in the total laboratory experience.

Good Luck!!

To save the data (optional):

1. Select the **[File], [Save Trial As]** menu item. The original drive will automatically be accessed. If this is a CD or server (you cannot write to the CD or server), and the data are to be saved to a different drive (e.g. **[Local Data Area]**), then locate the appropriate drive and sub-directory. **The data collection can also be saved to a floppy disk, if preferred.** In the **File Name** field the title of the source data, **jump.ht0,** will appear. The **.ht0** should be changed to an **.ht1** so that this data set is separate and not confused with the original data. If a **jump.ht1** file already exists, then respond **[Yes]** to the replacement question.

2. Click **[Save]** to activate the saving process.

To print a cover or title page (optional):
A general laboratory cover page or an individual laboratory title page is also available through the macro listing. (Print only when necessary.)
- click **[View]** in the main menu bar and then click the **[Macros]** menu item.

- from the list presented select the **Print Laboratory Cover Page** or **Print Title Page for this Laboratory** item and click the **[Execute]** button, responding **[Yes]** to the **Caution** query. A **Print Option** screen will appear. Ensure that the correct printer is selected and enter your name in the **Optional Header** text box. Click **[Proceed with Printing],** when ready. Retrieve the cover or title page from the printer.

If the newly created data are not to be saved, then, while exiting, respond **[Yes]** to the **exit without saving the data** caution message.

Follow the normal procedures for exiting the **Hu-m-an** program, that is, select the **[File], [Exit]** menu item.

Back