Chapter R: The 2D Motion Analysis Module

Datapac 2K2 User's Manual, Ver 3

Chapter R: The 2D Motion Analysis Module

Document Release Date: 08/26/2005

R-1. Introduction

Datapac 2K2's new 2D Motion Analysis module is a low-cost solution for tracking motion in two dimensional space. It is an extension of the Video Module, and thus both modules must be available in your Datapac 2K2 system for successful operation. Any video file that the Video Module will accept can be used as input into the 2D Motion Analysis module as well.

The 2D Motion Analysis module allows you to track points in X-Y space in a video record, combine them into segments (sticks) and angles, calculate displacement, velocity, and acceleration values for them, and easily synchronize such measurements with kinetic and analog data. The 2D Motion Analysis module offers both manual and automatic tracking modes. The manual mode can be used with or without markers for greatest flexibility. The automatic tracking mode can track multiple markers over sequential frames or it can serially track individual markers through the same frame sequence. The 2D Motion Analysis module automatically de-interlaces video frames on the fly, yielding 60 "frames" per second resolution from a standard AVI file (50 "frames"/sec in APL format). Throughout the remainder of this documentation we will employ the term "picture" to refer to a half-frame.

Although markers are not required, the 2D Motion Analysis module operates most effectively with markers in the visual spectrum. For best results, markers that stand in high contrast to the background, as in the example presented Figure R-1, are preferred. The marker detection algorithm is color, size, and velocity sensitive, and each of these variables are user adjustable on an individual marker basis, allowing greater specificity and better detection accuracy than many comparable packages from other manufacturers. When attempting to track markers that come into close proximity to each other, differently colored markers are recommended.

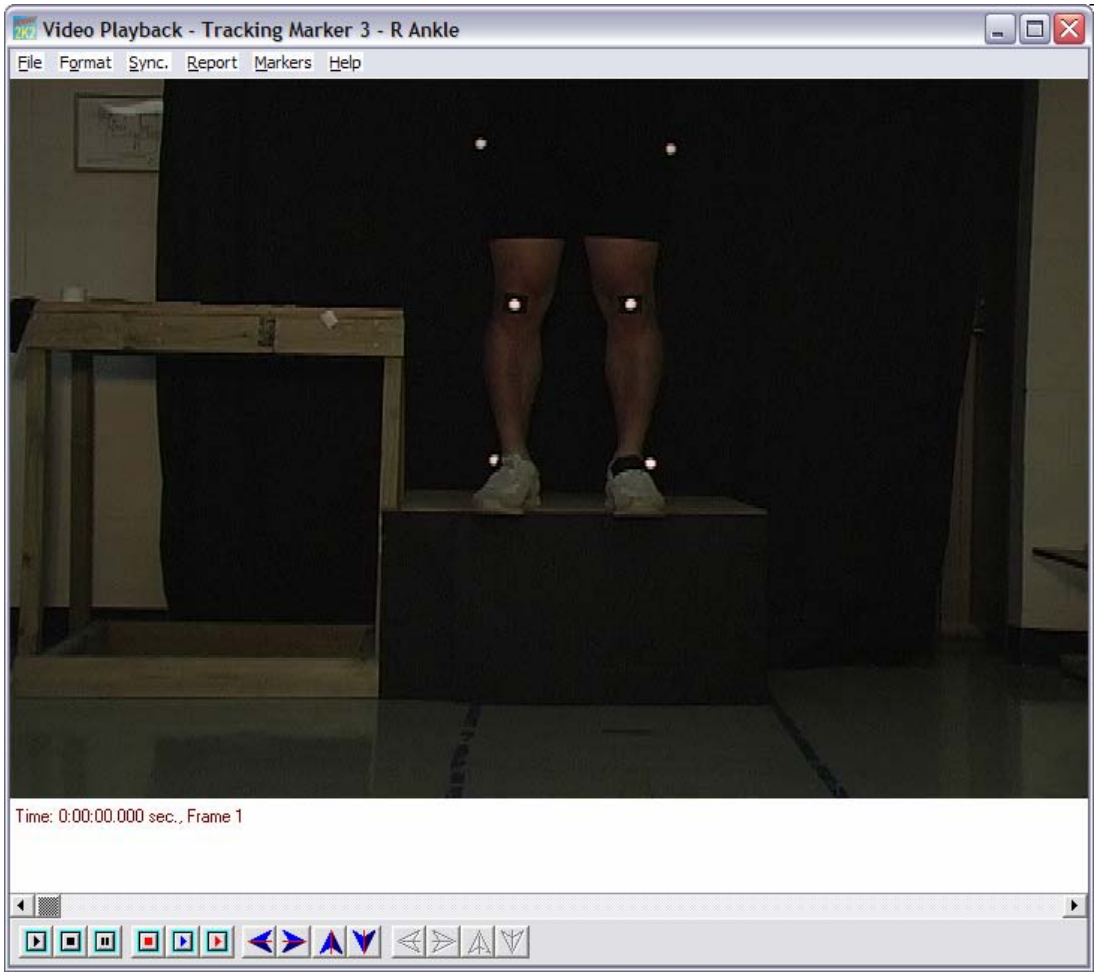


Figure R-1. An example of ideal, high contrast markers.

Before you begin operation of the 2D Motion Analysis module you must open the Video module and display the Video Playback window. An example of the Video Playback window is shown above. General configuration issues, such as opening a video file, video playback controls, using events to specify segments of interest in the video record, and synchronizing the video and analog records are handled by the Video module itself. Thus it is recommended that you familiarize yourself with the operation of the Video module before beginning operation of the 2D Motion Analysis module. See Chapter Q for details. Once that is done, follow the procedures described below.

R-2. Procedures

R-2.1. Calibration

Calibration of displacement measures should be performed prior to initiating tracking. To properly calibrate the dimensions of the X and Y axes, some kind of object of known length, such as a ruler or a box, should be available. A circle of known diameter is an ideal calibration object because it greatly simplifies the calibration procedure, but it is not necessary.

Once the object is in hand, record a small video file of the object. The calibration doesn't have to be in a separate file, but it is almost always easier that way. That is what we will assume here. If the calibration

object is one-dimensional, such as a ruler, be sure to record video segments of it in both horizontal and vertical orientations. Slowly wiggling the object around the approximate horizontal and vertical axes will increase accuracy. That way you know you will have at least one frame where the object is exactly horizontal and another where the object is exactly vertical. Also be sure that the distance of the object from the camera is the same as the distance of the camera to the subject for whom you intend to track movements. Once you have such information you are ready to start calibration.

After acquiring the calibration information, exit the Enhanced Acquisition module and open the Video Playback window to view the file with the calibration information in it. Play back the video file until you reach a representative frame. A representative frame, using a circular calibration object, is shown in Figure R-2.

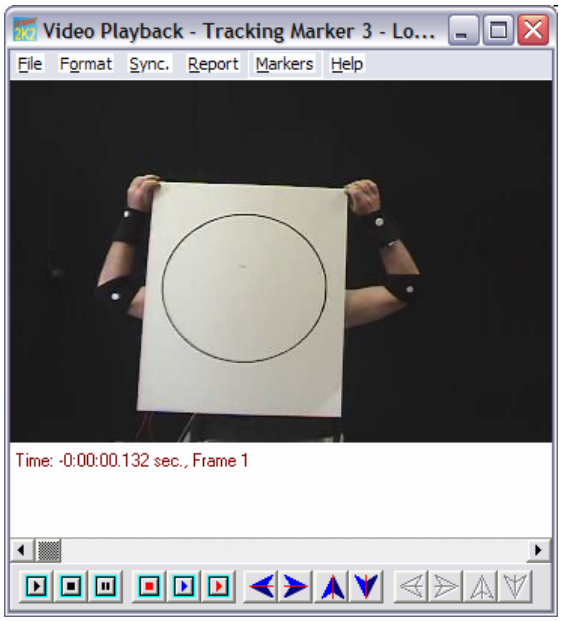


Figure R-2. An example of a circular calibration object.

Once a representative frame is chosen, select the **Markers|Calibrate** option from the Video Playback Window menu bar. Doing so opens a special Video Calibration window, along with a companion Zoom window. An example is shown below. Note that there are three elements within a rectangle in the top right corner of the window. The rectangle represents the dimensions of the zoom window. The vertical and horizontal bars are used to define known dimensions in the Y and X axes respectively. Finally, the small box with the cross-hair is used to define the zero displacement reference point from which all other distances are measured.

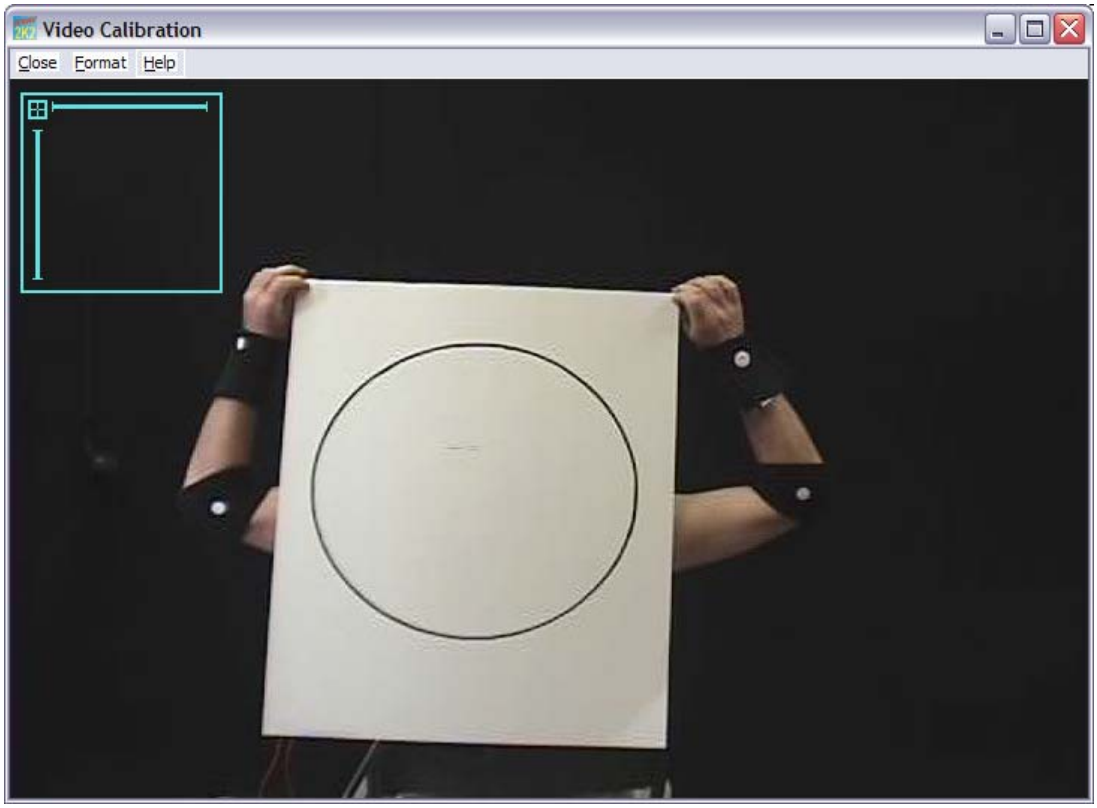


Figure R-3. An example of the Video Calibration window.

R-2.2. Manual Calibration

Manual calibration is performed by moving and/or resizing the vertical and horizontal calibration bars to most accurately match the dimensions of your calibration object, and moving the zero displacement cross-hair to the desired reference point. To move a calibration bar or the zero displacement cross-hair, hold down the shift key on the keyboard, put the tip of your mouse poiner on the item you wish to move (the mouse pointer icon should change to indicate that you have locked onto the item), hold down the left mouse button, and drag your mouse. Likewise, to stretch or shrink one of the calibration bars, hold down the shift key, put the tip of your mouse poiner on the end of the bar you wish to adjust, then hold down the left mouse button and drag your mouse. An example of a display with the calibration bars and zero reference point repositioned is shown in Figure R-4.

If both the calibration bars and the zero reference point can be successfully adjusted within a single frame, you are ready to complete calibration (see Section R-2.4 Completing Calibration for details). However, if you need to move to another frame to adjust one or more elements, close the Video Calibration window to return to the Video Playback window, then search until you find a frame that will allow you to adjust the remaining calibration elements.

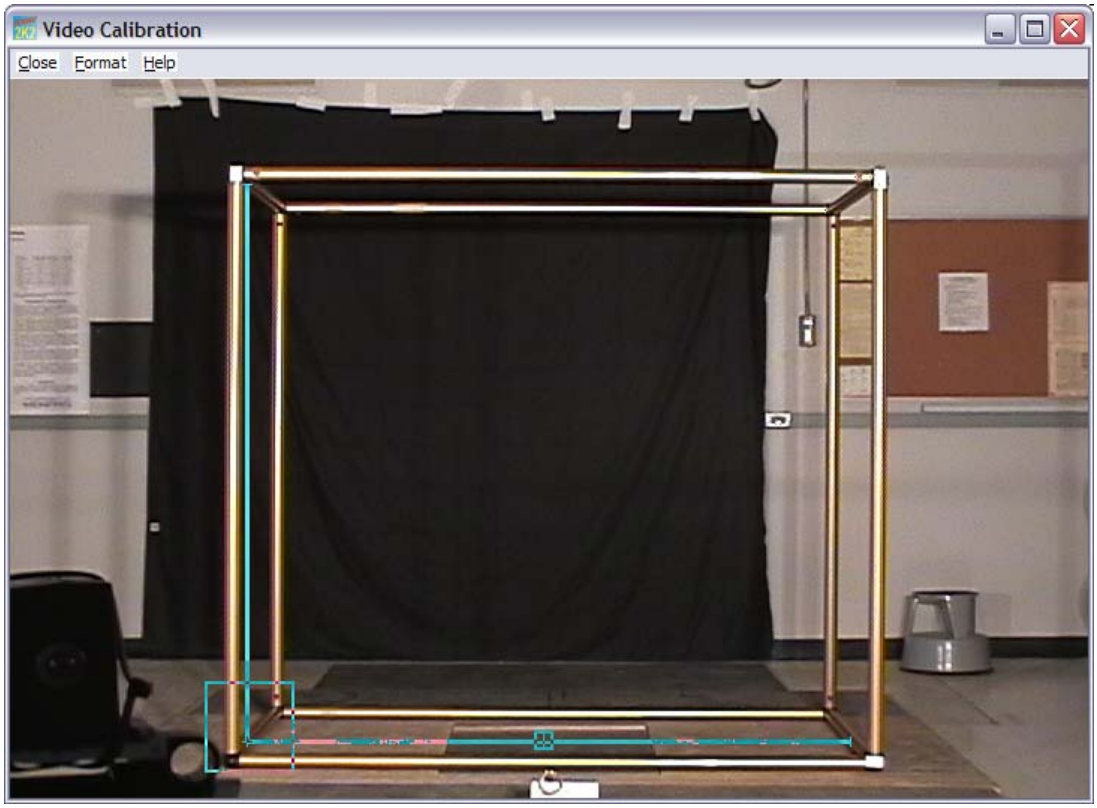


Figure R-4. An example of the Video Calibration window with the calibration bars and zero reference point repositioned.

R-2.3. Automatic Calibration

The automatic calibration procedure can be used only when a circle with a clearly defined border is employed as the calibration object. In the example above, the circle is white with the circumference drawn in black. A filled circle could be used just as easily as long as its borders around its circumference are clearly defined. To execute the automatic calibration procedure, hold down the Alt key on the keyboard, place your mouse pointer somewhere within the circle, and click the left mouse button. Upon doing so the program will search the video field to find the points of maximum diameter of the circle in both the vertical and horizontal dimensions. It may take a few moments for the program to complete the calculations, but once completed the calibration display is adjusted so that the vertical and horizontal calibration bars reappear at the locations of maximum diameter, the zero reference cross-hair is centered at the intersection of the two calibration bars, and the rectangle representing the borders of the zoom window is repositioned so that all three of the elements are shown within the zoom window. An example of this situation is shown below.

If automatic calibration fails -- that is, if the vertical and/or horizontal calibration bars are not accurately placed, select the **Format** option the Video Calibration window's menu bar, adjust the Color Change Percentage value, and try again.

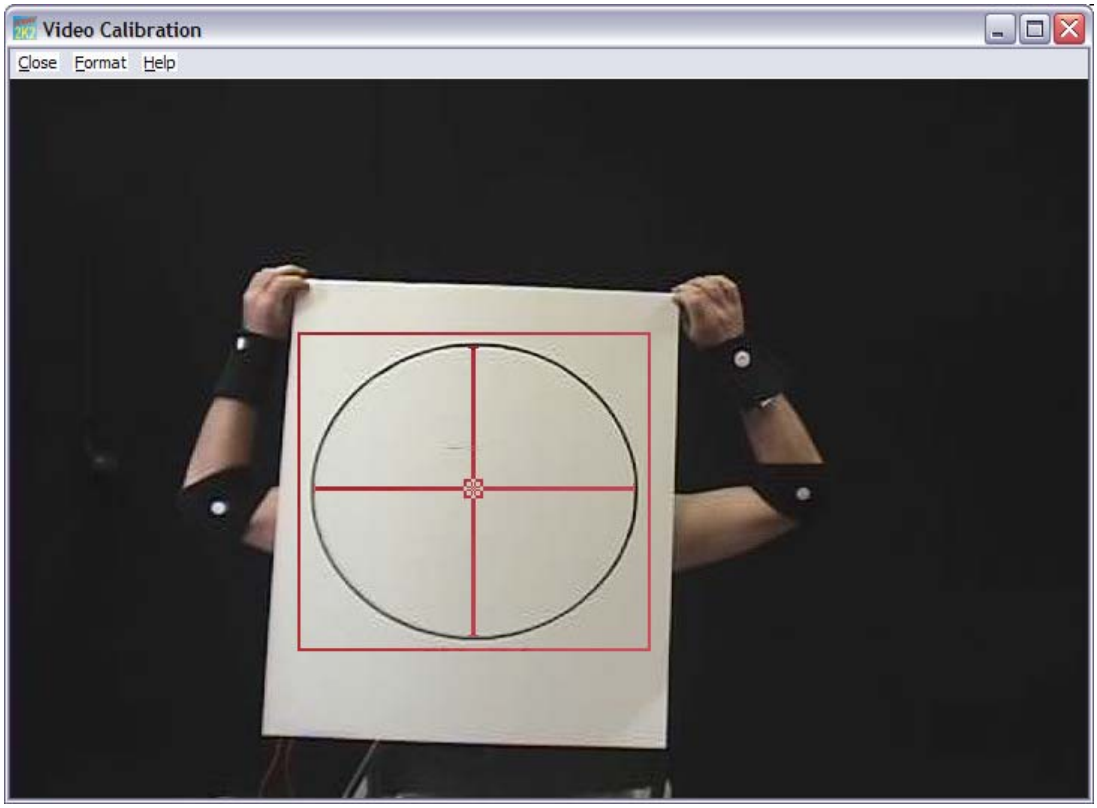


Figure R-5. An example showing the results of automatic calibration.

R-2.4. Completing Calibration

Once all of the calibration elements are positioned, the final step is to assign numerical values to them. To do so, select the **Format** option the Video Calibration window's menu bar. The following window appears. Enter the dimensions represented by the horizontal (**X Reference**) vertical (**Y Reference**) calibration bars, along with their unit labels in the appropriate locations. Then click the OK button to return to the Video Calibration window.

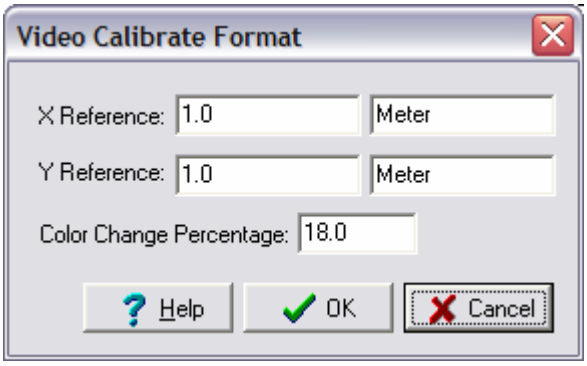


Figure R-6. The Video Calibrate Format window.

R-2.6. Saving the Calibration Parameters

To save the calibration parameters, select **Markers|Format** from the Video Playback window's menu bar. Then click on the  (Save Parameters) button and enter a file name. Enter just the filename prefix, as the extension, VMP is automatically appended. A few considerations are worth noting, however. First, the calibration parameters are saved to the same file as all the other marker tracking formatting parameters -- that is, all of the parameters contained in all of the tabs in the **Video Markers Format** window. Thus, whenever a VMP file is created, it will contain all of the marker tracking parameters that existed at the time, including but not limited to the calibration parameters. Second, whatever marker tracking format parameters exist at the time the Video Module is closed, they become the default parameters. And since they are the new default marker tracking parameters, they become incorporated into to any newly created data files from that point on.

R-3. Tracking

Tracking can be performed manually or automatically. Manual tracking does not require the presence of markers, but automatic tracking does. Two methods of tracking are available in both manual and automatic modes. One method, which we call the **Frames method**, allows you to identify multiple markers in an individual frame before moving on to the next. The second method, which we call the **Markers method**, allows you to identify one individual marker in successive frames before returning to the starting frame. Manual and automatic tracking can be used interchangeably as needed, as can the two methods available in each.

R-3.1. Manual Tracking: Markers Method

Manual tracking is the easiest method to configure and the most straight-forward to operate, but it is also the most time-consuming. In certain circumstances, however, it is the only method available. For example, manual tracking is the only method available in the absence of optical markers. Manual tracking procedures are also used to set up automatic tracking and for editing the results of automatic tracking when the need arises. Manual tracking using the Markers method allows you to define the location of an individual marker (or point) through successive pictures (half-frames).

To perform manual tracking using the markers method, please do the following:

1. **Format the tracking feature.** Details are provided in Section R-5. If you intend to use the manual marking method exclusively and to manually define the locations of all the markers (or points) you wish to track, it is only necessary to decide on the number of markers (or points) you intend to track, supply a verbal label for each, and select the color and size of the point that will be used to identify the location of each marker (or point) that you define. On the other hand, if you intend to employ the program to automatically detect one or more markers, then it is necessary to supply additional parameters for color and size sensitivity. To use the Markers method, be sure to click on the **Markers** radio button in the **Method** tab of the **Video Markers Format window**.

2. **View the first picture (half-frame) in the video record that you want to track.** Use the video control buttons in the Video Playback window to view the first picture in the sequence of interest.

3. **Select the active marker.** Assuming you have set up the tracking feature to track more than one marker (or point) it is important to make sure that you have selected the appropriate **"active marker"** -- that is, the number of the marker (or point) whose location is to be defined. The number (and title, if it is defined) of the currently selected active marker are reported in the header bar of the Video Playback window. For example, in the illustration shown in Figure R-7, the header bar reads: "Tracking Marker 2 - Bar", indicating that marker number 2 is the active marker, and it has been given the title, "Bar".

There are two ways to change the active marker number: 1. Press **Ctrl+X** on the keyboard to sequence through the markers, or; 2. Select **Markers|Format** from the menu bar of the Video Playback window, click on the **Tracking tab**, and select the desired marker number in the **Active Marker** box.

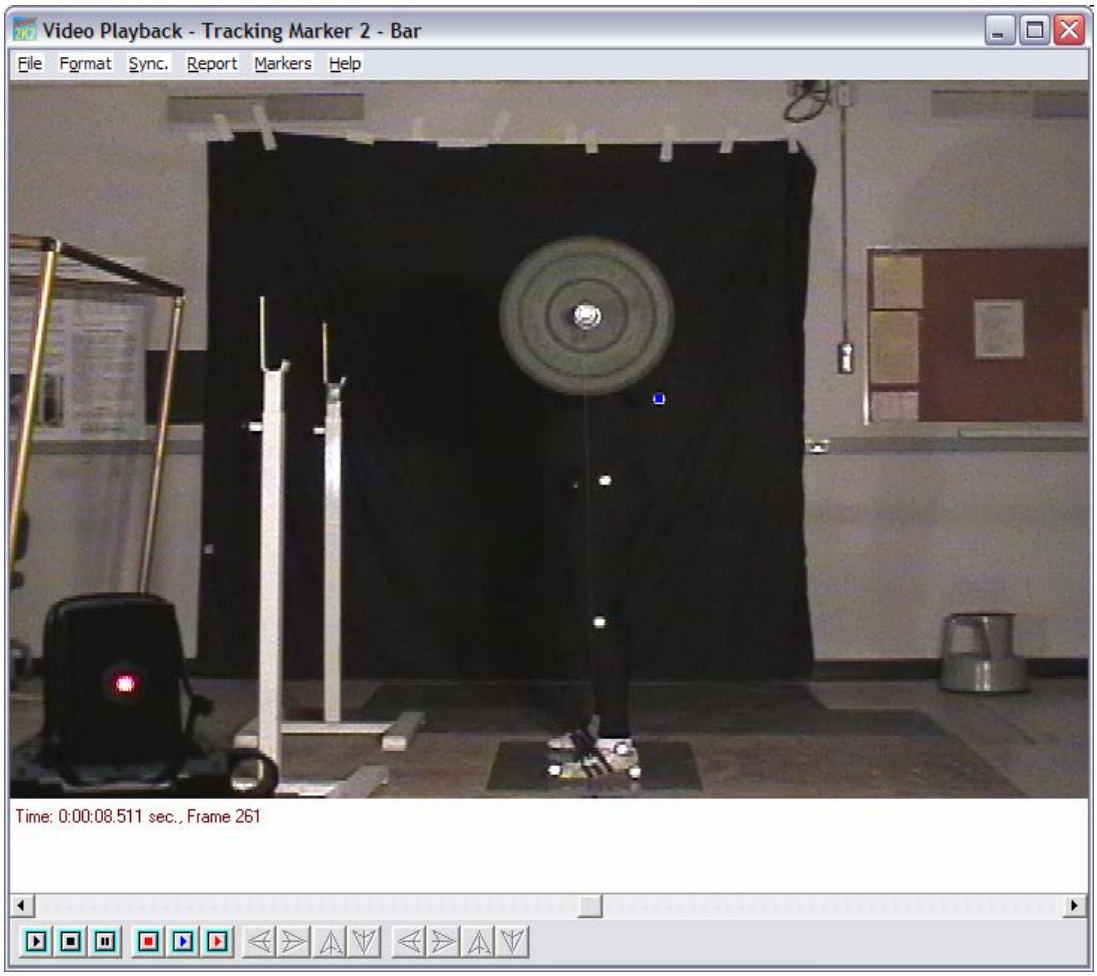


Figure R-7. The header bar of the Video Playback window always reports the active marker.

4. **Identify the location of the active marker in the first picture.** There are numerous ways to identify the location of the active marker depending upon how you wish to proceed.

   First let us assume that you do not have an optical marker available and thus wish to define a particular point as the location of the active "marker". To do so, hold down the **Ctrl** key, place the center of the crosshair on the point you wish to define as the marker location, then click the left mouse button (if you wish to remain on the presently displayed picture) or the right mouse button (if you wish to automatically advance to the next picture). If you elect to remain on the present picture then you must press the right arrow button on the keyboard or click on the right arrow button on the video control slider bar to advance to the next picture.

   ☞ For more precise placement of the defined marker (point), use the Zoom window.

   Now let us assume that you do have an optical marker available and you wish to allow the program to automatically detect it. To do so, hold down the **Alt** key, place the center of the crosshair on the

marker, then click the left mouse button (if you wish to remain on the presently displayed picture) or the right mouse button (if you wish to automatically advance to the next picture). If you elect to remain on the present picture then you must press the right arrow button on the keyboard or click on the right arrow button on the video control slider bar to advance to the next picture. After performing either alternative, all of the pixels identified as being contained within the marker are indicated in the selected marker display color for the duration of time indicated in the **Pause Time During Manual Marker Selection** box of the Markers|Format|Tracking tab. During this time, examine the accuracy of the identified area, and adjust the **Color Change Percentage** value if necessary. Repeat this step as required. After the pause time elapses the selected center of the marker appears as a small square (the size of the center marking is determined by the value in the **Size** box of the of the **Markers|Format|Markers** tab.

After defining the locations of the active marker through the sequence of pictures, return to the first picture in the sequence, select a new active marker number, and repeat the steps described above. There are two ways to select a new marker number: 1. Press **Ctrl+X** on the keyboard to sequence through the markers, or; 2. Select **Markers|Format** from the menu bar of the Video Playback window, click on the **Tracking tab**, and select the desired marker number in the **Tracking Marker** box.

R-3.2. Manual Tracking: Frames Method

Manual tracking using the Frames method allows you to define the locations of multiple markers (or points) in each picture (half-frame) before proceeding to the next.

To perform manual tracking using the frames method, please do the following:

1. **Format the tracking feature.** Details are provided in Section R-5. If you intend to use the manual marking method exclusively and to manually define the locations of all the markers (or points) you wish to track, it is only necessary to decide on the number of markers (or points) you intend to track, supply a verbal label for each, and select the color and size of the point that will be used to identify the location of each marker (or point) that you define. On the other hand, if you intend to employ the program to automatically detect one or more markers, then it is necessary to supply additional parameters for color and size sensitivity. To use the Frames method, be sure to click on the **Frames** radio button in the **Method** tab of the **Video Markers Format window**. Also be sure to highlight all of the markers you wish to track in the associated list box.

2. **View the first picture (half-frame) in the video record that you want to track.** Use the video control buttons in the Video Playback window to view the first picture of interest.

3. **Select the active marker.** The **"active marker"** is the number of the marker (or point) whose location is about to be defined. The number (and title, if it is defined) of the currently selected active marker are reported in the header bar of the Video Playback window. For example, in Figure R-7 (on the previous page), the header bar reads: "Tracking Marker 2 - Bar", indicating that marker number 2 is the active marker, and it has been given the title, "Bar".

   There are two ways to change the active marker number: 1. Press **Ctrl+X** on the keyboard to sequence through the markers, or; 2. Select **Markers|Format** from the menu bar of the Video Playback window, click on the **Tracking tab**, and select the desired marker number in the **Active Marker** box.

4. **Identify the location of the active marker in the first picture.** There are numerous ways to identify the location of the active marker depending upon how you wish to proceed.

   First let us assume that you do not have an optical marker available and thus wish to define a particular point as the location of the active "marker". One way to do so is to hold down the **Ctrl** key, place the center of the crosshair on the point you wish to define as the marker location, then click the

left mouse button. This method, however, requires you to use the **Ctrl+X** key combination to advance the active marker number. A better way to do it is to hold the **Ctrl** key down and click the right mouse button to define the cross-hair location as a point. Upon doing so you will be presented with a **Select Marker window** similar to the one shown in Figure R-8. Note that the window reports all of the markers that you have elected to include when formatting the Frames method, not just the currently selected active marker. You can select any one you want as the identity of the location you just defined. Using this procedure, therefore, the currently selected active marker is irrelevant. To make a selection, either double-click on the appropriate line, or highlight the appropriate line and click the OK button to return to the Video Playback display.

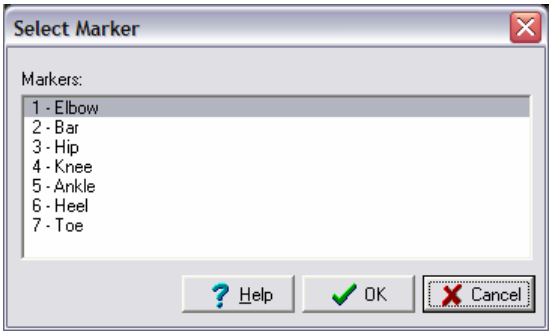


Figure R-8. An example of the Select Marker window.

Continue identifying the remaining markers in the current picture, then use the right arrow key on the keyboard or the display's slider bar to advance to the next picture. Then repeat the procedure as just described. However, because the location of each marker are now known in the previous picture, the Select Marker window will not appear because the program already knows how to identify each location you select in the current picture. After the first picture the Select Marker window will only appear when the program cannot determine with certainty how to automatically identify the location you define.

☞ For more precise placement of the defined marker (point), use the Zoom window.

Now let us assume that you do have an optical marker available and you wish to allow the program to automatically detect it. The available procedures are essentially identical to those just described, except you hold down the **Alt** key rather than the **Ctrl** key.

R-3.3. Automatic Tracking: Markers Method

Automatic tracking requires the presence of highly visible markers attached to the subject in the video record. Any type of marker can be used, but extant conditions will determine what qualities work best. Tracking is both size and color sensitive. Automatic tracking using the Markers method allows you to define the location of an individual marker through a sequence of pictures (half-frames), then to return to the starting picture and track a second marker through the same sequence, and so on.

1. **Format the tracking feature.** This includes setting up the number of markers you intend to track, and the parameters for each marker (marker title, color and size sensitivity, etc). For details, see Section R-5. To use the Markers method, be sure to click on the **Markers** radio button in the **Method** tab of the **Video Markers Format window**.

2. **View the first picture in the video record that you want to track.** Use the video control buttons in the Video Playback window to view the first picture in the sequence of interest.

3. **Select the active marker.** The **"active marker"** is the number of the marker (or point) whose location is about to be defined. The number (and title, if it is defined) of the currently selected active marker are reported in the header bar of the Video Playback window. For example, in the illustration shown in Figure R-7 on a previous page, the header bar reads: "Tracking Marker 2 - Bar", indicating that marker number 2 is the active marker, and it has been given the title, "Bar".

   There are two ways to change the active marker number: 1. Press **Ctrl+X** on the keyboard to sequence through the markers, or; 2. Select **Markers|Format** from the menu bar of the Video Playback window, click on the **Tracking tab**, and select the desired marker number in the **Active Marker** box.

4. **Identify the location of the active marker in the first picture.** To do so, point to the location of the marker with your mouse, then hold down the **Alt** key while you click the left mouse button. Upon doing so, all of the pixels identified as being contained within the marker are indicated in the selected marker display color for the duration of time indicated in the **Pause Time During Manual Marker Selection** box of the Markers|Format|Tracking tab. During this time, examine the accuracy of the identified area, and adjust the **Color Change Percentage** value if necessary. Repeat this step as required. After the pause time elapses the selected center of the marker appears as a small square (the size of the center marking is determined by the value in the **Size** box of the of the Markers|Format|Markers tab).

   ☞ The Markers method includes an **Auto-Increment** feature. When active, this feature makes it possible to track an individual marker from the first to the last picture in the sequence, then automatically return to the starting picture, automatically increment the active marker number, and begin tracking that marker. The process continues in serial fashion until all of the markers are tracked. If you wish to use the auto-increment feature it is necessary to identify the starting location of each marker. Thus, if you intend to use the auto-increment feature, repeat steps 3 and 4 above for each marker you wish to track. But do so only for the first picture.

5. **Begin automatic tracking.** There are two ways to start automatic tracking: 1. Press **Ctrl+T** on the keyboard, or; 2. Select **Markers|Start Tracking** in the Video Playback window's menu bar. After identifying the selected marker in the currently displayed picture the program automatically increments to the next picture, identifies the marker there, then automatically increments to the next picture, and so on. During automatic tracking the distance the marker has traveled from the previous picture, as well as the apparent size change of the marker compared to the previous picture, are reported at the bottom of the Video Playback window. The time and the frame number associated with the displayed picture (in deinterlaced mode there are two pictures per frame) are also reported, as they are in all other playback contexts.

   Automatic tracking stops after processing the last picture in the video record. If the **Auto-Increment** feature is enabled the program then automatically returns to the starting picture, increments the active marker number, and automatically begins tracking that marker. The sequence continues until all of the markers are tracked. If the **Auto-Increment** feature is not enabled, the Distance and Marker Size Change reports are replaced with "*****Finished*****" when the last picture is reached. When that happens you are ready to process the next marker. To do so, repeat steps 2 - 5 above.

R-3.4. Pausing and Restarting Automatic Tracking

To pause automatic tracking, click on any of the three play/pause buttons ( ,  , or ) or press the **Esc**ape key. To restart tracking, use the **Ctrl+T** key combination (*do not* use the play/pause buttons). It should be noted that ***automatic tracking will only restart if a marker is identified for the currently***

displayed picture. That will always be the case if you pause, then restart, without changing the picture you are viewing in between. But if you move forward or backward through the video record, be sure you either return to a picture which already has the marker identified, or to identify all of the markers in the current picture using the procedure described in Step 3 above.

R-3.5. If Automatic Tracking Fails

If the program fails to identify one or more markers in a picture, automatic tracking terminates on that picture and the following message appears at the bottom of the Video Playback window: **Lost marker tracking**. The program will also report the minimum and maximum distance (in pixels) the markers moved from one frame to another (referred to as the **Pixel Distance**), as well as the minimum and maximum **Size Change** percentages it encountered since the tracking process was last started. By comparing them to the parameters you set when you formatted the marker, these values can help you identify why the program failed to identify the marker(s). For example, if you set the marker's **Maximum Search Distance** parameter to **10**, and the **Pixel Distance** range reported at the bottom of the window is 0 - 10, then chances are the program failed to identify the marker because it moved more than 10 pixels from its position in the previous picture.

All of the parameters in the **Markers** tab of the **Video Markers Format** window can be changed at any time, so feel free to make any adjustments you might need before restarting the tracking process. You can restart the tracking process in one of two ways: (1) use the frame-by-frame video controls (i.e., the left arrow button on the scroll bar at the bottom of the Video Playback window, or the left arrow key on the keyboard) to back up one or more pictures until you get to a picture where the marker was correctly identified, then use the **Ctrl+T** key combination to restart the tracking process, or; (2) use the **Alt+left click** keyboard/mouse combination to identify the markers in the current picture, then use the **Ctrl+T** key combination to restart the tracking process.

☞ There may be times when the program fails to adequately identify a marker location no matter how you adjust the detection parameters. This can happen when the color of the marker is too similar to its immediate background. In such situations you are forced to revert to defining a marker location as if the marker did not exist. To do so, hold down the **Ctrl** key on the keyboard, point to the location you wish to define as the center of the marker, and click the right mouse button. If you feel you cannot accurately define a location for a marker, don't try. Just leave the marker undefined for that picture and advance to the next.

You cannot resume automatic tracking until you reach a picture where the program's marker detection algorithm is sufficient to accurately identify all marker locations in the current picture (using the **Alt+right click** keyboard/mouse combination). Thus, on occasions when you find it necessary to manually define one or more marker locations, or leave the marker undefined, you must continue doing so until you reach a frame where it is possible to use the program's marker detection algorithm to detect all of the marker locations. Only then can automatic tracking be resumed.

R-4. Finalizing Kinematic Data

Once all the markers are defined for the video segments of interest, it is time to finalize the results. Finalization makes marker displacement, velocity, and acceleration data, as well as angle information available to the rest of the Datapac environment so that they can be displayed, processed, and analyzed along with EMG, force plate, or any other analog channel. As will be explained in detail in a later paragraph, marker and angle information become available to the rest of the Datapac environment as vitual channels.

To begin finalization, select **Markers|Finalize Markers** in the Video Playback window's menu bar, or use the **Ctrl-M** keyboard combination. Upon doing so the **Finalize Markers** window appears. An example is presented in Figure R-9.

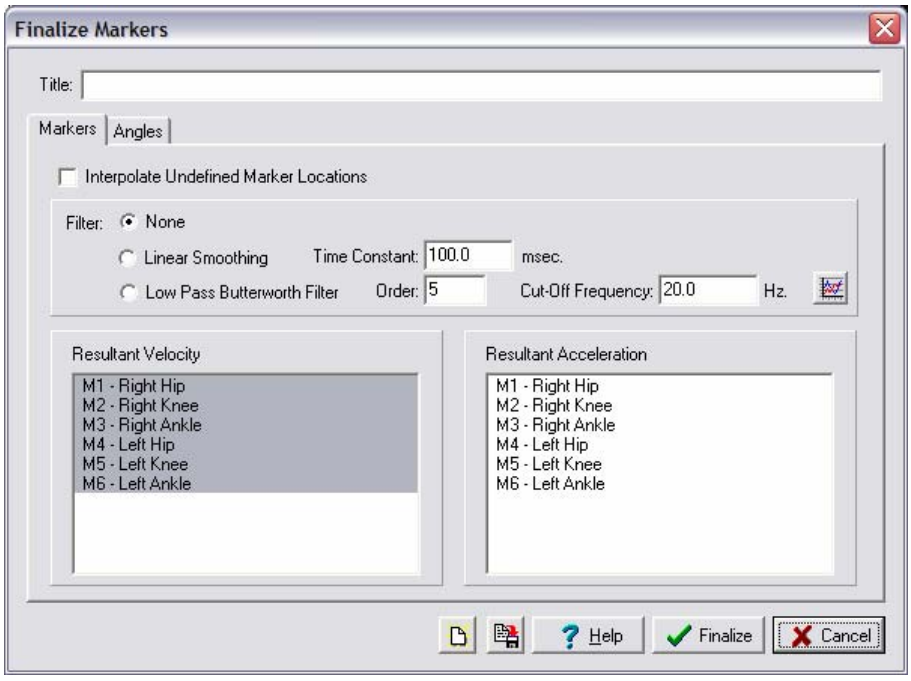


Figure R-9. An example of the Finalize Markers window showing the contents of the Markers tab.

As the example in Figure R-9 illustrates, the **Finalize Markers** window contains two tabs, Markers and Angles. By adjusting the parameters contained in the two tabs you will determine some of the kinds of information that will be made available to the rest of Datapac, specifically the resultant velocities and accelerations of each individual marker as well as angular displacements. This information is optional: you can elect to include it or not. The next two sections will explain how those choices are made. On the other hand, the X and Y displacements of each marker (or virtual point) are always calculated relative to the defined reference point, and they are always made available to the rest of Datapac.

The Markers Tab:

The **Markers** tab, which is shown in Figure R-9, contains two list boxes entitled **Resultant Velocity** and **Resultant Acceleration**. Each list box contains all of the markers and virtual points that you have defined. You can choose to make the resultant velocities and or resultant accelerations associated with each of them available to the rest of Datapac. And in order to choose them you must highlight them. Note in the example above, all of the markers are highlighted in the Resultant Velocity list box. That means that resultant velocities will be calculated for all six markers and made available to the rest of Datapac. On the other hand, none of the markers are highlighted in the Resultant Acceleration list box. That means that resultant accelerations will not be calculated for them, and thus, that information will not become available to the rest of Datapac.

The Markers Tab also allows you to decide whether you wish to estimate undefined marker locations through a process of linear interpolation. If you have missing marker locations and you want the program to estimate them, check the **Interpolate Undefined Marker Locations** check box. Finally, the Markers Tab also allows you to decide whether you wish to apply a linear smoothing or a low pass Butterworth filter to your data. Make your choice by clicking on the corresponding radio button and adjusting the corresponding parameters as desired.

The Angles Tab:

The **Angles** tab, shown in Figure R-10, lets you define angles. Since angles require sticks as line segments, at least two sticks must already be defined in order to define an angle. Enter the number of angles you wish to define in the **Number of Angles** box. Then in the **Convention** box, indicate whether you wish to express them in Degrees or Radians. The **Angle list box** now contains the number of entries equal to the value in the Number of Angles box.

To define an angle, first highlight its number in the **Angle list box**. Now the information to the right of the list box refer to the highlighted angle number. Enter a character string in the **Title** box to help you later identify the angle you are about to define. Then specify the two sticks to be used as line segments in the **Stick A** and **Stick B** boxes. In the illustration below, for example, we have titled our angle **R Leg Angle** and we have identified the two sticks as the **R Thigh** (which is a stick connecting the right hip and the right knee) and the **R Leg** (which is a stick connecting the right knee and the right ankle). For each stick you must also specify a marker or virtual point as the **Vertex**. If the two sticks are actually joined in space, then the Verex specified for both sticks will be the same marker or virtual point. That is the case in the example below: **M2 - R Knee** is the vertex specified for both sticks. But it is important to recognize that the two sticks don't actually have to meet in space. And if they do not, then the vertices specified for the two sticks will be different.

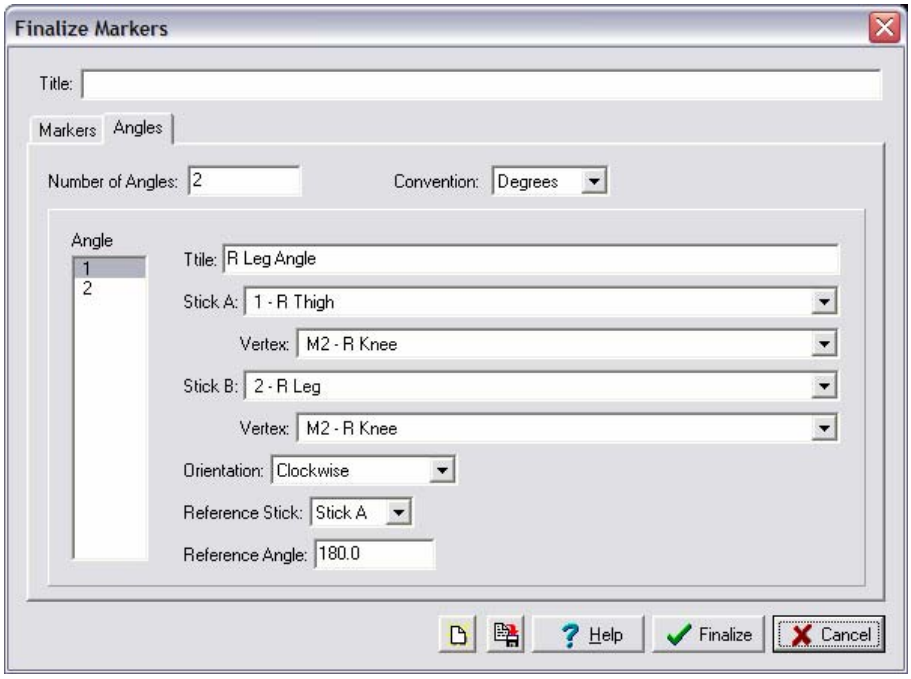


Figure R-10. An example of the Finalize Markers window showing the contents of the Angles tab.

So far we have defined the sticks and vertices that constitute our angle. Now we must define how it will be interpreted. There are three parameters relevant to that: **Orentation**, **Reference Stick**, and **Reference Angle**. As illustrated in Figure R-11, suppose we wish to calculate the angle of the right leg using the knee as the vertex. We have defined the blue stick as connecting the right hip and the right knee and given it the label "R Thigh". Likewise, we have defined the red stick as connecting the right knee and the right angle and given it the label "R Leg". In both cases we have defined the vertex as the right knee (R Knee).

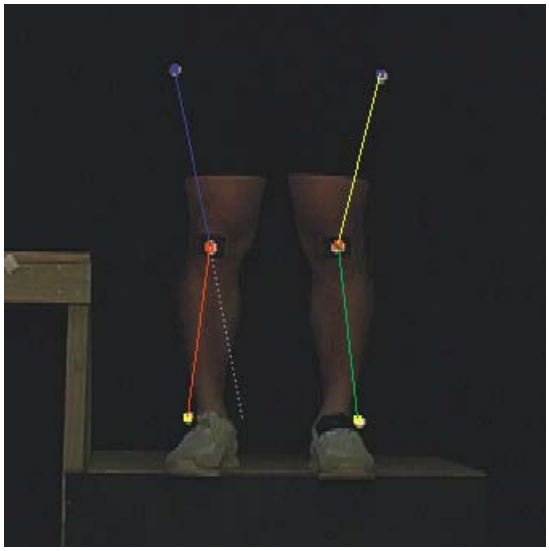


Figure R-11. An example illustrating the configuration of angles.

Now suppose we wish to define the condition when the right leg is completely straight (that is, when the hip, knee, and ankle all fall on the same line) as zero degrees of angle. That condition is represented by the white dotted line extending from the knee. However, according to the conventions of formal geometry, this orientation would actually be an angle of 180 degrees. So we have to correct for that. To do so we define our **Reference Angle** as 180, as shown in the example above. Essentially what we are doing is subtracting 180 from 180, allowing our reference angle to be interpreted as zero degrees.

Suppose further that we wish to define movements of the leg in the direction of the red stick as an increase in degrees. In other words, we wish to define the angle between the red and dotted white "sticks" as a positive angle. To do so we would first define the R Thigh stick (Stick A in the example above) as the **Reference Stick**. Then, because rotation of the leg toward the position of the red stick is a clockwise rotation, the **Orientation** we select is **Clockwise**.

☞ Why did we choose Stick A (R Thigh) as the reference stick? Well, we didn't have to. We could have just as easily selected Stick B (R Leg). However, we would have had to change our Orientation to Counterclockwise to get the same result. Think of it this way: the dotted white line in the example above represents the extension of the selected reference stick (Stick A). Thus, a rotation from that extension in the direction of the red stick is clockwise. Had we selected Stick B as our reference, then our white dotted line should be oriented to be an extension of it. And thus, a rotation from that extension in the direction of the blue stick is counterclockwise. With those changes the calculation will yield exactly the same result.

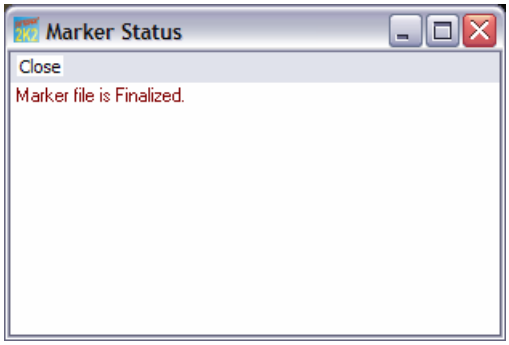
Completing Finalization:

After adjusting the finalization parameters as desired, click the **Finalize** button at the bottom of the Finalize Markers window to return to the Video Playback window. Your data are now finalized and thus can be made available for display, processing, and analysis throughout Datapac. To do that you must create a series of virtual channels. See Chapter 1, Section 1-5.3 for details.

It is important to recognize that **any modification you subsequently make to your marker formatting parameters (e.g., changing the number of active markers, adding or deleting virtual points or sticks), or re-defining one or more locations of one or more markers (or points) will erase all of**

your finalized data. It's easy enough to retrieve it, though -- just refinalize. Display modifications, such as adding or removing markers or sticks from the display do not affect the finalized data.

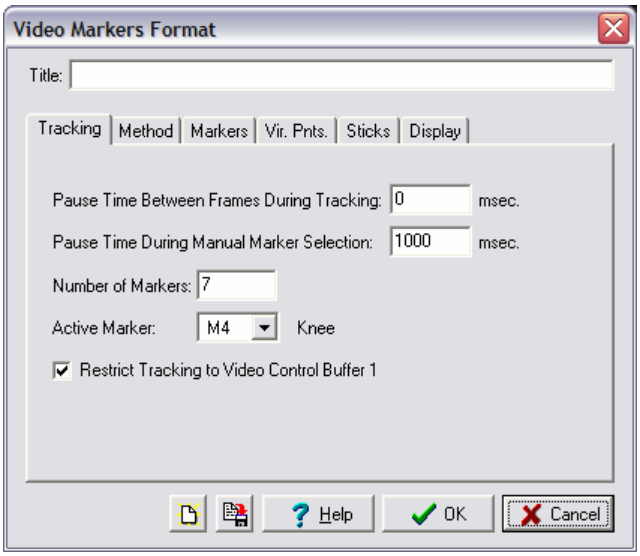
☞ If you are ever in question as to whether your data are finalized, select **Markers|Marker Status** from the Video Playback window (or use the Ctrl-U key combination). Doing so will produce a small window like the one shown in Figure R-12, informing you of the current finalization status.



R-12. The Marker Staus Window.

R-5. Formatting Marker Tracking

To format the marker tracking feature, select **Markers|Format** in the Video Playback window's menu bar. Opon doing so the **Video Markers Format** window appears. An example is shown in Figure R-13.



R-13. The Video Markers Format window showing the contents of the Tracking tab.

As you can see, the information in the Video Markers Format window is contained within six different tabs: **Tracking**, **Method, Markers**, **V. Points, Sticks**, and **Display**. Details are provided in the following subsections.

Tracking Tab

Number of Markers: Indicate the number of markers you wish to track, or points you wish to manually identify, in this box. The maximum number is 100. The number of markers you indicate can be changed at any time prior to finalization.

Active Marker: Once the number of markers are defined, each marker will be listed by number (preceeded by an "M") in this list box. Indicate the number of the marker you wish to identify as the active marker by selecting it from the list. The marker identified as active is unimportant when performing automatic frame-by-frame tracking, but it is important when performing automatic individual marker tracking or manual marking. In the latter two contexts it indicates the marker that is currently tracked or manually identified. The active marker is reported in the header bar of the Video Playback window. To select another marker as active you can do one of two things: 1) Use the **Ctrl-X** hot key combination) while you are viewing the Video Playback window to incrementally cycle through the markers or; 2) Return here to the Tracking tab in the Video Markers Format window.

Pause Time Between Frames During Tracking: This value lets you slow down the automatic tracking process by pausing the specified number of milliseconds between each picture (a "picture" is a de-interlaced, or half-frame). Slowing down the tracking process lets you view the areas identified as markers in each picture as tracking proceeds. To maximize the speed of the tracking process, enter the value, 0 (zero).

Pause Time During Manual Marker Selection: This value determines the amount of time the area identified as the marker (in other words, all of the pixels that are considered to be part of the marker) remains in the picture after its position is manually selected (using the Alt-Left click or Alt-Right click keyboard/mouse combinations). When the pause time elapses, only the center point is shown.

Restrict Tracking to Video Control Buffer 1: This checkbox lets you restrict automatic marker tracking to only those regions identified as events in the event file selected as Video Control Buffer 1. If this checkbox is cleared, automatic tracking will continue until the end of the video file is reached. Restricting automatic tracking to defined events is useful in situations where only one or more select regions in a longer video file are of interest.

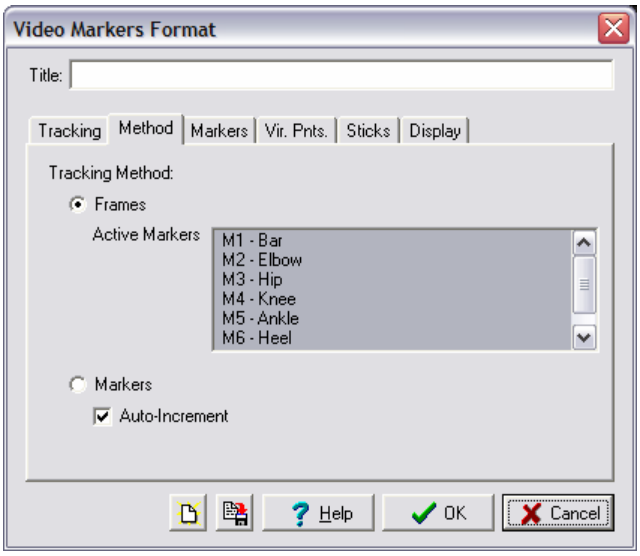
Method Tab

The Method Tab is of concern only if you intend to track markers automatically. If you intend to manually select all of your markers (points), you can ignore the information contained in this tab. The contents of the Method Tab are shown in Figure R-14. There are two automatic tracking strategies, which we call **Frames** and **Markers**.

Frames: The **Frames** option allows you to identify several markers in each frame before proceeding to the next frame. To use the Frames option, check its radio button, then highlight all of the markers you wish to track. You can track all of the markers or any subset of them. To select multiple markers, hold the Ctrl or Shift keys down on the keyboard before clicking with your mouse.

Markers: The **Markers** option allows you to identify an individual marker in sequential frames. The **Active Marker**, the one selected for identification, is determined in the Tracking Tab of the Video Markers Format window. When the **Auto-Increment** check box is checked the program will automatically return to the first frame of the video file (or the first frame of the event, if the **Restrict Tracking to Video Control Buffer 1** checkbox is checked in the Tracking Tab) and begin tracking the next marker in numerical sequence.

☞ If using the Auto-Increment feature, be sure to mark the first location of each marker prior to initiating automatic marking.



R-14. The Video Markers Format Window showing the contents of the Method tab.

Markers Tab

This tab contains the parameters that are used to identify markers. When manually selecting markers (points), only the **Marker List Box**, **Title**, **Display Color** and **Size** are relevant. When automatically selecting markers (using either the Frames or Markers method), all parameters are relevant.

Marker List Box: All of the information on the right side of the window (Title, Color Change Percentage, etc.) are reported for the marker number highlighted in this list box. Thus, to review or edit the information associated with any marker, highlight its number here.

Title: Enter a character string, or title for the highlighted marker number here to help you identify it. For example, if the marker is placed on the subject's left shoulder, enter "Left Shoulder".

Color Change Percentage: This value allows you to adjust the sensitivity with which the system tracks the marker's color/contrast characteristics. The smaller the value the greater the sensitivity. There is no predetermined ideal value. That depends on the lighting characteristics of the environment, the reflectance characteristics of the markers you are using, and the contrast between the marker and its immediate background. These factors can affect the apparent hue and intensity of the marker in the video frame, and thus can affect its apparent size when the sensitivity is not accurately set. The best rule of thumb is to set an initial Color Change Percentage value (15 - 20% is a good place to start), then detect the initial location of the selected marker (see Procedures). Doing so will provide feedback with regard to exactly which pixels in the image are identified as part of the marker. If that area is too constricted (that is, if portions of the marker are not identified as such), then increase the Color Change Percentage value. Likewise, if the area identified as the marker is too broad, decrease the value.

Adaptation: This parameter refers to whether the Color Change Percentage is always measured relative to the color of the first marker location in the series or relative to the color of the immediately preceding identified marker in the series. There are three options: **None**, **Partial**, and **Full**.

None: Select this option when you wish to measure the Color Change Percentage for all other marker locations throughout the file relative to the average color of the first marker location in the

series. In other words, when this option is selected, the program does not "adapt" to progressive changes that may occur in the color characteristics of the marker throughout the file. When the visual field is properly illuminated such that the color, contrast, and/or reflectance of the marker remains relatively constant throughout the file, this is the preferred option.

Full: Select this option when you wish to measure the Color Change Percentage for the current marker location based upon the average color of the immediately previous marker location. In other words, when this option is selected, the program "adapts" to progressive changes that may occur in the average color characteristics of the marker over time. This is the preferred option if the illumination of the visual field contains shadows or other forms of inconsistencies which may affect the marker's apparent color, contrast, and/or reflectance.

Partial: This option operates exactly like the Full adaptation option -- until the average color of identified marker location in any frame falls outside the Color Change Percentage boundary of the first identified marker location.

Size Change Increase Percentage/Size Change Decrease Percentage: These values allow you to adjust the sensitivity with which the system tracks variations in the marker's apparent size. The smaller the value the greater the sensitivity. And again there are no predetermined ideal values. Larger change percentage values are likely to be needed when the marker's apparent size is small. Likewise, it is usually a good idea to use a larger increase percentage value than decrease percentage value.

Maximum Search Distance: This value determines how far the program will search, from one image to the next, for the location of the marker. The distance is measured in pixels, from the edges of the marker identified in the most recent frame.

Display Color Check Box and Display Color: The Display Color check box determines whether the highlighted marker appears in the display. When checked, the position of the marker will appear in the color indicated. To change the color, click on the {bmc c:\forehelp\dp3-95\COLOR.BMP} (**Change Display Color**) button. Note that the indicated color has nothing to do with the color of the actual marker in the image.

☞ In order to view marker locations in the display the **Show Markers** check box must also be checked in the Display Tab

Size: This value indicates the size of the spot used to identify the center of the marker, once the marker's apparent size is identified. The value is expressed in pixel units.

Vir. Points Tab

The Vir (Virtual) Points tab contains the parameters that allow you to generate imaginary, or "virtual" points from the intersection of two stick segments.

Vir[tual] Points List Box: All of the information on the right side of the window (Title, Stick, Display Color, and Size) are reported for the number of the virtual point highlighted in this list box. Thus, to review or edit the information associated with any virtual point, highlight its number here.

Title: Enter a character string, or title for the highlighted virtual point here to help you identify it. For example, if the marker is placed on the subject's left shoulder, enter "Left Shoulder".

Stick[s]: Virtual points consist of the intersection between two stick segments extrapolated into infinity. Thus, there are two "Stick" boxes to identify the two stick segments you wish to employ to create the virtual points.

Display Color Check Box and Display Color: The Display Color check box determines whether the highlighted virtual point appears in the display. When checked, the position of the virtual point will

appear in the color indicated. To change the color, click on the {bmc c:\forehelp\dp3-95\COLOR.BMP} (**Change Display Color**) button.

☞ In order to view marker locations in the display the **Show Markers** check box must also be checked in the Display Tab

Size: This value indicates the size of the spot used to identify the center of the virtual point. The value is expressed in pixel units.

Sticks Tab

A "stick" represents a connection between two markers, two virtual points, or a combination of the two. This tab provides the parameters to allow you to create stick segments.

Number of Sticks: Indicate the number of sticks you wish to define here.

Stick List Box: All of the information on the right side of the window (Title, and Markers) are reported for the stick number highlighted in this list box. Thus, to review or edit the information associated with any stick, highlight its number here.

Title: Enter a character string, or title for the highlighted stick number here to help you identify it. For example, if you want to identify a stick connecting markers placed on the subject's left elbow and left wrist, enter "Left Forearm".

Marker[s]: Enter the numbers of the markers that define the endpoints of the stick in these boxes.

Display Color Check Box and Display Color: The Display Color check box determines whether the highlighted stick appears in the display. When checked, the stick will appear in the color indicated. To change the color, click on the {bmc c:\forehelp\dp3-95\COLOR.BMP} (**Change Display Color**) button.

☞ In order to view sticks in the display the **Show Sticks** check box must also be checked in the Display Tab

Display Tab

Use the checkboxes in this tab to indicate what will appear in the Video Playback window (**Show Video**, **Show Markers** and **Show Stick Segments**), and to activate or deactivate the **Zoom Window**. The Zoom window is a daughter of the Video Playback window that you can used to view any portion of the displayed image in greater detail.