User Guided Tracking Full Guide

I. Introduction

This document describes how to use the Matlab application UGT (User Guided Tracking). This application is used to track a phonomicrosurgery instrument in a video. The video should be captured using the simulated phonomicrosurgery setup. After performing the tracking, a .mat file containing the tracking information can be saved.

The application can semi-automatically track a set of instrument features over the course of a video. Section I of this document describes the set of features tracked by the application. Section II describes the scheme used for tracking. Following this, Section III gives an overview of the application's graphical interface. Finally, Section IV gives specific instructions on using the application.

a. Starting UGT

UGT runs using Matlab. To start UGT, first start the latest version of Matlab on the PC. Within the "Simulated_Surgery_Software" folder there should be a folder named "Matlab". Prior to starting UGT, you must set Matlab's current folder to this directory. This can be done in two ways. If you know the full file path of this folder method 1 is simplest.

- Method 1 : In the Matlab command window type "cd [full file path]" without the quotation marks where [full file path] is the full path to the Matlab folder within the Simulated_Surgery_Software folder. For example, if the full path is "C:\Simulated_Surgery_Software\Matlab", you would type "cd C:\Simulated_Surgery_Software\Matlab" and press enter.
- Method 2 : The current Matlab folder is listed near the top of the application below the file menu. To the right of the folder name is a button with three dots. Select this button and navigate to the "Matlab" folder within the "Simulated_Surgery_Software" folder.

After doing this, type "pathScrip" without quotation marks at the command line and press enter. A message will appear in the command line indicating that Simulated Surgery Folders are being added to the Matlab path. To start UGT, type "UGT" at the command line without quotation marks and press enter.

II. Tracked Features

UGT tracks a set of features related to the 2D position and orientation of a phonomicrosurgery instrument in a video. When using the simulated phonomicrosurgery setup, a paper marker is wrapped near the end of the instrument's cylindrical rod. UGT tracks this region using a square window. Additionally, it tracks the instrument's visible boundaries using a pair of lines. These boundary lines are

used to estimate the instrument's midline. UGT also tracks a feature called the instrument's track point. This is a composite feature given by the intersection of the midline with the vertical midpoint of the marker window. **Figure 1** is a video frame of a phonomicrosurgery instrument with these features overlaid in red.

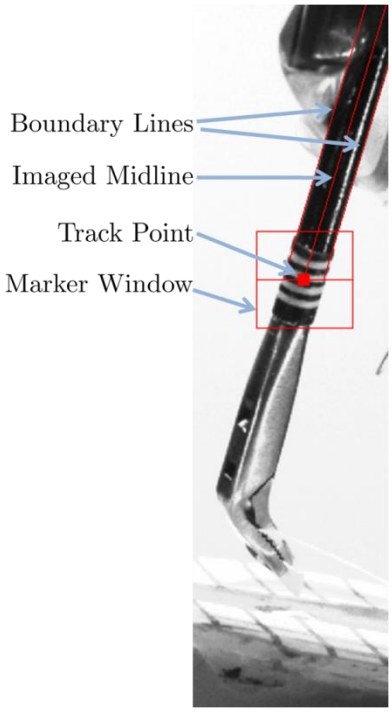

Figure 1: Instrument with Overlaid Features

III. Tracking Scheme

a. Video Files Used

Two video files are used by UGT to perform tracking: a background video and a video of the surgical exercise. UGT is used to track an instrument in the exercise video. The background video is a single frame taken of the surgical setup without any instruments present. It is used by the tracking algorithm to segment the instruments from the background in the surgical exercise video. The application *vidCaptureGUI* contains tools to capture both of these videos.

b. Initialization

Prior to performing tracking using UGT, the instrument to be tracked must be initialized. This consists of initializing a template window enclosing a marker placed on the instrument. Window initialization consists of two steps: window size and position initialization and marker mask selection.

First, the user must initialize a window to enclose the instrument's marker. The size and position of the window is set by the user. **Figure 2** shows a properly initialized window. The window should be selected so that it encloses all of the boundaries between the black and white stripes in the striped region.

Additionally, the top of the window should go slightly beyond the top of the paper marker. This is important for properly tracking the boundaries of the instrument. **Figure 3** shows incorrectly initialized windows. The far left initialization is too small, it does not completely contain the striped region. Also, it does not extend to the top of the paper marker. The middle initialization is incorrect because it does not extend to the top of the paper marker. The far right initialization is incorrect because it does not contain all of the striped region.

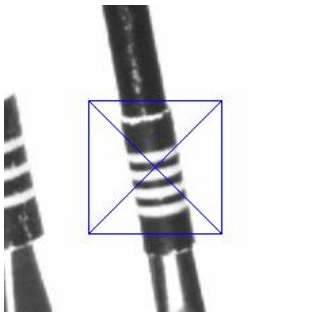

Figure 2 : Properly Initialized Marker Window

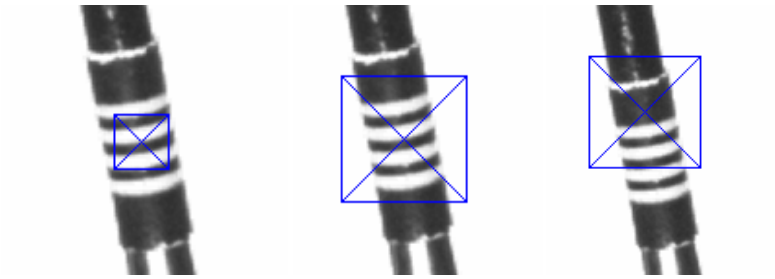

Figure 3 : Incorrectly Initialized Marker Windows

The properly initialized window in **Figure 2** contains the instrument marker along with some background regions. The second step of initialization is setting a mask of the striped marker region within the window. This mask should contain the vertical edges of the marker and all the horizontal boundaries between the black and white stripes. The boundaries of this mask are seen in the left hand image of **Figure 4** as a blue polygon enclosing the striped marker region. The resulting mask is seen in right hand image of **Figure 4**. The pixels in the white region are used by the program in the proceeding frames to track the instrument. Therefore, it is important to include the entire striped region and exclude background regions. Some examples of incorrect marker masks are seen in **Figure 5**. The left hand mask is too thin. It does not contain the vertical boundaries of the marker. The middle mask is too wide, it contains background regions. The right hand mask is too tall, it extends to the top of the paper marker. The mask only needs to enclose the striped region.

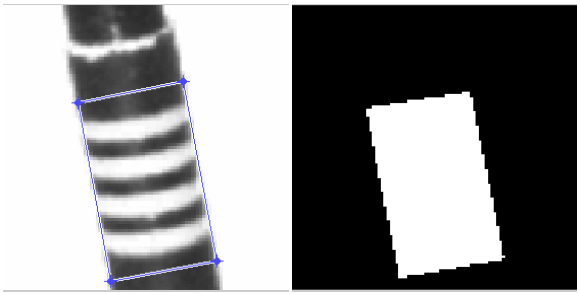

Figure 4 : Properly Initialized Template Mask

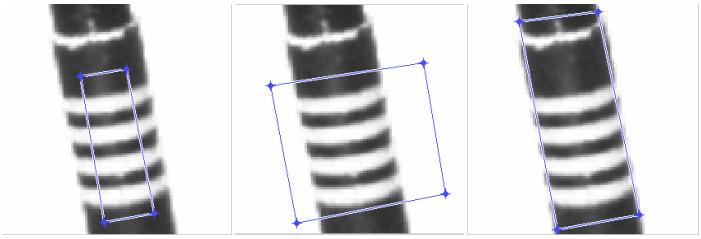

Figure 5 : Incorrectly Initialized Template Masks

c. Labeling

Instrument tracking consists of two primary components: the actual tracking of instrument features and the verification of the features. **Figure 1** illustrates the features properly found by the program. **Figure 6** is a frame with incorrectly tracked features. Motion blur in this frame makes it difficult to find the instrument's features.

UGT utilizes a labeling system to deal with the incorrectly tracked frames. **Figure 7** is a block diagram of the labeling system scheme. After features are detected in a frame, the frame is labeled either correct or incorrect. If the features are detected properly, the frame is labeled correct. If the features are detected incorrectly (like the motion blur frame in **Figure 6**), the frame is labeled an error. As explained in the next two subsections, this labeling scheme can be performed in a manual or semi-automated fashion using UGT.

d. Manual Tracking

When performing tracking manually using UGT, the user supplies every frame label. After detecting an instrument's features in a frame, the program presents the frame with the featured overlaid graphically to the user. At this point, the program waits for the user to label the frame either as correct or an error. After the user provides the label, this process is repeated for the next frame. In this scheme, the program is responsible for detecting the instrument features and the user is responsible for verifying the features though labeling.

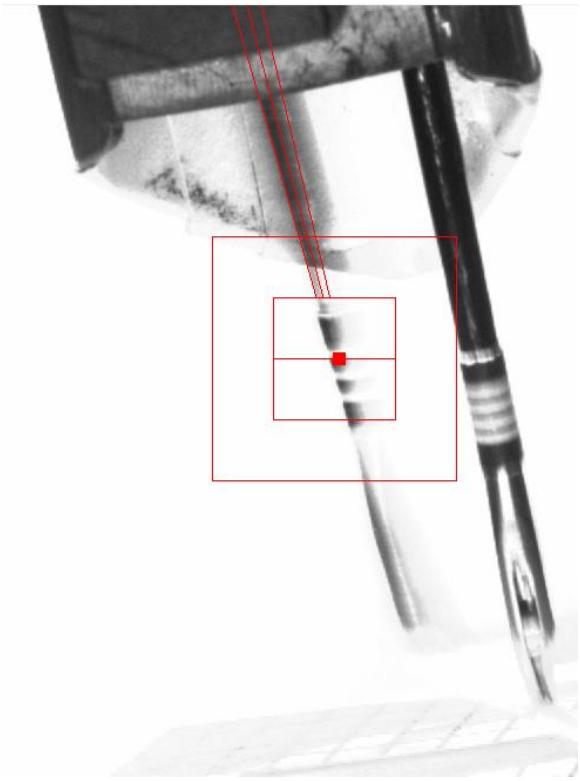

Figure 6 : Incorrectly Tracked Features Due to Blur

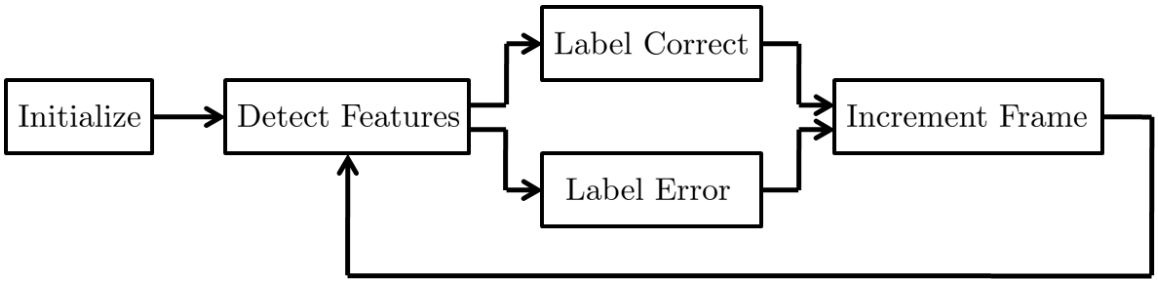

Figure 7 : Labeling Scheme

e. Semi-automated Tracking

Using the manual tracking scheme is time consuming. To speed up the process, UGT can track in a semi-automated fashion. This mode of operation is called “Auto-Pilot”. In “Auto-Pilot”, the tracking algorithm will asses it’s confidence after detecting instrument features. If the algorithm is confident, it will automatically label the frame as correct and proceed to detecting features in the next frame. If the algorithm is under confident, it will ask for user-intervention. When under confident, the frame with the tracked features will be graphically presented to the user. The user must tell the program to continue or

stop "Auto-Pilot". If it has correctly detected the features, the user should tell the program to continue running "Auto-Pilot". The program will label the frame as correct and continue running automatically. If it has incorrectly detected the features (for example due to motion blur like **Figure 6**), the user should tell the program to stop "Auto-Pilot". The program will then enter manual tracking mode as described in **Section III d**. "Auto-Pilot" can be re-entered after a frame with correctly detected frames has been manually identified (a frame after the error frame has been labeled correct). When performing semi-automated tracking, UGT is responsible for detecting the instrument features. If the algorithm is confident it is responsible for labeling frames, if it is under confident the user is responsible for labeling.

IV. Interface Overview

UGT is a single window GUI seen in **Figure 8.** It contains a set of buttons and indicators used to extract tracking information from a simulated surgery video. Additionally, a file menu at the upper left hand corner of the application is used to create new, save, and load tracking files.

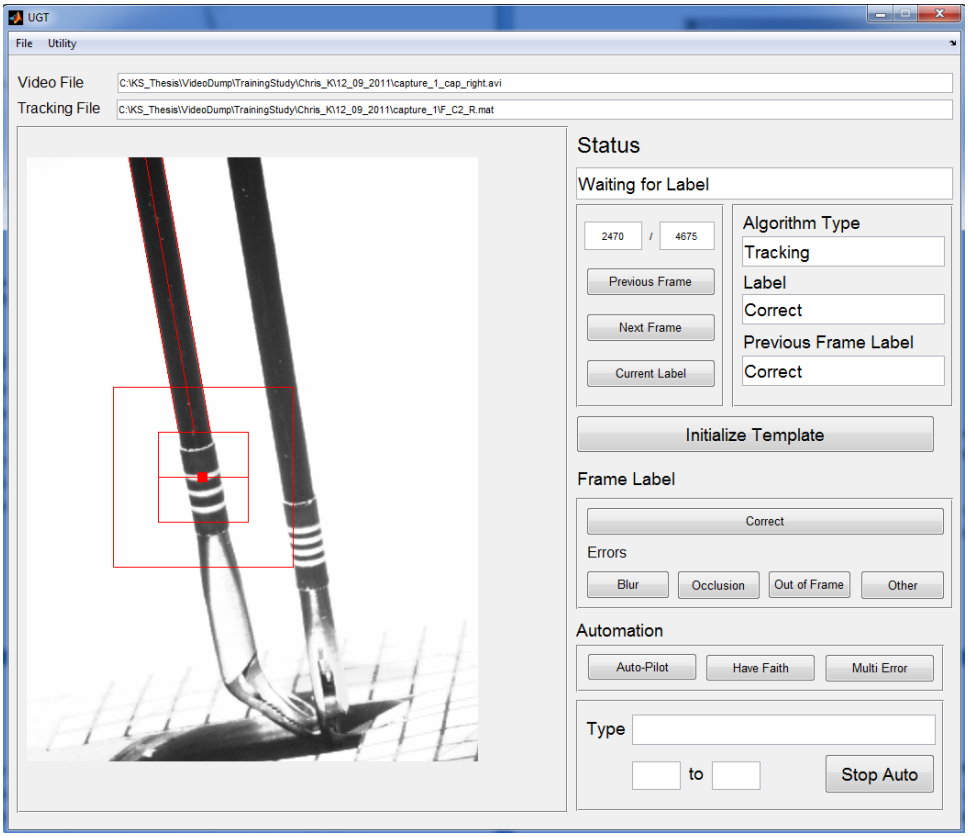

Figure 8 : UGT Primary Graphical Interface

a. File Menu

A file menu is located in the upper left hand corner of the application. This menu contains the following commands : "New Tracking", "Load Tracking", "Save Tracking", "Save Tracking As", "Exit".

When the application is started it is in an idle state. Either a new tracking file needs to be started or a tracking file needs to be loaded. The "New Tracking" command starts a new tracking file. After pressing this button, windows will appear in which the exercise video and the background video are selected. After selecting the videos, the controls on the main interface can be used to perform tracking. The "Load Tracking" command is used to load a tracking file (.mat) that has already been started. Tracking data can be saved to a file on the hard-drive using the commands "Save Tracking" and "Save Tracking As". The first time either command is selected for a new file, a window appears prompting the user for the name and location of the file. It is saved as a .mat file, which is a general Matlab file format. After a file has been associated with the tracking data, future selections of "Save Tracking" will update this file. "Save Tracking As" allows the data to be saved to a different file name. The "Exit" button is used to close the application. Alternatively, the "x" button in the application's upper right hand corner can be used to close.

b. File Information Indicators

Below the file menu are two text indicators: "Video File" and "Tracking File". "Video File" shows the full name of the video file that tracking is being performed on. "Tracking File" shows the full name of the file that tracking data is being saved to after the tracking has been saved once.

c. Status Indicator

The status indicator is a text indicator located under the text "Status" . It indicates the current status of tracking in the application. When the application is opened, it reads "Waiting for File". After starting a new file, it reads "Waiting For Initialize". At this point, the application is waiting for the marker template to be initialized (**Section III b**). After this has been initialized, the program detects features in the initialization frames and the status indicates "Waiting For Label". The status will remain in "Wait For Label" as the user labels frames manually. If one of the automation routines is called the status will indicate that an automation routine is running by reading "Auto-Pilot", "Have Faith", or "Multi Error".

d. Frame Navigation

The frame navigation panel is seen in **Figure 9**. This panel is located below the status indicator. The two boxes at the top of this panel indicate [current frame being viewed] / [total video frames]. The left box is editable, to allow a user to jump to a specific frame. Below these boxes are three buttons: "Previous Frame", "Next Frame", and "Current Label". The "Previous Frame" and "Next Frame" button allow the frames of the video to be browsed. The "Current Label" button navigates to the frame that is currently waiting to be labeled. The frame will be shown in the display panel with the detected features overlaid.

e. Frame Display Panel

The large display panel showing a video frame in **Figure 8** is the frame display panel. The current frame selected is displayed in this panel. If feature data has been detected in this frame, it is overlaid with red graphics. **Figure 1** shows the overlaid features which are described in **Section II.**

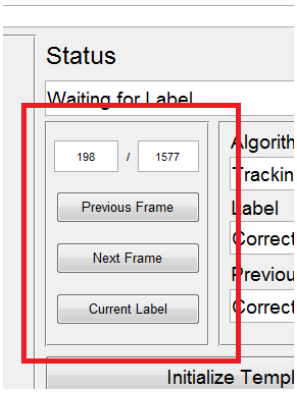

Figure 9 : Frame Navigation Panel

f. Initialize Template Button

A large button labeled "Initialize Template" is located below the frame navigation panel. After a video file has been selected to perform tracking on, the instrument to be tracked must be initialized. This is done by initializing a window and mask as described in **Section III b**. The "Initialize Template" button starts this process.

g. Frame Label Panel

The frame label panel is located below the "Initialize Template" button. It is enclosed by a red rectangle in **Figure 10**. As described in **Section III c**, verification of feature tracking is performed by labeling a frame as "Correct" or "Error". The frame label panel contains buttons to do this manually. The button " Correct" is used to label the current frame being viewed as correct. There are four buttons used to label the current frame being viewed as an error : "Blur", "Occlusion", "Out of Frame", and "Other". If the features are incorrect due to motion blur, the "Blur" button should be used. If the features are incorrect due to occlusion by the other instrument, the "Occlusion" button should be used. If the instruments are out of frame the "Out of Frame" button should be used. If there is a tracking error due to other reasons, the " Other" button should be used. This is useful for simply excluding frames from tracking. For example, assume you want to perform tracking for frames 1-20 and 50-70. In this case, you could start tracking at frame 1 and label frames 21-69 as "Other". The resulting file would have tracking data for frames 1-20 and 50-70. The error type selected does not affect the operation of the tracking algorithm.

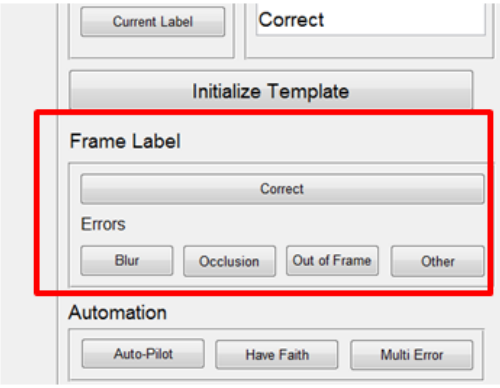

Figure 10 : Frame Label Panel

h. Automation Panel

The frame label panel contains buttons for verifying tracking data manually. As described in **Section III e**, tracking data can be verified semi-automatically. The automation panel seen in **Figure 11** contains controls and indicators for doing this. The three buttons : "Auto-Pilot", "Have Faith", and "Multi Error" are used to initiate an automation mode.

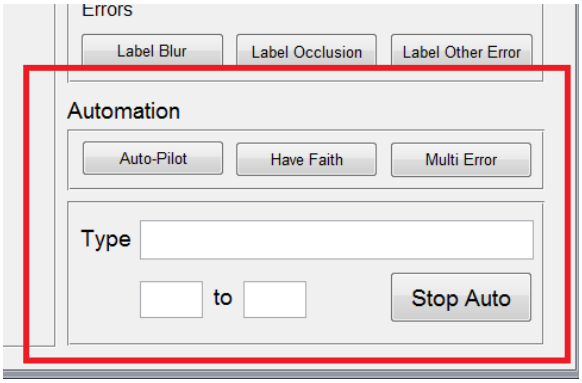

Figure 11 : Automation Panel

"Auto-Pilot" initiates the semi-automated tracking scheme described in **Section III e**. "Auto-Pilot" will run from the current label frame to a user specified end frame. After the button is pressed, a window will appear prompting the user for this end frame. Then, the auto-pilot process will begin. The running of the process is indicated by the indicators below the three buttons. The type indicator will read "Auto-Pilot" and the two boxes below will read [start frame] to [end frame]. The current frame indicator in the frame navigation panel will update as the auto-pilot tracks and labels correct frames. Note, the display panel will NOT update when running auto-pilot unless an under confident frame is reached. The "Stop Auto" button stops "Auto-Pilot" early.

The "Have Faith" button runs a process similar to "Auto-Pilot". "Auto-Pilot" asks for user intervention if it is under confident about features it has detected. "Have Faith" will not. Instead it

assumes that all the features it has detected are correct and labels them correct. To stop this process early, the "Stop Auto" button can be used.

The "Multi Error" button is used to label multiple frames in a row as a single error type. For example, the instrument could be occluded for 25 consecutive frames. Instead of pressing "Label Occlusion" for 25 frames, the "Multi Error" button can be used. When the button is pressed, the dialog in **Figure 12** appears. It indicates the first frame (start frame) that will be labeled an error. Below this is a box for the user to enter the last frame (stop frame) to be labeled an error. A pull-down menu below this allows the error type to be assigned to the frames to be labeled. After pressing "ok", the program will enter the multi error automation mode.

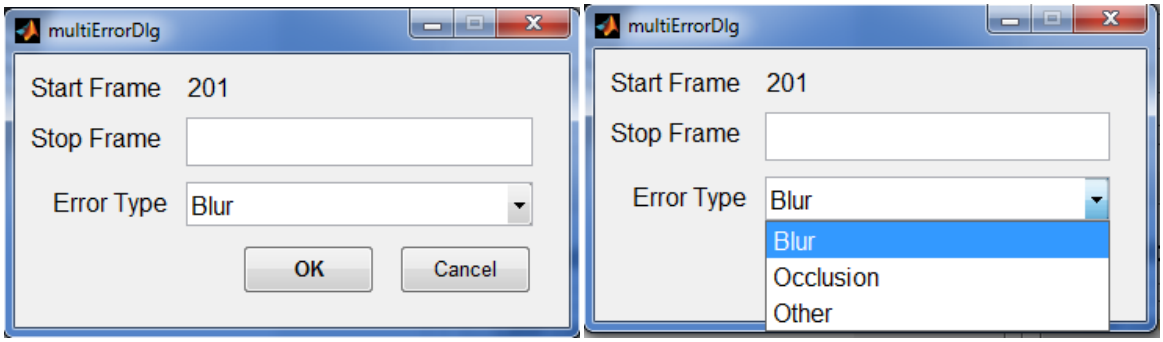

Figure 12 : Multi Error Dialog

V. Using UGT Step-By-Step Guide

This section gives instructions on how to use UGT to start a new tracking file.

a. Open UGT

Follow the instructions in **Section I a** to start UGT.

b. Open Video File in VirtualDub

It is helpful to identify the frames that you want perform tracking on prior to using UGT. VirtualDub is a great tool for quickly seeking and viewing frames in a video. After starting UGT you should be able to open it by typing "VirtualDub" at the Matlab command line without quotation marks and pressing enter. If this does not work, VirtualDub.exe can be found at \Simulated_Surgery_Software\VirtualDub\VirtualDub.exe. You can open it through the windows file browser. After starting the application, a video can be loaded by selecting "File" -->"Open Video File". A bar near the bottom of the program provides frame seeking. The frame number is given by a text indicator below the seek bar. Use VirtualDub to identify the first and last frame you want to track the instrument over.

c. New Tracking File Selection

After opening UGT, select "File"--> "New Tracking". A file dialog named "Load Video File" will appear. Navigate to and select the video file you want to perform tracking on. After selecting this file, another dialog named "Load Background File" will appear. Select the background video associated with the exercise video. After the two files have been selected, the program will return to the main application window. The first frame of the exercise video will be displayed and the status indicator will read "Waiting for Initialize".

d. Initialize Marker Template

At this point, the application is waiting for you to initialize the marker template as described in **Section III b**. First, navigate to the tracking start frame you identified using VirtualDub. Click on the left hand box in the frame navigation panel. This box is enclosed by a red rectangle in **Figure 13** . Type in the start frame. The display panel should update to this frame.

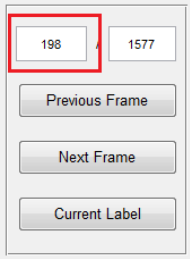

Figure 13 : Editable frame number indicator

Now, select the "Initialize Template" button. A new Matlab figure window will open with the current frame image. The mouse will appear as a crosshair in this window. Select a point near the center of the black and white stripe region of the marker. The dialog in **Figure 14** will appear.

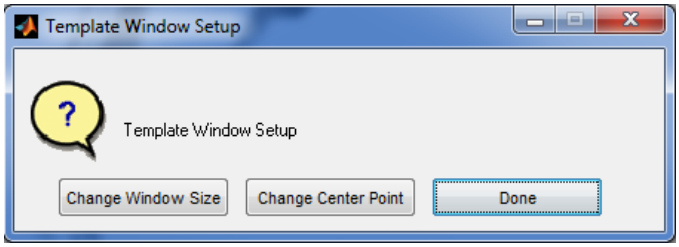

Figure 14 : Window Setup Dialog

The two buttons in this dialog : "Change Window Size" and "Change Center Point" allow the square window position and size to be adjusted. "Change Window Size" will open a dialog that allows the window's size to be input. The dialog will initialize with the current window's size. After changing the

window's size, the window displayed in the figure will update. "Change Center Point" allows the center point of the window to be adjusted. After pressing it, the mouse will change to a crosshair. Select the desired center position of the window. The window should be positioned and sized so that it contains all stripe boundaries and extends slightly further than the top of the paper marker. **Section III b** gives more information on window selection. When satisfied with the window press "Done" in the Template Window Setup dialog.

The figure will close and a figure of the window region only will open. Maximize this figure window. Now, the marker mask must be selected as described in **Section III b** . This is done by drawing a polygon around the striped region of the marker. Clicking on the figure, places a vertex of the polygon. Place four vertices to enclose the striped marker region by a rectangle. To complete the polygon, click on the first vertex that was placed. This will enclose a region of the image within the polygon. **Figure 4** shows an example of this. If satisfied with the selection, double click on the blue polygon. This will close the figure window. If unsatisfied, a vertex position can be adjusted by clicking and dragging. **Section III b** gives more information on properly setting up this polygon. Once this is complete, the tracking process has been initialized. The status indicator should now read "Waiting For Label".

e. Manual Tracking

The frame display panel should show the current frames with the detected features overlaid. A box with a horizontal line across the middle should be enclosing the marker. A pair of boundary lines should be hugging the boundaries of the instrument and a midline should be at the middle of these two lines. **Section III c,d** describes the scheme used for manual tracking in more detail. The program will detect instrument features and the user will label the frame as correct or error. The buttons in the frame label panel are used to do this. Press "Label Correct". The frame is labeled "Correct" and the current frame is incremented. The features detected in the next frame are displayed, and the application is waiting for the user to label this frame using one of the buttons. If it is an error frame, one of the three buttons : "Label Blur", "Label Occlusion", or "Label Other Error" should be used. This process could be repeated until the end frame, but this is very time consuming. Instead the Auto-Pilot automation routine described next should be used.

f. Auto-Pilot

As described in **Section III e, "**Auto-Pilot" is used to semi-automatically track and label frames. Press the "Auto-Pilot" button. A dialog will appear requesting the end frame, enter it and select "OK'. The application status will change to "Auto-Pilot" and the automation indicators will indicate the frame numbers over which "Auto-Pilot" will run. When running in "Auto-Pilot", the application tracks, and labels frames correct automatically. At each frame, it determines if it is confident or under confident. If it is

confident, it continues to the next frame. If it is under confident, it stops and the dialog in **Figure 15** is shown.

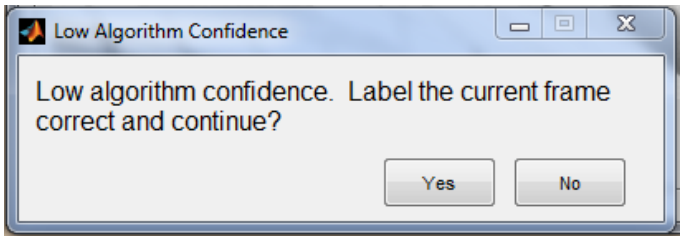

Figure 15 : Under Confident Algorithm Dialog

Using this dialog, you must tell the application if it should continue. The frame with overlaid features will be shown in the frame display panel. If it has properly detected features, press "Yes". The auto-pilot automation routine will continue. The dialog will reappear if the algorithm is under confident at a different frame. If it reaches the end frame, the application status will change from “Auto-Pilot” to “Waiting for Label”. If the incorrect features have been identified, (for example, due to motion blur) press the "No" button. This will stop the auto-pilot routine and return to manual tracking. You should label error frames until a correct frame is found. Now, the auto-pilot can be restarted by pressing the "Auto-Pilot" button again.

g. Multiple Error Labeling

It is time consuming to manually label multiple frames in a row as an error. This is because the program tries to detect features in the next frame after an error. The "Multi Error" button runs an automation routine that quickly labels multiple frames as error frames. For example, assume the application is waiting for frame 201 to be labeled and the instrument leaves the field of view from frame 201 to 300. Instead of pressing the "Label Other Error" button 100 consecutive times, the "Multi Error" button should be pressed. The dialog in **Figure 12** will open **.** For this example, the end frame should be set to 300 and the "OK" button pressed. The Multi Error automation routine will then run. When it is finished, the application status will return to "Waiting for Label".

h. Saving Tracking Data

Tracking data is saved using the "Save Tracking" and "Save Tracking As" commands in the file menu. The first time either command is called a file save dialog will open. The name and location of the file is set using this dialog. After setting this, future calls to "Save Tracking" will update this file.

i. Starting a New Tracking File

To start a new tracking file using the same video, navigate to the desired starting frame and press "Initialize Template". Tracking will initialize at this frame after the template is set. To start a new tracking file for a different video, select “New Tracking” from the file menu. Remember to save any changes prior to starting a new tracking file.