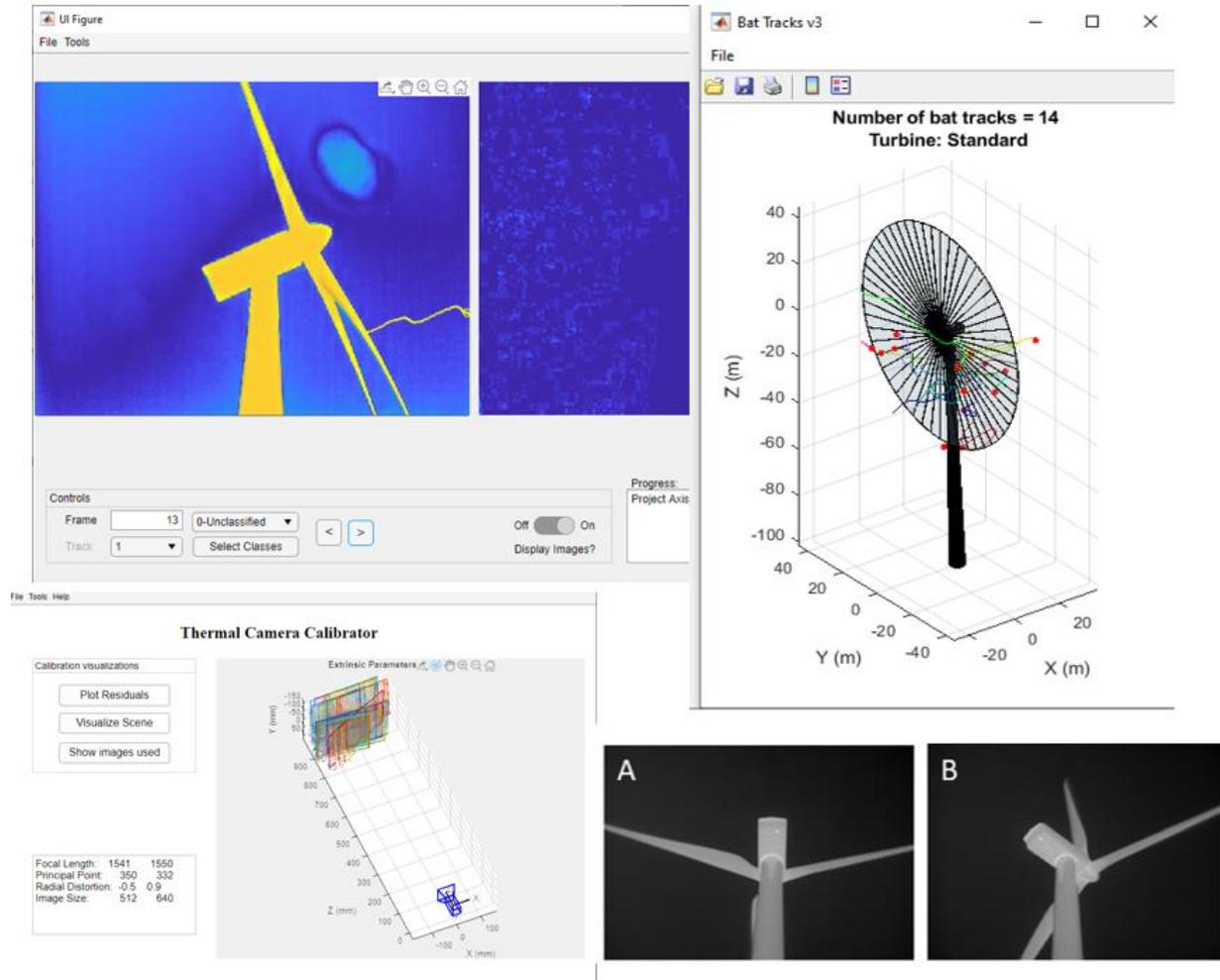


ThruTracker User Manual



Verson 1.6

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Updates: www.sonarjamming.com/thrutracker

(code with also be posted at batcon.org)

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1. Overview

1.1 Capabilities and Limitations

ThruTracker is a powerful software platform for automated two-dimensional (2-D) and three-dimensional (3-D) video-based animal tracking. ThruTracker detects moving objects within fixed (non-moving) field of view cameras using robust algorithms and flexible settings (Chapter 5). Detections are linked together across frames to generate tracks, which can be manually or automatically classified into different categories such as bird, bat, insect, turbine tip, etc. Those interested in 2-D tracking can skip straight to chapter 5, as chapters 1-4 pertain only to 3-D tracking.

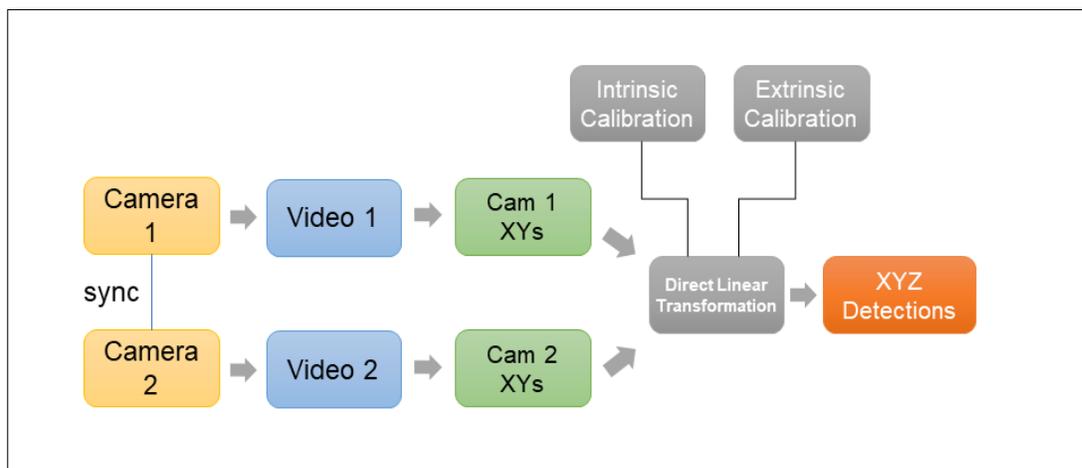
ThruTracker uses a form of background subtraction to detect moving objects within a stationary background. This requires some amount of contrast between the focal animal and the background. Options are available to detect and remove moving and stationary wind turbines. Moving clouds can also be a problem. Filters have been developed to help remove false detections of turbines and clouds both at the level of object detection and based on track properties (see Chapter 5). However, false detections of clouds and turbines can remain a problem, especially when aiming to make detections of animals that are near the background noise level of the image.

There are several requirements for generating 3-D tracks. Specifically, two or more cameras must have an accurate time synchronization. Cameras must also be fixed in space and not move over the recording period. Finally, care should be taken to set up the cameras with a proper orientation to ensure optimal overlap of the camera fields of view (Chapter 2). Two cameras are usually sufficient for tracking up to a few animals at a time. However, three cameras that are properly staggered in space are required for simultaneous tracking of many animals.

1.2 3-D tracking workflow

Figure 1 provides an overview of the workflow for generating 3-D tracks. Video is acquired from a minimum of two frame-synchronized cameras. Each video is processed to generate two-dimensional (XY) detections. A direct linear transformation (DLT) procedure utilizes information from intrinsic and

Figure 1. Overview of 3-D tracking workflow.



extrinsic camera calibrations to convert XY coordinates into 3-D XYZ coordinates, which are then stitched together across frames to make 3-D tracks.

DLT effectively triangulates 3-D positions of objects by using known properties and positional information of the cameras. The intrinsic calibration determines properties of the cameras themselves, including the amount of magnification of the image (which is determined by the focal length of the lens and size of the sensor in the camera), optical distortion caused by the lens, and the principle point, which is the optical center of the sensor (see <http://www.kwon3d.com/theory/dlt/dlt.html> for a more detailed explanation). These values allow conversion from a particular XY detection into a vector from the perspective of the camera. Often intrinsic values will not vary substantially over time or between cameras, so a single intrinsic calibration done in the lab (Chapter 3) may be sufficient. However, it is recommended to validate intrinsic calibration data for your project.

The extrinsic calibration procedure determines the positions and orientations of cameras in 3-D space for a particular camera setup. Even a slight change in camera position or orientation (i.e., which way the cameras are facing) can cause large errors in generating 3-D points. Therefore, care should be taken to ensure cameras have not moved during the recording period. If the cameras have moved, a new extrinsic calibration should be conducted. The extrinsic camera coordinate values allow the vectors from the cameras to be used to triangulate the positions of objects in 3-D space. Two vectors in 2-D space will always intersect at a single point if the vectors are not parallel. However, in 3-D space two vectors need not intersect, as they could be offset in the third dimension. The minimum distance between the two vectors (measured in pixels) is one measure of the amount of error in the 3-D point generation process. This error is referred to as the DLT residual. The DLT residual (and the 3-D point itself) is more accurate when using at least three cameras. However, two-camera setups may be sufficient in many cases.

2. Field recording setup and measurements

2.1 Camera selection

ThruTracker is compatible with any camera that saves video to standard formats (.avi, .wmv, etc.). Camera selection will depend on the application. For recording at wind turbines, we have successfully used Flir A65 cameras with 25 mm lenses. These cameras are capable of capturing the majority of the rotor-swept zone as well as detecting animals at heights up to 150-200 m, depending on the size of the animal. We recommend cameras such as the Flir A65 that have dedicated electronic cables for frame-synchronization. Cameras that have audio-in ports can also be used for synchronization, however this option has greater potential for errors.

2.2 Camera placement in the field

There is no single ideal arrangement of cameras, as any camera setup represents a trade-off between multiple factors. Closely spaced cameras (Figure 2A) will have fields of view with greater overlap and therefore a larger 3-D volume is captured. However, their views are closer to being parallel, which leads to greater error, especially along the axis of the camera field of view. In contrast, Cameras that are oriented such that their views are closer to perpendicular (Figure 2B) will have narrower regions of overlap between their fields of view and therefore a smaller 3-D volume is captured. However, this orientation will reduce the amount of error in estimating 3-D positions. One rule of thumb that has been proposed is that the baseline distance between cameras should be at least $1/10^{\text{th}}$ of the distance to the

furthest expected target. Therefore, if aiming to capture animals up to 100 meters away, the cameras should be placed at least 10 meters from one another.

For recording at wind turbines another question is how far away to place the camera from the base of the turbine monopole. Placing cameras closer to the monopole will provide a perspective that captures more of the monopole itself, but the monopole can occlude part of the view. Placing the cameras further away from the monopole base will provide a more oblique perspective. This can be helpful if using the turbine itself for 3-D calibration points (Chapter 4) because the tips of turbine blades are easier to see.

As a general recommendation, we suggest placing cameras approximately 30 meters from the base of the turbine monopole and having cameras 10-20 meters apart from one another, depending on the needs of the project.

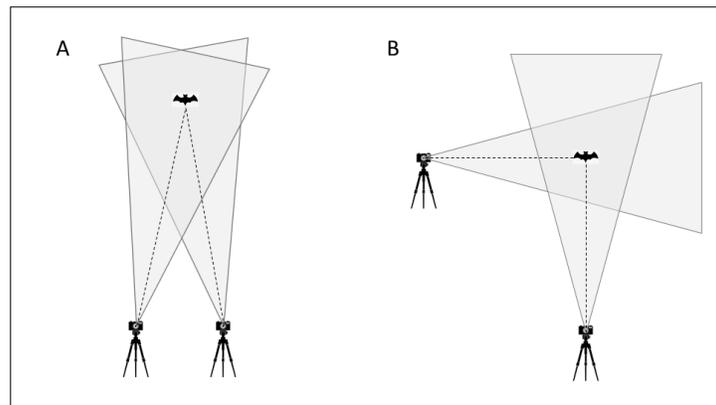
2.3 Field measurements

In the field one should measure: 1) the distance between the cameras; 2) the distance between each camera and the monopole base; and 3) the angle that each camera is inclined relative to the horizon (i.e., inclination or altitude). It is important to take these measurements prior to starting recordings to avoid bumping cameras and changing their orientation.

For measuring distances between cameras and between the cameras and the monopole, we recommend using a laser distance measurer such as the Bosch GLM-50C or a similar device that is capable of measuring distances up to 30-50 meters with accuracy within a few millimeters. With a bit of practice, it is possible to measure the needed distances with high accuracy during daylight conditions. We recommend mounting the laser distance measurer on a tripod and placing it such that it is just adjacent to one of the cameras and at the same approximate distance from the other camera or monopole as the camera itself. Especially during daylight conditions, you will likely need a reflective target. One can be made by adhering night-reflective tape such as ULINE S-22329W to a 0.3 m x 0.3 m piece of cardboard. A second person should hold the reflective board just above the target camera or on the surface of the monopole. For taking the measurement, it can be helpful to use the edge of the laser measurer as a sighting device. It is recommended to practice this procedure prior to going to the field, starting at shorter distances and progressing to the longest distance that will need to be measured in the field. Note the field measurements on the data sheet in Appendix A of this document

For measuring inclination angles, we recommend using a digital inclinometer such as a Wixey WR300 that has a precision of at least 0.1 degrees. Some laser distance measurers such as the Bosch GLM-50C also have a built-in inclinometer that can be used for this purpose. Prior to use, the device should be

Figure 2. Comparison of camera configurations optimized for (A) camera overlap and (B) accuracy of 3D reconstruction.



calibrated by following the instructions in the user manual. One can check the accuracy of the measurements to comparing readings before and after rotating the device 180 degrees on a flat surface. After calibrating and checking the device, one should measure the inclination angle of each camera by placing the device on the flat top surface of the camera in the camera's deployed position.

3. Calibrating camera intrinsic parameters

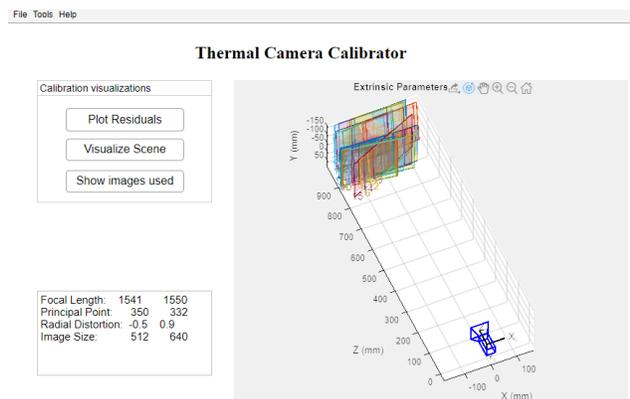
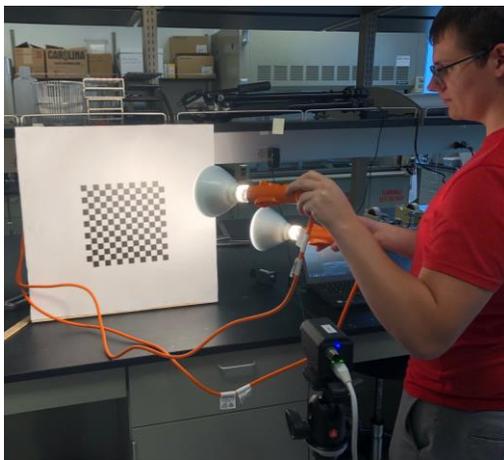
3.1 Overview

As noted in Chapter 1, the intrinsic camera calibration determines properties of the camera that allow conversion from a detected XY pixel in the camera's image to a vector originating at the camera and pointing in the direction of the object in the camera's frame of reference. This is an essential component of the overall 3-D calibration procedure. At a minimum, the intrinsic calibration needs to be done for each camera-lens combination. Therefore, one may be able to use the intrinsic calibration parameters that someone else generated using the same camera model and lens. However, it is recommended that these values be tested with the individual cameras and lenses by doing a 3-D calibration under controlled conditions. There may be some conditions where an intrinsic calibration is required for each individual camera. For example, when very high accuracy is required or with certain cameras whose production quality is relatively low.

The intrinsic calibration procedure consists of taking multiple images of a checkerboard pattern placed at a known reference distance from the camera. These images should be taken at slightly different 3-D orientations. One complication is that thermal cameras will not detect the visual contrast of a checkerboard pattern. Therefore, the pattern must be heated up for thermal contrast to be present. Here, we combine built-in Matlab calibration procedures with a previously-published thermal calibration procedure (Yahyanejad et al. 2011).

3.2 Setup

Figure 3. Demonstration of intrinsic calibration procedure (left image) and results (right image).



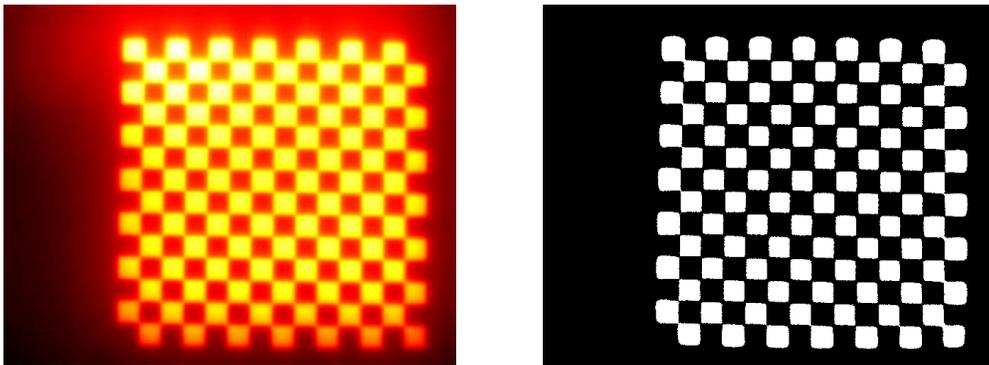
This procedure requires a printed checkerboard pattern, camera and recording equipment, a means of heating the checkerboard pattern such as two 120-Watt flood lights (white or red lights work equally well), and a meter stick or other device for measuring distances.

3.2.1 The checkerboard pattern

The first step is to determine the minimum distance at which the cameras will provide useable images. The minimum focal distance of the lens can be used as a guideline, but it is best to test this empirically. This can be done by pointing the camera at an object with heat contrast, such as an A/C adapter that is plugged into the wall. The camera should then be moved toward the object progressively until the minimum distance is found where the object still provides good contrast. The width and height of the total field of view at this distance should be measured and noted down.

Next, a checkerboard pattern of the appropriate size should be printed. The total size of the checkerboard pattern should be ~80% of the height of the field of view of the camera at the minimum focal distance found in the preceding step. This will allow the full checkerboard pattern to be visible in the field of view at different orientations, and it will be no larger than necessary. It is important to make the checkerboard pattern as small as is acceptable because this will facilitate heating the pattern in a uniform manner (see below). We recommend a 14 x 14 checkerboard pattern (7 black and 7 seven white squares along each axis) with a large white border. The pattern should be printed on poster paper and mounted on a rigid frame (We built a simple frame out of 2-inch x 2-inch boards; another option would be to cut out the center of a poster board). The poster can be held taut and then stapled to the wooden frame with a staple gun. This procedure ensures that the checkerboard portion of the poster is not in contact with any other objects. If the poster is mounted directly on another object, the poster will not heat up quickly enough and the images will not be useable.

Figure. 4 Example images of the heated checkerboard pattern (left) and the same image that has been processed with a local adaptive threshold (right).



3.2.2 Acquiring images

After printing and mounting the checkerboard properly, the camera should be setup so that images can be acquired of the heated checkerboard at a reference distances. For the Flir A65 cameras, we used reference distances of 0.9 m and 1.0 m with a checkerboard pattern that was a total size of 0.254 x 0.254 m (18.14 mm square sides). One should practice heating the checkerboard pattern with the lights to provide an image that is of relatively uniform illumination/heating. Figure 4 shows an example image that is of sufficient quality for use as a calibration image. We found an effective method of heating the pattern was to move two heat lamps across the image left to right then top to bottom with each pass taking about 2-3 seconds. The heat in the black squares will quickly begin dissipating into the white squares,

eliminating the required image contrast. Therefore, the video should be recording the entire time and images should be selected immediately after the pattern has been heated. We found that with good timing, the checkerboard pattern could be moved from left to right across the field of view of the camera such that the pattern could be recorded at different locations within the field of view. We recommend a total of 20-30 images be taken of the pattern at different locations, including some images where the pattern is perpendicular to the camera's field of view, and some images where the image is at an oblique angle up to about 30-45 degrees from perpendicular. After recording several videos of the heated checkerboard at different orientations, the user should find images of acceptable quality and use the camera's software or other video software to extract .jpeg images of the required 20-30 frames into a designated folder.

3.2.3. Processing the images in thruTracker

A utility within ThruTracker is provided for conducting the intrinsic calibration.

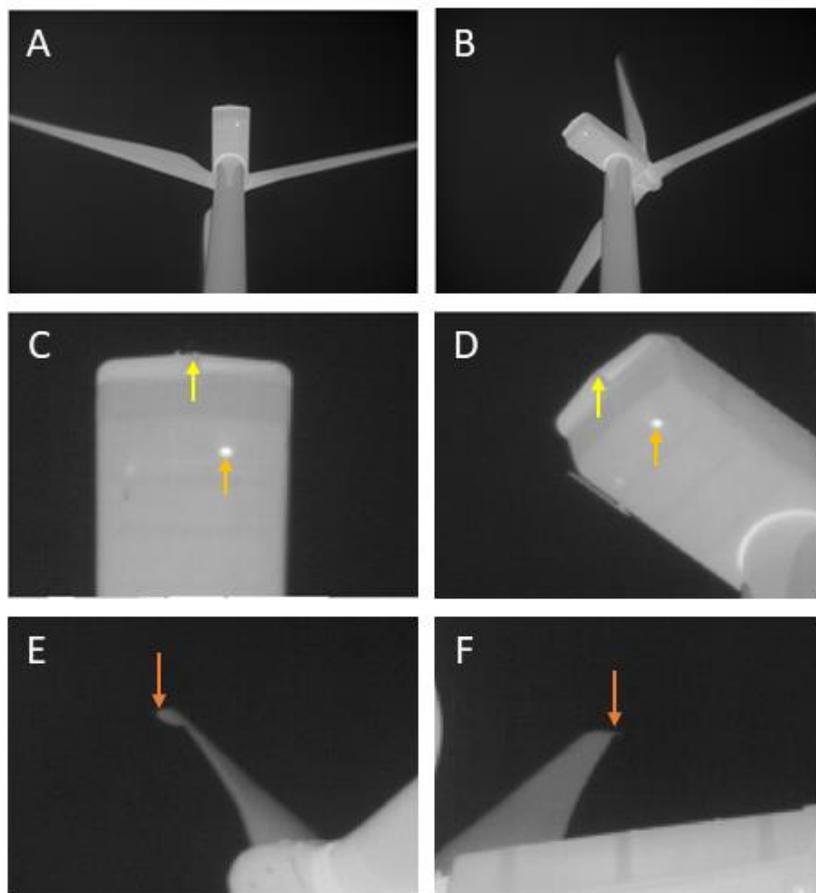
- Open ThruTracker
- Under the Tools Menu select "Intrinsic Calibration". This will open the user interface shown in Figure 3.
- Go to Menu->Tools->Convert Images
- Select the folder where you saved the images in the previous section.
- Converted black and white images (Figure 4) are saved in the subfolder "BW" in the folder where the original images were stored.
- Review converted images and ensure that at least 15-20 underwent a proper conversion. If not, acquire additional images using the procedure in section 3.2.2.
- Under the Menu go to Tools-> Calibrate.
- Enter the number of horizontal and vertical squares and the width/height of each square in millimeters into the dialogue box.
- Review the quality of the calibration by "Plot Residuals" Button (Residuals < 1 pixel indicate acceptable quality).
- Visualize the reconstructed scene by clicking the "Plot Extrinsic" button.
- Examine the scene and check that the re-constructed patterns are at the appropriate distance. If they are either closer or further than they should be, then the focal length will be off proportionally. You may need to add more images at oblique angles to correct for this problem.
- After an acceptable result is obtained, Go to File-> Export Camera Profiles to save the resulting camera parameters file. Note the location of this file for use in generating 3-D Calibration(Section 4.3).

4. Calibrating camera extrinsic parameters

4.1 Overview

The extrinsic calibration determines the camera positions in 3-D space and their orientations (roll, pitch and yaw). These values, when combined with the intrinsic calibration parameters generated in Chapter 3, allow for calculation of the direct linear transformation (DLT) coefficients. The DLT equation transforms sets of XY points that have been corrected for lens distortion into 3-D points. Because of the difficulty of putting objects into the field of view of our cameras, we use objects that occur naturally within the scene—including parts of the turbine and animals themselves—as calibration objects. Because the 3-D positions of these points are not known, a relatively large number of these points is required. We recommend at least 50-100 of these points, which are referred to as unpaired points. The points should be spread out to cover as much as possible of the 2-D coverage of each camera and the 3-D volume that is captured by the camera set. These points set the overall geometry of the scene. The

Figure 5. Example images from two synchronized thermal cameras recording at a wind turbine. A and B show the full field of view from the two cameras. C and D show cropped regions of A and B near the nacelle. Yellow and orange arrows indicate points that were used for the 3-D calibration. E and F show a cropped region around a turbine tip from another point in time.



scale of the scene is set by inputting the distance between the cameras, and the scene is oriented to gravity by inputting the inclination of the second (slave) camera relative to the horizon.

4.2 Digitizing background points in DLTdv

Synchronized video should be saved in a standard video format such as AVI or WMV. The videos should be opened in DLTdv8 (freely available for installation on mac, windows and linux machines from <http://biomech.web.unc.edu/dltdv/>). DLTdv software includes a digitizing platform as well as deep learning modules, which could be used for automatic tracking of turbine tips, hub and nacelle. More information is available at the link provided above.

In DLTdv8, manually digitize 50-100 points that capture as much as possible of the 2-D space of each camera field of view and the 3-D recording volume. Avoid digitizing the same point or closely spaced points multiple times, as this does not add new data to the calibration and can amplify digitization errors.

One should take great care in finding discrete points that are clearly visible in each camera. For example, Figure 5C and D show two points in each of two cameras. The orange arrows indicate a small “hot spot” on the turbine that makes an excellent digitization point. Yellow arrows indicate the pointed center of the back of the nacelle, which also makes a good point. One should avoid using points with curved 3-D edges where it is difficult to match locations between camera perspectives. Turbine tips should be used albeit with caution. Figure 5E and 5F show a turbine tip that was used for a 3-D calibration but note that it is difficult to determine the exact matching location of the turbine tip between frames. This is complicated by the curved tip of the turbine blade. One should take care to find images where the 3-D perspective facilitates matching specific points on the turbine and turbine blades. One can also digitize animals flying through the 3-D volume.

After digitizing the points in DLTdv8, click the “Export points” button to save the data for use in simpleWand.

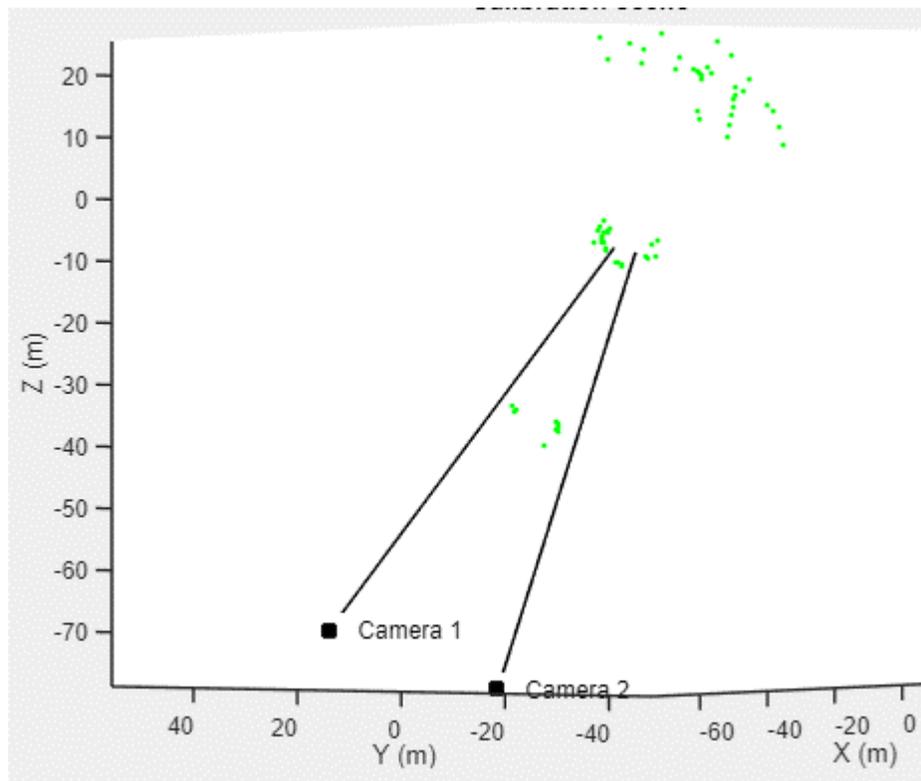
4.3 Making an extrinsic calibration in simpleWand

You are now ready to make a calibration!

- Open simpleWand within ThruTracker by going to the Menu Tools->Make 3D Calibration
- In simpleWand Menu click Project-> New Project
- Enter “2” for the number of cameras
- In the Menu go to Data-> Load Unpaired Points and select the file you exported from DLTdv8
- Click the “Unpaired Points” tab just below the menu bar and check that your points were loaded
- In the Menu go to Data-> Load a camera profile and choose the camera profile provided with the software or that you made using the Intrinsic Calibration procedure in section 3
- Go the “Alignment and Scale” Tab and enter the Slave camera’s inclination/elevation angle and the distance between the two cameras.
- Bo to Menu-> Compute Calibration.
- Review the Calibration scene and check that it appears to be scaled appropriately
- Check the DLT Camera residuals, which are shown just below the Calibration scene. Values < 1 are acceptable, although < 0.5 is preferred.

- Review the Unpaired Point Errors. You may want to remove points that are more than 2-3 times average error rates, but do not remove more than 10-20% of the total points.
- Go to Operations-> Compute Calibration to recompute the calibration.
- When finished save the project (Project-> Save this Project) and export the DLT Coefficients (Project-> Export DLT Coefficients).
- You're done!

Figure 6. Example of a successful calibration using simpeWand. Three clusters of points are visible that correspond to 1) the hub and nacelle (middle cluster), 2) tips of blades pointed away and 3) toward the two cameras (top and bottom clusters, respectively). Note that the hub and nacelle points are at the expected height of ~80 meters above the 2nd (reference) camera indicating proper scaling of the scene. Twelve of 67 points were removed as outliers because they had DLT residuals > 2 pixels. The Mean reprojection error of the remaining points was 0.38 pixels.



5. Processing video detections

ThruTracker has a range of options for automated detection, track-generation, and manual and automated classification 2-D tracks. To process a video go to File-> New 2D Detection. It will open the window shown in Figure 7.

Figure 7. Menu for 2-D tracking options

The screenshot shows a window titled "UI Figure" with a note: "Note: Hover mouse over entry boxes for more info". The window contains the following controls:

- Choose Video File** (button) and **Filename** (text input)
- Detection Options** section:
 - First frame:
 - Last frame:
 - Min object pixels:
 - Max object pixels:
 - Sensitivity:
 - Turbine detector:
 - Turbine buffer:
 - Header rows:
 - Processors:
 - Save filename:
 -
- 2D Tracking options** section:
 - Min Track Length:
 - Match Threshold:
 - Max gap Length:
- (large blue button at the bottom)

Detection Options

- First click the **“Choose Video File”** Button and select the video you’d like to process. This will automatically populate the “First Frame”, “Last Frame” and “Save filename” entry boxes.
- Choose the **range of frames** you’d like to process.
- **NOTE: VERY IMPORTANT—If processing a large file, do a test batch using a short range of frames and make sure it saves properly. ThruTracker won’t be able to save the data if you don’t have administrative privileges to the location where you are trying to save the data!**
- Select the **minimum and maximum acceptable object size in pixels**. The default values are designed for thermal cameras with resolutions of approximately 640x480 pixels.
- Choose the **Sensitivity**. Recommended value is “High” for most applications
- Choose the **Turbine Detector**. The Edge Detector works well for most situations. The Neural Network detector was designed for an application where the cameras were mounted at the base of the monopole. If you are having trouble with accurately detecting the turbine, you might consider building your own segmentation network to be used in ThruTracker.

- The **Turbine buffer** is the number of pixels around the detected turbine that will be considered part of the turbine. Increase this number if you are having problems with turbine smear. We have observed this as a bigger problem when the camera is placed directly below the turbine on the monopole.
- Choose the **header rows** for your video. Options are provided for Flir and Axis cameras, or none if no header rows are provided in the images.
- Choose the number of **processors**. Use 1 if you'd like to visualize the images as they are processed. Use a higher number for parallel processing to speed up the calculations. You can check how many processors are available using the "Check" button.
- Change the **Save filename and location** if desired.

2D Tracking Options

After detecting the objects in each frame, ThruTracker attempts to link detections across frames into tracks. Generally these options will involve a tradeoff between being more conservative in linking points, leading to shorter tracks, but fewer false positives, versus being more aggressive in linking points into tracks.

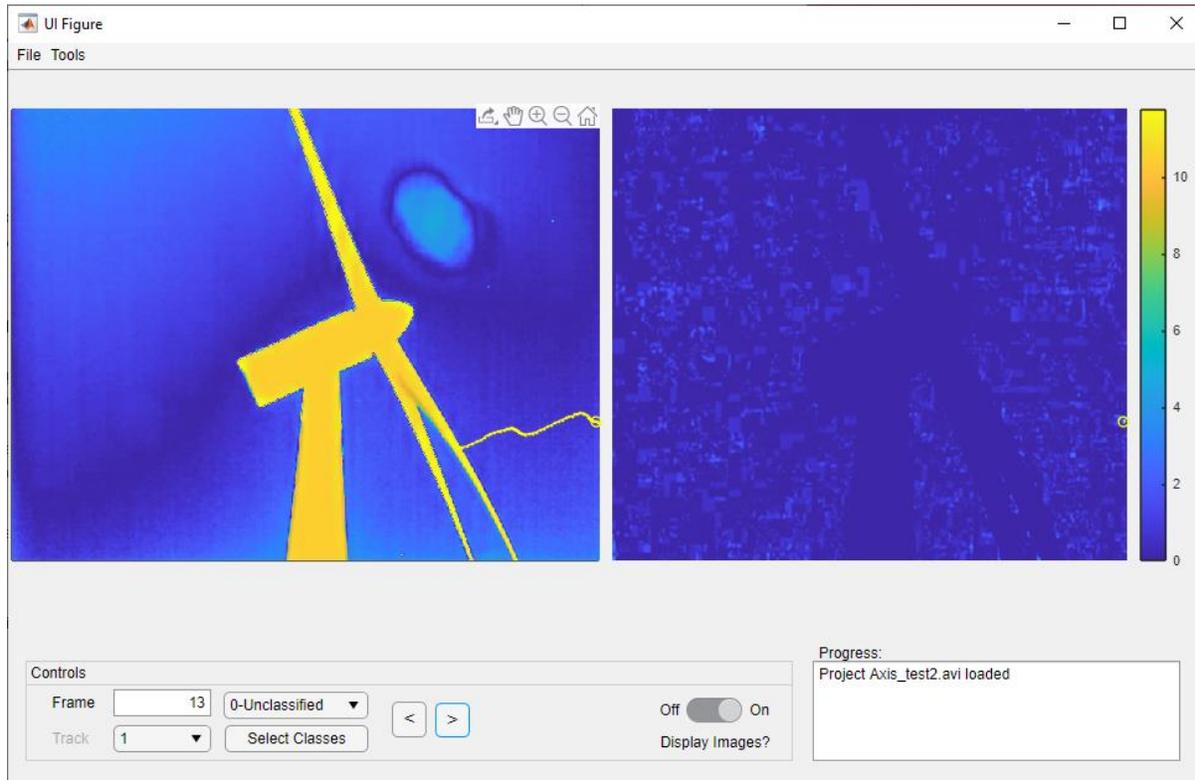
- **Minimum Track Length:** The minimum number of points that are required to be accepted as a track. Tracks with fewer points than this number will be discarded.
- **Maximum Gap Length:** Maximum number of frames after a detection that ThruTracker will keep looking for another point. Note that setting this number above the recommended value of 5 will increase the number of false detections considerably.
- **Match Threshold:** The number of pixels between the predicted location of the track in the frame and actual position of detections that will be allowed for the detection to be accepted as part of the track.

After setting your options, click on "**Run ThruTracker**". Updates will be provided in the console window if more than 1 processor was selected.

Reviewing and Classifying detections

After processing the detections, the data will automatically be saved in the specified file location. It will also be loaded into ThruTracker for visualization and review.

Figure 8. ThruTracker 2-D visualization



In the **Controls Panel** you can **enter what frame** to visualize, or **advance or go back a frame** using the “>” and “<” buttons. You can also use the left and right arrows on your keyboard to move between frames.

The left image shows a colorized version of the raw image. The right panel shows the background-subtracted and turbine-subtracted version of the image. **2-D detections are shown with circles**, and **tracks are shown as dotted lines**. The current track is shown in yellow. Other tracks that are present in the current frame are shown in white.

You can **scroll through tracks** either using **the Tracks dropdown**, or by using the **up and down arrows on your keyboard**.

You can **Classify tracks** using the **Classification dropdown**, or by using the **number keys on your keyboard**. You can select which tracks are available in the dropdown menu by clicking the “Select Classes” button.

There is also the option **automatically classify tracks** by going to Tools-> Classify 2D tracks. This is currently largely a demonstration of the auto-classification feature. More capabilities will be added as additional analyses are conducted.

6. Generating 3-D tracks

To generate 3-D tracks, you will first need to have made a 3-D calibration for your scene (Chapter 4) and made 2-D detections for both of your video files (Chapter 5). When you are ready to make your 3-D tracks go to the menu File-> Make 3-D Tracks. This will open the dialogue box shown in figure 9.

Figure 9. Dialogue box showing options for generating 3-D tracks

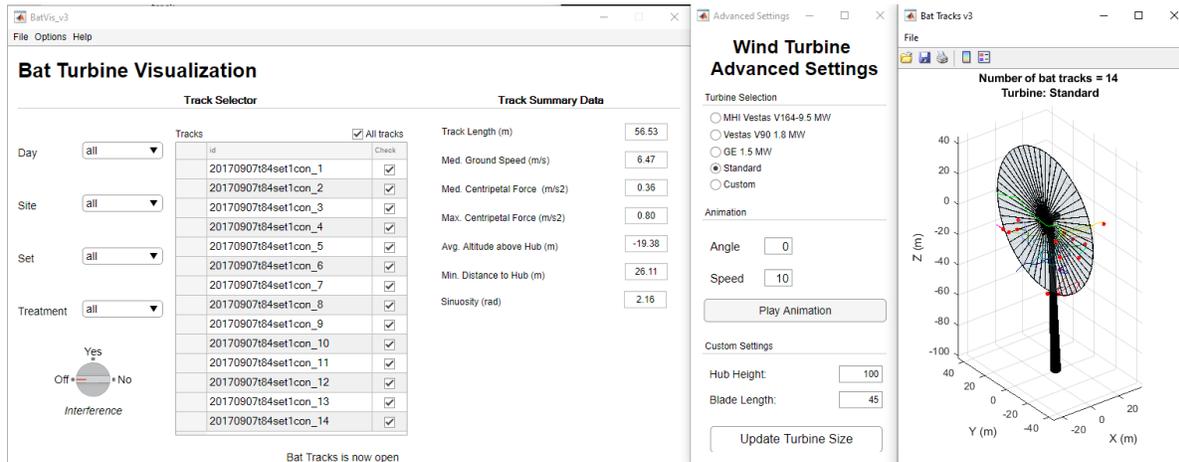
Steps for making 3-D Tracks

- Click the “Select Files” Button
- Choose the **detections file** for your master camera then your slave camera
- Choose the **simpleWand calibration file**
- Choose the filename and directory if different from the default
- **3-D tracking options:**
- Choose the frames you’d like to process if different from the range that is auto-populated
- **Minimum Track Length:** Minimum number of frames required for a track to be accepted
- **Maximum Gap Length:** Number of frames to keep searching for a detection after the end of a track
- **DLT Threshold:** Maximum DLT residual error accepted for two detections to be made into a 3-D point
- **Match Threshold:** Maximum value of combined XY and XYZ errors for a point to be accepted as part of a track. The “Match” value equals the average XY error in pixels for each camera divided by the **XY divisor** plus the XYZ error in meters divided by the **XYZ divisor**.
- Click the “Make 3D Tracks!” button
- A visualization of the 3-D tracks will be shown and the data will automatically be saved in the location specified

7. Data visualization

ThruTracker includes a built-in data visualization tool called BatVis3. To open the visualization tool go to the menu Tools-> Visualize 3-D tracks. This will open the BatVis display shown in Figure 10.

Figure 10. BatVis3 track visualization software



- Load data using the menu File-> Load Data
- Choose the folder containing the XYZ track data and the digitized hub-nacelle points for each track.
- XYZ track data should first be exported from the 3D track file using the File-> Export Data menu in ThruTracker
- Hub-Nacelle points should be digitized in DLTdv8. Each 3-D track should have a corresponding track in DLTdv8. The hub should be digitized using the first frame of each track and the nacelle should be digitized using the second frame for each corresponding track. Note: This workflow will be updated in future versions to thruTracker to speed up the workflow.
- The 3-D track data should be saved using the following format: “bat_date_site_set_treatment_xyzpts.csv”.
- The digitized turbine data should be saved using the same format except the file should start with “turbine” instead of “bat”.
- After loading the data, the display shown in Figure 10 will be loaded with all of the tracks. The “Bat Turbine Visualization” window allows you to select which tracks are displayed by choosing the Day, Site Set and Treatment
- You can also choose to display only those tracks that fly through the rotor-swept zone (interference=“Yes”), or not (Interference= “No”) or all tracks (Interference “Off”).
- Track Summary Data shows averaged track parameters for all tracks that are selected

Advanced Settings

The Wind Turbine Advanced Settings window allows you to:

- Change the size of the turbine by selecting the turbine model or entering custom dimensions
- Play an animation of the 3-D tracks and animation with options for adjusting the speed of playback and the view angle.
- A view angle of 0 indicates profile view; 45 a 3-D view from partially overhead, and 90 a complete overhead view.

Turbine Visualization

The wind turbine visualization shows the bat flight tracks with respect to the turbine itself (Right panel in Figure 10). The default cursor shows a cross hairs that allows you to select a track. Selecting a track will show track parameters for that individual track. You can also rotate, pan and zoom in and out using the menus at the top of the turbine visualization. Deselect these options to return to the cross hairs for selecting individual tracks.

8. Additional Information and Contact

ThruTracker was developed by Dr. Aaron Corcoran (UC Colorado Springs) and Dr. Tyson Hedrick (University of North Carolina) in collaboration with Bat Conservation International and with funding by the Department of Energy and support from the National Renewable Energy Laboratory.

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Updates to this software will be available at the following sites:

www.sonarjamming.com/thrutracker

www.batcon.org

Questions and comments should be sent to Dr. Aaron Corcoran (acorcora@uccs.edu)

ThruTracker is provided free of charge. Underlying Matlab code will be made publicly available after publication of the software in the peer-reviewed literature. This software comes with no warranty is meant for use by individuals. It includes components that are published with licenses that prevent its use into additional products that are commercialized.