User_Manual

Getting Started

Welcome to the FastTrack user manual. This manual will present the tracking software and how to use it. Please contact by email at **benjamin.gallois@fasttrack.sh** if you need more information or to signal a bug. Subscribe to the mailinglist to get the FastTrack dev team's last updates.

FastTrack is a cross-platform application designed to track multiple objects in video recording. Stable versions of the software are available for Linux, Mac, and Windows. The source code can be downloaded at https://github.com/FastTrackOrg/FastTrack.

Two main features are implemented in the software:

- An automatic tracking algorithm that can detect and track objects, conserving the objects' identities across the video recording.
- An ergonomic tool allowing the user to check, correct and annotate the tracking.

The FastTrack user interface is implemented with Qt, the image analysis with the OpenCV library. This allows a performant and responsive software amenable

to process large video recording.

FastTrack was first a Ph.D. thesis side project started by Benjamin Gallois in his spare time that has then taken dedicated time in his Ph.D. project. The software's core is still maintained in his spare time; therefore, new features implementation, bug fixes, and help can take some time.

Not sure if you want to use FastTrack? Check these five most common questions:

What video quality is required? FastTrack is designed to work with any video quality and frame rate.

What type of objects and numbers can FastTrack handled?

How it performs? Tracking performances depend on systems (number and type of objects). However, with the built-in ergonomic tool, it is possible to achieve 100% tracking accuracy with minimal effort.

It is free? FastTrack is a free software under the GPL3 license.

Do I need programming skills? No.

Installation

Download

Stable versions of FastTrack are released for Linux, Mac (as dmg), and Windows (installer). The nightly version is available on the Github Actions artifacts.

Installation

1. For Windows:
   - Download the FastTrack installer.
   - Execute the installer and follow the provided instructions.
2. For Linux (all distributions) as AppImage:
   - Download the AppImage file.
   - Allow FastTrack.AppImage to be executed:
     - Right click on the AppImage file.
     - Click on Properties.
     - Click on Permissions.
     - Tick "Allow executing file as program".
   - Check the AppImage Launcher to integrate AppImage into the system.
3. For Linux natively:
   - Fedora: `sudo dnf install fasttrack fasttrack-cli`
   - Arch Linux: `yay -S fasttrack fasttrack-cli`
   - From source : `qmake src/FastTrack.pro ; make ; sudo make install ; qmake src/FastTrack-Cli.pro ; make ; sudo make install`

4. For Mac:
    - Minimal version required: 10.15.
    - Download the FastTrack dmg file.
    - Double click on the dmg file.
    - Drag the application from the dmg window into the Applications folder.

Update

FastTrack will display a message at the start-up when a new release is available.

1. For Windows:
   Search the *FastTrackUpdater* in the *Windows Start Menu* or execute the *MaintenanceTool.exe* in the installation folder directly and follow the provided instructions.
2. For Linux:
   The FastTrack AppImage does not currently support the automatic update. Replace the current AppImage with the latest AppImage released.
3. For Mac:
   The FastTrack App does not currently support the automatic update. Replace the current App with the latest App released.

A step by step example

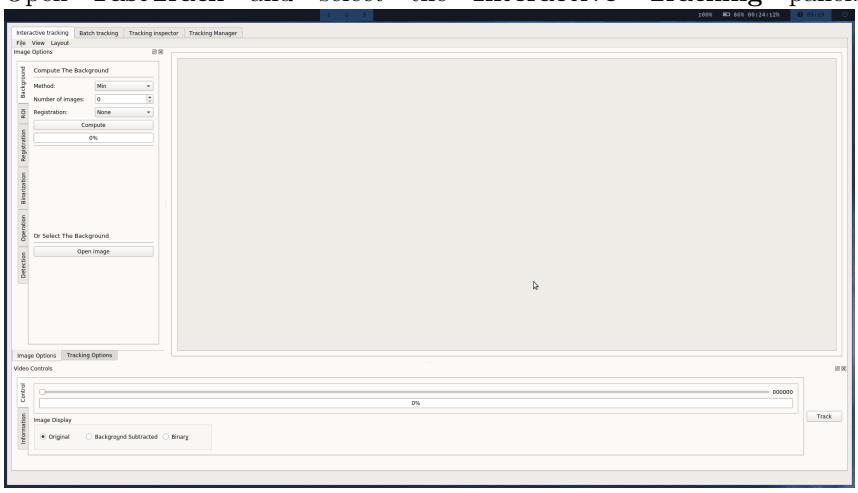
This section details step by step the process to test FastTrack using data from the Two-Dimensional Tracking Dataset. Illustrations originate from v4.x.y and can differ from the current stable version.

Downloading

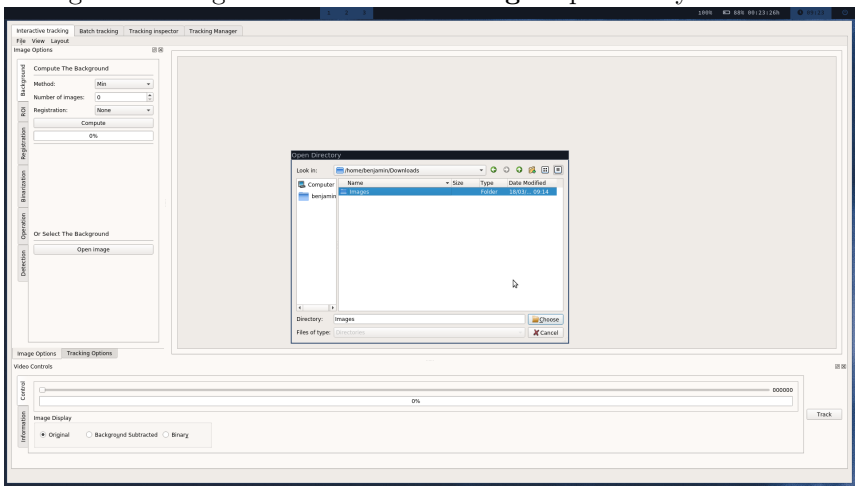
In this example, we will use the challenging movie ZFJ_001. This movie features 14 very active juvenile zebrafish. The principal difficulty of this movie is the frequent and complex occlusions. First, download the zip file and extract it. The image sequence is located inside the **images** folder.

Tracking

1. Open **FastTrack** and select the **Interactive Tracking** panel.



2. Import the movie by clicking on **File** then **Open** and by selecting one image in the folder **images** previously downloaded.



3. Compute the background by clicking on the **Background** tab and selecting these parameters:

- Method: **Max** (project the maximal intensity)
- Number of images: **199** (all the images)
- Registration: **None** (No registration is needed)
- And click the **Compute** button.

4. Click the **Binarization** panel and select these parameters:

- Type: **Light Background** (dark objects on light background)
- Value: **49**

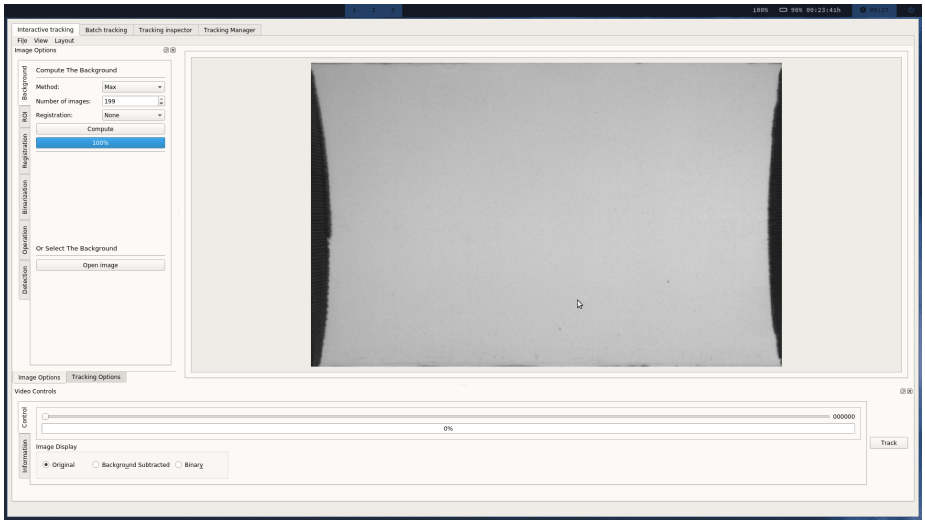


Figure 1: alt text

Figure 2: alt text

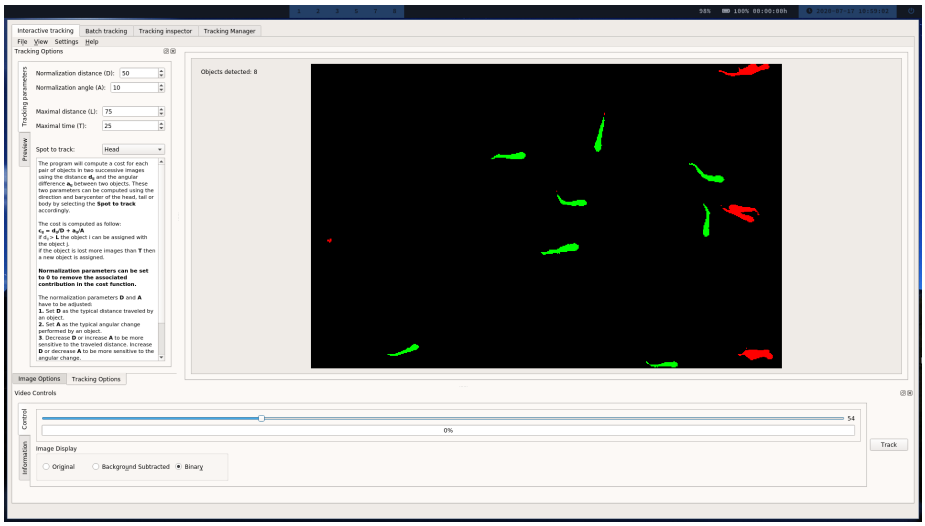
5. Click on the **Detection** panel and select:

- Maximal size: **190** (overlapping objects are rejected in most cases)
- Minimal size: **50** (noise is rejected)

Figure 3: alt text

6. Click the **Tracking Options** tab and select:

- Normalization Distance: **50**
- Normalization Angle: **10**
- Maximal Distance: **75**
- Maximal Time: **25**
- Spot to track: **Head** (best for deformable asymetric objects)



Note: these parameters were found by trials and errors.

7. Click on the **Track** button to start the tracking

Reviewing

When the tracking is completed, FastTrack automatically opens the **Tracking Inspector** which allows the user to review and correct the tracking.

With the previous tracking analysis, only seven corrections and six deletions are necessary to achieve a perfect tracking accuracy.

image	id	delete	swap with
17-20	1-0	x	
17-20	0	x	
22	0		1
23	1		4
27-28	1	x	
63	1		8
97	6		12
50-57	1	x	
109-121	0	x	
114	9		13
116-118	0	x	
122	0		13
124	4		12

Import Data

Image sequence

FastTrack is able to open image sequences if they follow the leading 0 naming convention (name000.xyz, name001.xyz, name002.xyz, etc...). *.bmp,* .dib, *.jpeg,* .jpg, *.jpe,* .jp2, *.png,* .pbm, *.pgm,* .ppm, *.sr,* .ras, *.tiff,* .tif formats are supported. To open an image sequence, select the first image of the sequence.

Video

FastTrack is able to open video files, and a lot of codecs are supported.

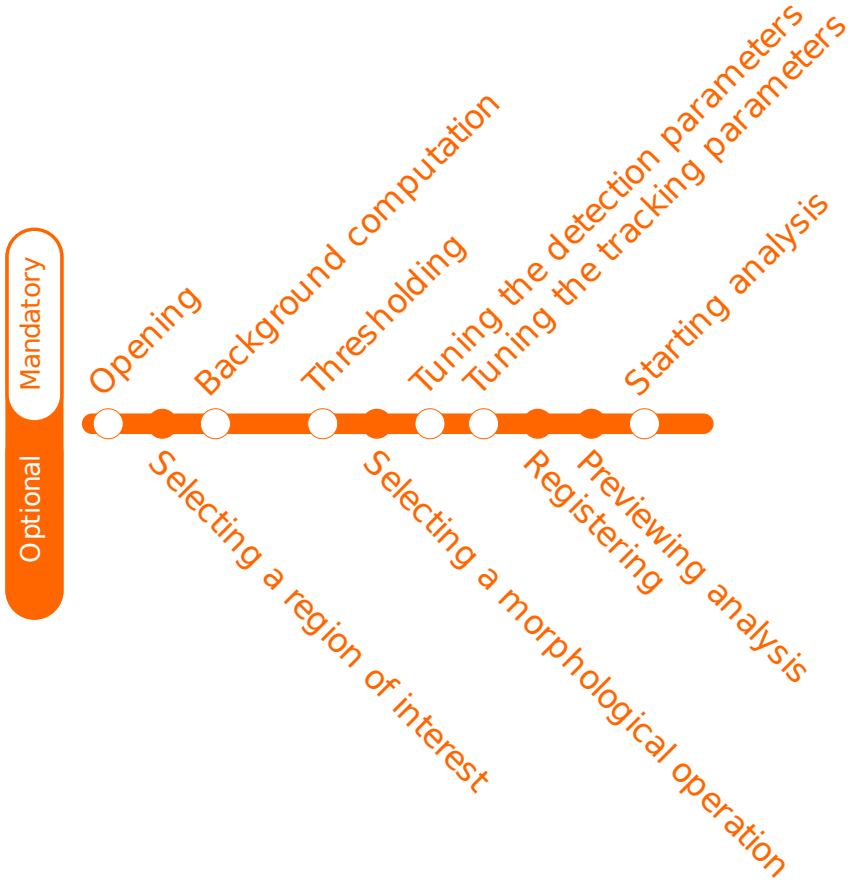
Timeline

To navigate inside a video rapidly, FastTrack provides a tool called the timeline. Hover the mouse cursor above the timeline to move across the video. Right-click to place the cursor at a given position. This will save this position when the cursor exit the timeline. Double left-click to place a marker, right-click on this marker to delete it. Keyboard shortcuts are available to move the cursor frame by frame:

- D: move to the next frame.
- Q: move to the previous frame (AZERTY layout).
- A: move to the previous frame (QWERTY layout).
- Space: start/stop autoplay.

Interactive Tracking

The Interactive panel provides a means to perform a tracking analysis and review it in an interactive environment. Several steps have to be performed in the right order (some are mandatory, some are optional) to perform a successful tracking anal-



ysis.

Open a file

The first step of a tracking analysis is to open a video file. FastTrack supports video files and image sequences. Click on the file or on an image of a sequence to

automatically load the movie. 

Compute the background

The background can be computed or imported. To compute the background, select a method and a number of images. Images are selected in the image sequence at regular intervals, and three methods of computation by z-projection are available:

- Min: each pixel of the background image is the pixel with the minimal value across the selected images from the image sequence. Useful when the objects are light on a dark background.
- Max: each pixel of the background image is the pixel with the maximal value across the image sequence's selected images. Useful when the objects are dark on a light background.
- Average: each pixel of the background image is the average of the pixels across the image sequence's selected images.

The images can be registered before the z-projection. Three methods of registra-

tion are available.

Select a region of interest (optional)

To select a region of interest, draw on the display a rectangle with the mouse and click on the Crop button. Cancel the crop by clicking on the reset button.

Compute the binary image

To compute the binary image from the background image and the image sequence, select the threshold value, and see the result on the display. The background type is automatically selected after the background computation. However, it can be modified: select Dark Background if the objects are light on a dark background, and Light background if the objects are dark on a light background.

Apply morphological operations (optional)

It is possible to apply a morphological operation on the binary image. Select a morphological operation, kernel size, and geometry. See the result on the display. For more information about the different operations, see https://docs.opencv.org/trunk/d9/d61/tutorial_py_morphological_ops.html.

Tune the detection parameters

Objects are detected by their size. Select the maximum and minimum size of the detected objects. The detected objects will be colored in green in the display, and the rejected object will be displayed in red.

Tune the tracking parameters

Several parameters can be modified to ensure a good tracking analysis. See this page for more details:

Hard parameters

Hard parameters have to be set manually by the user:

- Maximal distance: if an object traveled more than this distance between two consecutive images, it would be considered as a new object.
- Maximal time: number of images an object is allowed to disappear. If an object reappears after this time, it will be considered as a new object. If the number of objects is constant throughout the movie, set the Maximal Time equal to the movie's number of frames.
- Spot to track: part of the object features used to do the tracking. Select the part that reflects the better the direction of the object. Legacy parameter, head corresponds to the smaller mid-part of the object, tail ellipse the wider mid-part of the object, and body is the full object.

Soft parameters

The soft parameters can be leveled automatically by clicking on the Level button. This will automatically compute the soft parameters as each contribution weighs one quarter of the total cost. It has to be manually tuned by the user to find the optimal soft parameters with the system's knowledge. For example, for a system where the objects' direction is not relevant, the user will select the Normalization angle equal to 0.

- Normalization distance (legacy Maximal length/ Typical length): typical distance traveled between two consecutive images.
- Normalization angle (legacy Maximal angle/Typical angle): typical reorientation possible between two consecutive images.
- Normalization area: typical difference in the area.
- Normalization perimeter: typical difference in the perimeter.

Registration

The image registration is the process to correct small displacements and rotation of the camera during the movie recording. FastTrack provides several methods for registering the movie:

- By phase correlation
- ECC image alignment
- Features based

Image registration is very computationally intensive and can drastically decrease the speed of the program.

Preview the tracking

The tracking can be previewed on a sub-sequence of images. It can be useful to tune parameters if the tracking is slow.

Display options

Several display options are available and unlocked at each step of the analysis.

- Original: original image sequence
- Background subtracted: image sequence minus the background image.
- Binary: binary image sequence with detection overlays.
- Tracking: tracking data overlay.

Layout options

Several layouts and themes are available in the layout menu in the top bar. The user can also build his layout by dragging the option docks in the window.

See a video demonstration

Batch Tracking

- 1: Open folder
- 2: Unique background
- 3: Suffix selection
- 4: Processing stack
- 5: Background selection

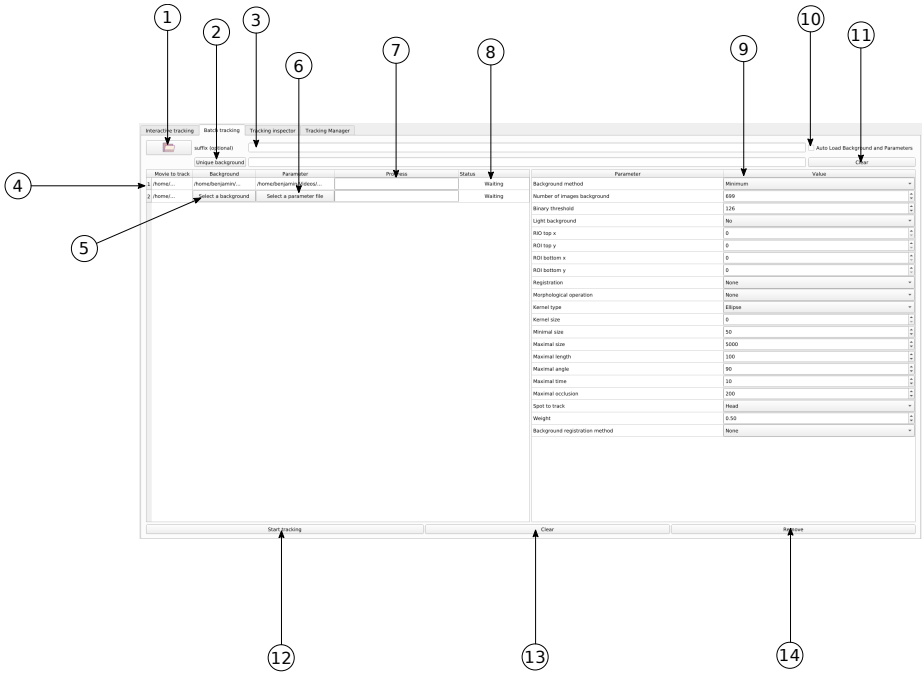


Figure 4: alt text

- 6: Parameter selection
- 7: Progress bar
- 8: Status
- 9: Parameters table
- 10: Autoload
- 11: Clear background
- 12: Start tracking
- 13: Clear stack
- 14: Remove from stack

The Batch Tracking panel is an advanced tool to track a large number of movies automatically. Several behaviors can be combined to load image sequences in a batch with specific background images or parameter files.

Basic usage

The user can open several image sequences by clicking on the **Open folder** (1) button and select one or several folders. FastTrack can automatically load a background and/or a parameters file if a **Tracking_Result** folder is provided with the image sequence; check the **Autoload** (10) tick to activate this behavior. After opening, image sequences are added to the **Processing stack** (4). If a background image and/or a set of parameters are automatically loaded, the path will be displayed in the second and third columns. If not, the user can select them with the (5) and (6) buttons after importation. **By default**, if no background image and parameter file are selected, FastTrack will use the parameters provided in the Parameters table (9) **before** the image sequence importation. The user can delete an image sequence by selecting the corresponding line in the **Processing stack** (4) and click on the **Remove** (14) button. The user can clear all the **Processing stack** (14) by clicking the **Clear** (13) button. To process the stack, click the **Start Tracking** (12) button.

More advanced options

Add a suffix

The user can append a suffix to the imported folders *folder_path/ + suffix/* For example, it can be usefull with a folder tree like this one:

- /myExperiment/Run1/images
- /myExperiment/Run2/images
- /myExperiment/Run3/images

The user can easily select in one time the folders:

- /myExperiment/Run1
- /myExperiment/Run2
- /myExperiment/Run3

And then add the suffix *images/* to select the desired folders without having to do it manually three times.

Unique background image

The user can select a unique background image. Open an image with the **Unique background** (2) button, and **all the sequences in the stack** and sequences that will be imported will be using this background image. The user can use the **Clear** (12) to reset the default behavior.

One parameter file

To apply the same parameters file to all the imported sequences:

Manual selection:

- Untick the **Autoload** (10).
- Select a set of parameters in the **Parameters table** (9).
- The sequences that will be imported will use this set of parameters.

With a file:

- Tick the **Autoload** (10)
- Load the sequence with the right parameters file.
- Untick the **Autoload** (10).
- The sequences that will be imported will use this set of parameters.

With a file:

- Untick the **Autoload** (10).
- Load a sequence.
- Select the parameter file with the (6) button.
- The sequences that will be imported will use this set of parameters.

Behavior reminder

- 10. unticked, (2) not selected: FastTrack will use the parameters provided in the Parameters table (9) **before** the image sequence is added to the stack. It can be overwritten after importation with the (5) and (6) buttons.
- 10. ticked, (2) not selected: FastTrack will use the background and the parameters file in the Tracking_Result folder. If these files are missing, FastTrack will use the parameters provided in the Parameters table (9) **before** the image sequence is added to the stack.
- 10. ticked, (2) selected: the background selected in (2) will overwrite the automatically detected background.
- 3. selected: the image sequence path will be appended with the suffix, and default behavior will be applied with this path.

- 2. selected: select a unique background will overwrite all the existing background in the stack.

Tracking Inspector

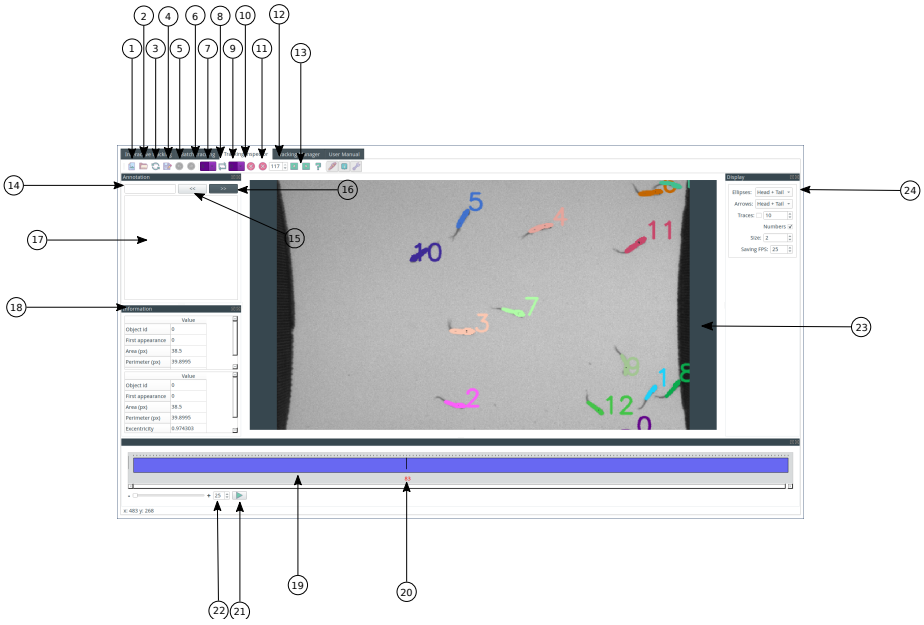


Figure 5: alt text

- 1: Open
- 2: Open Tracking_Result directory
- 3: Reload
- 4: Export video
- 5: Undo
- 6: Redo
- 8: First object selection box
- 9: Swap
- 9: Second object selection box
- 10: Delete one
- 11: Delete
- 12: Delete selection box
- 13: Previous/Next occlusion (experimental)
- 14: Annotation search
- 15: Annotation previous match
- 16: Annotation next match
- 17: Annotation entry
- 18: Objects information table

- 19: Timeline
- 20: Image number
- 21: Play
- 22: FPS selection box
- 23: Display
- 24: Overlay

The Tracking Inspector is a tool to display the result of a tracking analysis and to correct the tracking manually if necessary. For example, the user can delete an object to remove an artifact or change the object ID to correct a tracking error. To make the user's life easier, an ergonomic interface with build-in keyboard shortcuts are provided. FastTrack alleviates the tedious work of review and correction, and the user can achieve 100% tracking accuracy rapidly and efficiently.

Load a tracking analysis

To load a tracking analysis previously tracked in FastTrack, first click on the **Open** button (1) and select a movie or an image of an image sequence. If the movie was tracked several times, the last tracking analysis is stored in the **Tracking_Result** folder and the previous tracking analysis in the **Tracking_Result_Date** folders and can be loaded using the **Open Tracking_result directory** button (2) (can only be activated if a movie is loaded). Click on the **Reload)** button (3) to reload the tracking data if necessary. The software can only load a tracking analysis if the folder architecture is preserved, .ie the folder with the image sequence has to have a sub-folder named **Tracking_Result** containing at least the *tracking.txt* file.

Display options

Several tracking overlay options are available on the tracking overlay panel (24):

- Ellipse: display the head, tail, and or body ellipses on the tracked objects.
- Arrows: display an arrow on the head, tail, and or body of the tracked object indicating the orientation.
- Numbers: display the ids of the tracked objects.
- Traces: display the previous 50 positions of the tracked objects.
- Size: the size of the tracking overlay.
- Frame rate: display and saving frame rate.

Several useful information on the selected object can be found in the information table (18). The user can go to the image where the object has appeared for the first time by clicking directly on the table's corresponding cell.

Inspect the tracking

The tracking can be inspected by moving the display cursor (19), see the image number (20), and automatically play the movie (21) at a selected frame rate

(22). Automatically detected occlusions (overlapped objects) can be reviewed by clicking on the **Previous** (12) and **Next** (13) occlusion buttons (this function is experimental and can miss some occlusions).

Annotate the tracking

The user can annotate any image of the tracking. Write the annotation in the annotate text entry (17). The user can search across annotations with the find bar (14) and the buttons (15)(16). All the annotations are saved in the *annotation.txt* file in the **Tracking_Result** folder.

Correct the tracking

Swap the data of two objects

The user can correct an error by swapping two object's ID from the current image to the end of the sequence as follow:

- Left-click on the first object, the object ID and color are displayed on the first selection box (6).
- Left-click on the second object, the object ID and color are displayed on the second selection box (8)
- Right-click or click on the **Swap Button** (7) to exchange the ID of the two selected objects from the current image to the last image of the sequence.

Delete the data of an object

To delete one object of several frames:

- Double left click on the object, the object ID and color are displayed on the second selection box (8).
- Select the number of frames on which to delete the object in the box (11). Shortcut C is available to focus on the selection box.
- Click on the **Delete** button (10) to delete the object from the current frame to the current frame plus the selected number.

To delete one object on the current frame:

- Double left-click on the object, the object ID and color are displayed on the second selection box (8).
- Click on the **Delete One** button (9) to delete the object on the current frame.

Keyboard shortcuts summary

A set of keyboard shortcuts are available to speed-up the tracking correction.

- Q/A: go to the previous image.
- D: go to the next image.

- F: delete the selected object on the current image.
- C: enter the number of images where an object has to be deleted.
- G: delete an object from the current image to the current plus the selected number.

Saving

All the changes made in the inspector are automatically saved in the original *tracking.txt* file.

Export a movie

To export a movie of a tracking analysis, select the desired display overlay and click on the **Save** button (3). Select a folder and a name to save the file. Only .avi format is supported.

Note: Movie with many objects by frame can be challenging to load and review in the tracking Inspector.

See a video demonstration

FastTrack Command line interface

Installing fasttrack-cli

A command-line interface is available for macOS, Linux, and by using WSL for Windows. It can be downloaded on the release page.

The full list of parameters can be found by calling `./fasttrack-cli --help`. Parameters can be declared individually by calling `./fasttrack-cli --path path/to/movie.webm --parameter1 value --parameter2 value` or in batch with a parameters file `./fasttrack-cli --path path/to/movie.webm --cfg path/cfg.toml`. Note that the path option need to be the first option.

fasttrack-cli does not support Windows natively. The workaround is to use WSL. * Install WSL https://docs.microsoft.com/en-us/windows/wsl/install-win10. * Install FastTrack in a Linux terminal:

```
wget https://github.com/FastTrackOrg/FastTrack/releases/download/continuous_cli/fasttrack-cl
chmod +x fasttrack-cli-x86_64.AppImage
./fasttrack-cli-x86_64.AppImage --appimage-extract
sudo ln -s ~/squashfs-root/usr/bin/fasttrack-cli /usr/local/bin/
```

- FastTrack-cli can now be called directly by typing fasttrack-cli –help

Calling FastTrack from a Python script

FastTrack can be called inside a Python script to automate the tracking.

```
import os

cmd = "./fasttrack-cli --maxArea 500 --minArea 50 --lightBack 0 --thresh 80 --reg 0 --spot 0
os.system(cmd)
```

```
import os

cmd = "./fasttrack-cli --path ZFJ_001.avi --cfg Tracking_Result_ZFJ_001/cfg.toml"
os.system(cmd)
```

Tracking parameters

This section details how to select the relevant tracking features to be included in the cost function and how to tune them.

How it works

FastTrack uses the so-called Hungarian method to solve the assignment problem of each object between two frames. This method is based on minimizing the global cost of the association pairs of objects.

Cost function

The cost is calculated from a cost function that can be constructed from several parameters, in the following, i is indexing the image n, and j the image n + 1: * The distance \(d{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}\) * The angle \(a_{ij} = min(\theta_i - \theta_j)\) * The area \(ar_{ij} = abs(area_i - area_j)\) * The perimeter \(p_{ij} = abs(perimeter_i - perimeter_j)\)

The relative weight of these contributions to the cost function are set by 4 normalization parameters: \[c_{ij} = \frac{d{ij}}{D} + \frac{a{ij}}{A}+ \frac{ar{ij}}{AR} + \frac{p{ij}}{P}\] These parameters can be set to 0 to cancel one or several tracking feature from the cost computation. All these features are not always relevant and has to be chosen carrefully for the best tracking accuracy. For example, for tracking circles of radius r, and squares of the same area moving at 10px/image, it is best to set \[(D=10, A=0, AR=0, P=2r(\pi-2\sqrt{\pi}))\]. For tracking fish of the same size, travelling at 35px/image, doing small reorientation of 20°, it is best to set \[(D=35, A=20, AR=0, P=0))\]. For tracking fish of different size, travelling at 35px/image, doing small reorientation of 20°, with size difference of 100px it is best to set \[(D=35, A=20, AR=100, P=0))\].

The best way to set the parameter is to first set the normalization parameters to the mean of the variable, .ie the typical change between two consecutive images: * \(D = mean(d_{ij})\) where i and j are the same object. * \(A = mean(a_{ij})\) where i and j are the same object. * \(AR = mean(ar_{ij})\) where i and j are the same object. * \(P = mean(p_{ij})\) where i and j are

the same object. In this case, each tracking feature has the same contribution to the cost. To tune the cost function by weighting more (resp. less) a tracking feature, decrease (resp. increase) the normalization parameter of this feature, or increase (resp. decrease) all the normalization parameters of the others.

Memory and distance

A parameter of memory named maximal time can be set to account for disappearing objects. If the maximal time is set to m, one object can only disappear during m image. If it reappears after, it will be considered as a new object.

To speed-up the tracking, the maximal distance (L) parameter sets an infinite cost for all the pairs of objects to such as \(d_{ij} > L\). In practice, L is corresponding to the maximal distance an object can disappear.

Spot

The spot to track will determine if the distance and the angular difference will be calculated from the head, the tail, or the body of the object. Area and perimeter are always computed from the body. Head is defined as the bigger half of the object, separated alongside the object's minor axis.

Conclusion

Setting the tracking parameters can be tedious. It can be best achieved by trials and errors (see the Preview option in the Interactive panel). to summarize: 1. Choose the right tracking features. 2. Set the normalization parameters equal to the tracking feature's std, ie, the typical value change. 3. Tune the normalization parameters to increase or decrease the relative weight between each contribution.

Tips and Tricks to set parameters

Setting the parameters

They are several tricks that can be used to increase tracking accuracy and select the optimal parameters.

Detection

The detection parameters reject objects that are smaller or bigger than a specific size. To increase the tracking accuracy, we want to reject noise and artifacts and reject blobs constitute of more of one object. If all the objects are of similar size, these two parameters can be selected easily in four steps:

- Select an image where two objects are in contact forming a single blob.
- Select the **Maximal Size** parameter just at the limit to reject this blob.

- Select the **Maximal Size** parameter just at the limit to detect the movie's smaller object.
- Fine tune these parameters to account for size variability across the movie.

Tracking

Tracking parameters are mostly found by trials and errors. However, some rules of thumbs can be applied.

Spot to track has to be set to **Body** for quasi-symmetric objects and low-resolution objects. For deformable objects with enough resolution, select **Head** or **Tail** according to the part that predicts best the object's traveling direction.

Parameters file

For each tracking analysis, FastTrack will save the parameters used in `cfg.toml` that can be reloaded in the software or in fasttrack_cli. Before FastTrack version 5.2.1, the software used to saved the parameters in `parameter.param`, these files can be converted as following (left: old file, right: new file):

```
                                    title = "FastTrack cfg""

                                    [parameters]
Light background = 0                lightBack = 0
Maximal size = 170                  maxArea = 170
Maximal occlusion = 200             maxDist = 200
Maximal time = 100                  maxTime = 100
Background method = 1               methBack = 1
Minimal size = 50                   minArea = 50
Morphological operation = 8         morph = 8
Kernel type = 2                     morphSize = 2
Kernel size = 0                     morphType = 0
Number of images background = 20    nBack = 20
Maximal angle = 90                  normAngle = 90
Binary threshold = 60               normArea = 0
Normalization area = 0              normDist = 100
Maximal length = 100                normPerim = 0
Normalization perimeter = 0         reg = 0
Registration = 0                    regBack = 0
Background registration method = 0  spot = 0
Spot to track = 0                   thresh = 60
ROI bottom x = 0                    xBottom = 0
ROI top x = 0                       xTop = 0
ROI bottom y = 0                    yBottom = 0
ROI top y = 0                       yTop = 0
```

Tracking Result

After a tracking analysis (or an analysis preview), FastTrack saves several files inside the **Tracking_Result** folder located inside the image sequence folder or inside the **Tracking_Result_VideoFileName** for a video file:

- *tracking.txt*: the tracking result
- *annotation.txt*: the annotation
- *background.pgm*: the background image
- *cfg.toml*: the parameters used for the tracking

The tracking result file is simply a text file with 20 columns separated by a ' character. This file can easily be loaded to subsequent analysis see this Python and this Julia.

- **xHead, yHead, tHead**: the position (x, y) and the absolute angle of the object's head.
- **xTail, yTail, tTail**: the position (x, y) and the absolute angle of the object's tail.
- **xBody, yBody, tBody**: the position (x, y) and the absolute angle of the object.
- **headMajorAxisLength, headMinorAxisLength, headExcentricity**: parameters of the head's ellipse (headMinorAxisLength and headExcentricity are semi-axis length).
- **bodyMajorAxisLength, bodyMinorAxisLength, bodyExcentricity**: parameters of the body's ellipse (bodyMinorAxisLength and bodyExcentricity are semi-axis length).
- **tailMajorAxisLength, tailMinorAxisLength, tailExcentricity**: parameters of the tail's ellipse (bodyMinorAxisLength and bodyExcentricity are semi-axis length).
- **imageNumber**: index of the frame.
- **id**: object unique identification number.

xHead

yHead

tHead

xTail

yTail

tTail

xBody

yBody

tBody

Float64

Float64

Float64

Float64

Float64

Float64

Float64

Float64

Float64

2,475 rows × 23 columns (omitted printing of 14 columns)

1

514.327

333.12

5.81619

499.96

327.727

6.10226

508.345

330.876

5.94395

2

463.603

327.051

0.301279

449.585

330.323

0.245547

458.058

328.346

0.238877

3

23.9978

287.715

3.70646

34.9722

278.836

3.99819

29.2056

283.505

3.84844

4

372.536

230.143

0.194641

354.226

231.604

6.08737

364.822

230.759

0.0515087

5

480.58

213.482

1.28236

478.125

228.52

1.53303

479.428

220.543

1.42567

6

171.682

143.55

6.09077

155.507

140.116

6.1146

164.913

142.113

6.08216

7

498.151

121.32

6.00177

483.712

119.285

0.0223247

492.683

120.55

6.15298

8

329.56

123.418

6.08726

312.526

119.042

5.9098

322.531

121.614

6.01722

9

465.256

115.045

4.44359

470.057

99.911

4.40559

467.106

109.205

4.40862

10

423.663

66.3789

0.0888056

409.105

67.2971

6.12053

417.615

66.7623

0.0292602

11

424.487

40.4232

5.48198

411.594

30.3912

5.88869

418.96

36.1192

5.64923

12

370.591

35.2147

5.99688

354.672

29.5633

5.89121

364.007

32.8767

5.94008

13

498.502

20.2527

5.66339

487.254

9.19499

5.39497

493.758

15.5781

5.5026

14

367.791

5.03034

6.05933

352.076

6.75603

0.653641

361.12

5.75904

0.152688

15

512.965

332.575

5.86617

499.435

327.759

6.052

507.626

330.673

5.95102

16

463.385

324.659

0.707

451.431

332.193

0.246265

458.959

327.443

0.542368

17

19.4579

293.022

4.28861

25.5579

281.206

4.18379

21.8962

288.302

4.23379

18

379.037

230.527

6.10571

361.728

229.616

0.199343

371.74

230.144

6.25939

19

478.884

206.712

1.27832

475.454

221.757

1.40929

477.197

214.108

1.35472

20

173.923

143.042

0.00732468

157.261

142.182

6.00453

167.066

142.689

6.20403

21

498.561

122.687

5.83253

486.357

118.196

6.13893

493.718

120.906
5.95151
22
328.812
124.134
6.05932
312.848
119.605
5.98617
322.331
122.294
6.00901
23
461.738
116.731
4.47649
466.371
101.736
4.40285
463.615
110.656
4.41641
24
428.631
69.2715
5.87139
415.665
64.6444
6.13862
423.218
67.3364

5.96558

25

425.821

44.9942

5.59983

414.84

33.2028

5.37159

421.248

40.0897

5.461

26

368.362

35.6219

5.97427

353.22

30.4625

5.88261

362.109

33.4891

5.94605

27

503.484

22.7293

5.76026

489.632

16.6315

5.92136

497.924

20.2857

5.86668

28

369.184

5.84074

6.15994

352.622

4.25328

6.24787

362.144

5.16766

6.19236

29

510.519

331.417

5.88883

495.784

327.366

6.12889

504.484

329.758

6.02088

30

464.242

323.533

0.290639

451.756

328.194

0.532686

459.432

325.326

0.37736

Positions are in pixels, in the frame of reference of the original image, zero is in the top left corner. Lengths and areas are in pixels. Angles are in radians in the intervale 0 to 2*pi.

```
0  --  > x
¦
v
y
```

Note: If several tracking analyses are performed on the same image sequence, the previous folder is not erased. It will be renamed as **Tracking_result_DateOfTheNewAnalysis**.

Data analysis

The tracking file can be opened for subsequent analysis:

```python
# Python
data = pandas.read_csv("tracking.txt", sep='\t')
```

```julia
# Julia
using CSV
CSV.read("tracking.txt", delim='\t')
```

```r
# R
read.csv("tracking.txt", header=T sep="\t")
```