Pose-Trigger

Release v1.0.0

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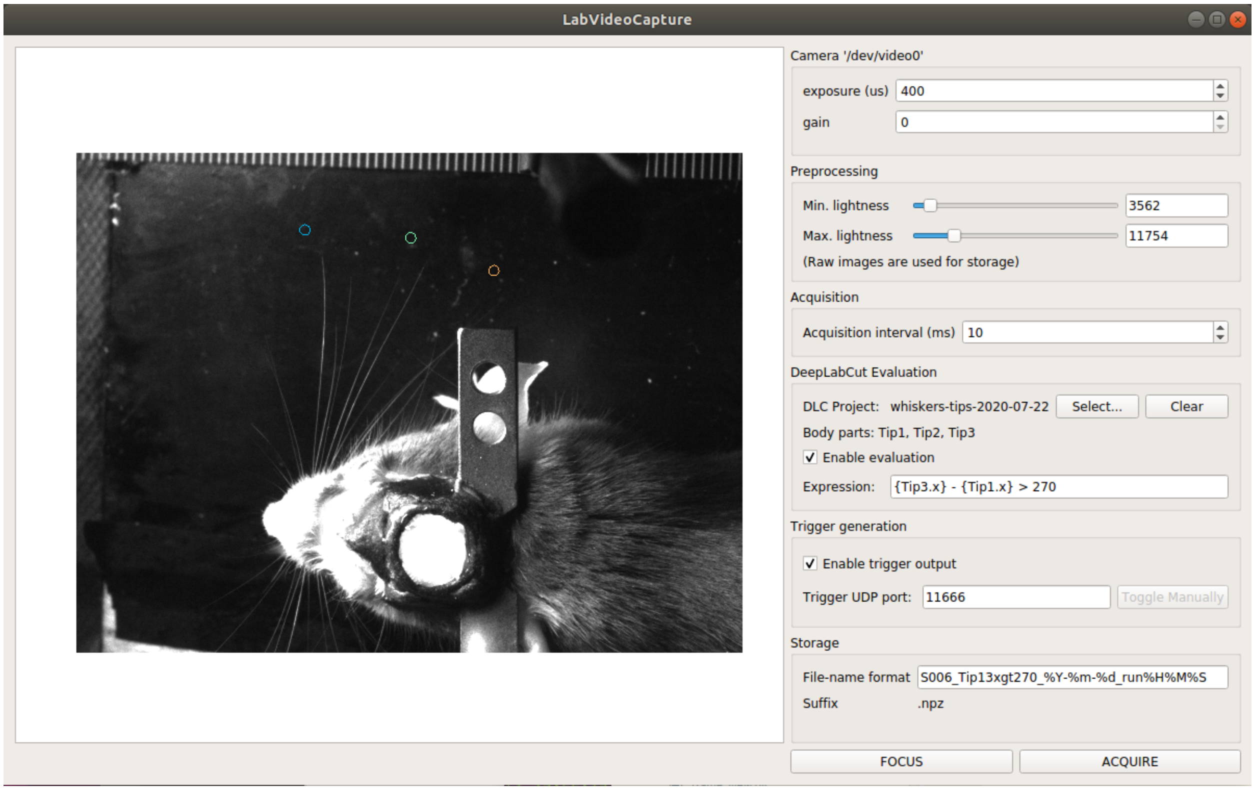
CONTENTS:

Pose-Trigger is a python application for real-time, closed-loop application of TTL trigger generation based on the pose of the subject.



LabVideoCapture

Camera '/dev/video0'

exposure (us) 400

gain 0

Preprocessing

Min. lightness 3562

Max. lightness 11754

(Raw images are used for storage)

Acquisition

Acquisition interval (ms) 10

DeepLabCut Evaluation

DLC Project: whiskers-tips-2020-07-22

Body parts: Tip1, Tip2, Tip3

☑ Enable evaluation

Expression: {Tip3.x} - {Tip1.x} > 270

Trigger generation

☑ Enable trigger output

Trigger UDP port: 11666

Storage

File-name format S006_Tip13xgt270_%Y-%m-%d_run%H%M%S

Suffix .npz

Fig. 1: A screenshot of a working Pose-Trigger app (development version)

CHAPTER

ONE

INTRODUCTION

Contents

1.1 What Pose-Trigger can do

Pose-Trigger is designed to work on a linux computer equipped with a high-speed video camera.

The current version of the software features:

- Acquisition of **high-speed videos** (up to 100-200 fps without on-line pose estimation).
- On-line exposure/gain adjustment.
- Adjustment of acquisition intervals.
- **On-line estimation of body-part positions** using DeepLabCut.
  - On-line evaluation of **arbitrary posture conditions** based on the estimated body-part positions.
  - **Fast output-trigger generation** (<1 ms) using the FastEventServer program.
- **Brightness/contrast adjustment** for on-line display.
- **Storage of frames** into the NumPy-style zip archive.

1.2 How Pose-Trigger works

Pose-Trigger is essentially a Python application. You can install Pose-Trigger on a Linux computer, and run from Terminal by typing:

```
$ pose-trigger
```

(The `$` character represents a prompt. You are not supposed to type it)

1.2.1 The model setup

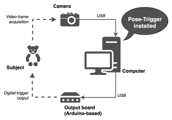


Fig. 1: The model setup

Above is the model setup that uses Pose-Trigger. Pose-Trigger is designed to work in a closed-loop experiment setup, where a single PC acquires video frames from the camera and generates trigger output based on the behavior of the subject.

For more detailed system requirements, refer to the *System requirements* section.

1.2.2 The main acquisition loop

Below is the schematics for the main acquisition loop:

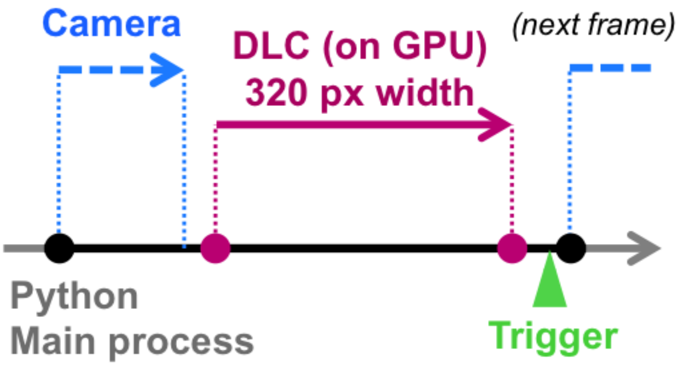


Fig. 2: The main acquisition loop

1. The **timer** generates timings for the acquisition of the next frame (black filled circles).
2. Pose-Trigger commands the camera to acquire a video frame, and receive it (blue dashed arrow).
3. Pose-Trigger delegates body-part estimation to the underlying DeepLabCut library (in case it exists; magenta arrow).
4. Pose-Trigger updates the status of trigger output by sending information to FastEventServer (in case it is serving; green arrowhead).

CHAPTER

TWO

INSTALLATION

Contents

2.1 System requirements

2.1.1 Minimum installation requirements

If you have the followings, you can perform acquisition of video frames *without body-part estimation or trigger generation*:

- **A linux computer** (tested on Ubuntu 18.04 LTS)
- An installation of **Python, version >=3.4**. We recommend installing the following libraries using e.g. Anaconda:
  - NumPy
  - Matplotlib
  - python-opencv
  - PyQt (required for pyqtgraph)
  - pyqtgraph (through `pip`, instead of through `conda`)
- **a 16-bit monochrome video camera** from ImagingSource (e.g. refer to the *Reference setup specifications*).

Note: Other Video4Linux2-compliant cameras should also work with a few adjustments in the code, but will require some efforts.

2.1.2 Requirements for on-line position estimation

The on-line position-estimation feature requires the followings in your environment:

- An installation of DeepLabCut (any versions after 1.11 should work).
- For a faster working of DeepLabCut, **NVIDIA graphics board with a large amount of RAM** is required.

Note: For example, running DeepLabCut on ResNet-50 requires ~10.6 GB of RAM, so we use GeForce RTX 2080 Ti that has 11 GB on-board RAM (refer to the *Reference setup specifications*).

2.1.3 Requirements for trigger-output generation

In addition to the pose-estimation feature, the trigger-output feature requires the followings:

- The FastEventServer **server program**.
- An Arduino UNO or its clone, being flashed with the arduino-fasteventtrigger program.

For installation of the softwares, refer to the README file in the "libraries" directory of the repository.

Caution: `arduino-fasteventtrigger`, in reality, will **only make use of the serial-to-USB conversion tip on the UNO (i.e. `ATmega16U2`_)**. This means:

- Make sure that your UNO clone has the ATmega16U2 as its converter chip.
- Other USB-based boards that uses the ATmega16U2 chip *may* work (not recommended nor supported).

2.2 Reference setup specifications

We develop and test Pose-Trigger in the following environment:

2.2.1 Hardware

Table 1: Reference setup hardware specifications

Part name	Model type
CPU	3.7 GHz Core i7-9700K
RAM	64 GB DDR4-3200
GPU	NVIDIA GeForce RTX 2080 Ti (11 GB RAM)
Camera	ImagingSource DMK 37BUX287
Output board	Arduino UNO, rev. 2 (clone), with arduino-fasteventtrigger

2.2.2 Software

Table 2: Reference setup software environment

Software	Specification
Operating system	Ubuntu 18.04 LTS
Python environment	Anaconda3, Python 3.7.7
CUDA Toolkit	version 10.1 (through *conda*)
Tensorflow	version 1.13.1 (*tensorflow-gpu* package of *conda*)
DeepLabCut	version 2.1.3
NumPy	version 1.19.1 (through *conda*)

2.3 Install procedures

Install all the python packages in your DeepLabCut environment.

1. If you need DeepLabCut, install it first.
2. Install the libraries specified in the *minimum requirements* section.
3. Install `timedcapture`: this is the library for video acquisition.
4. Install the `pose-trigger` module.
5. You can install `FastEventServer` and connect Arduino at any moment during the procedure (please refer to the README file in the "libraries" directory of the repository).

Note: Upon the public release of Pose-Trigger in the future, both `timedcapture` and `pose-trigger` packages will be made available in PyPI. One will be able to install these packages through the `pip install` command.

Before this becomes the case, below are the procedures:

1. Clone the repository.
2. Open the cloned repository directory in Terminal.
3. Run `pip install .` on Terminal.

CHAPTER

THREE

QUICK USAGE GUIDE

Contents

3.1 Launching Pose-Trigger

1. Open Terminal.
2. Run the following command on Terminal:

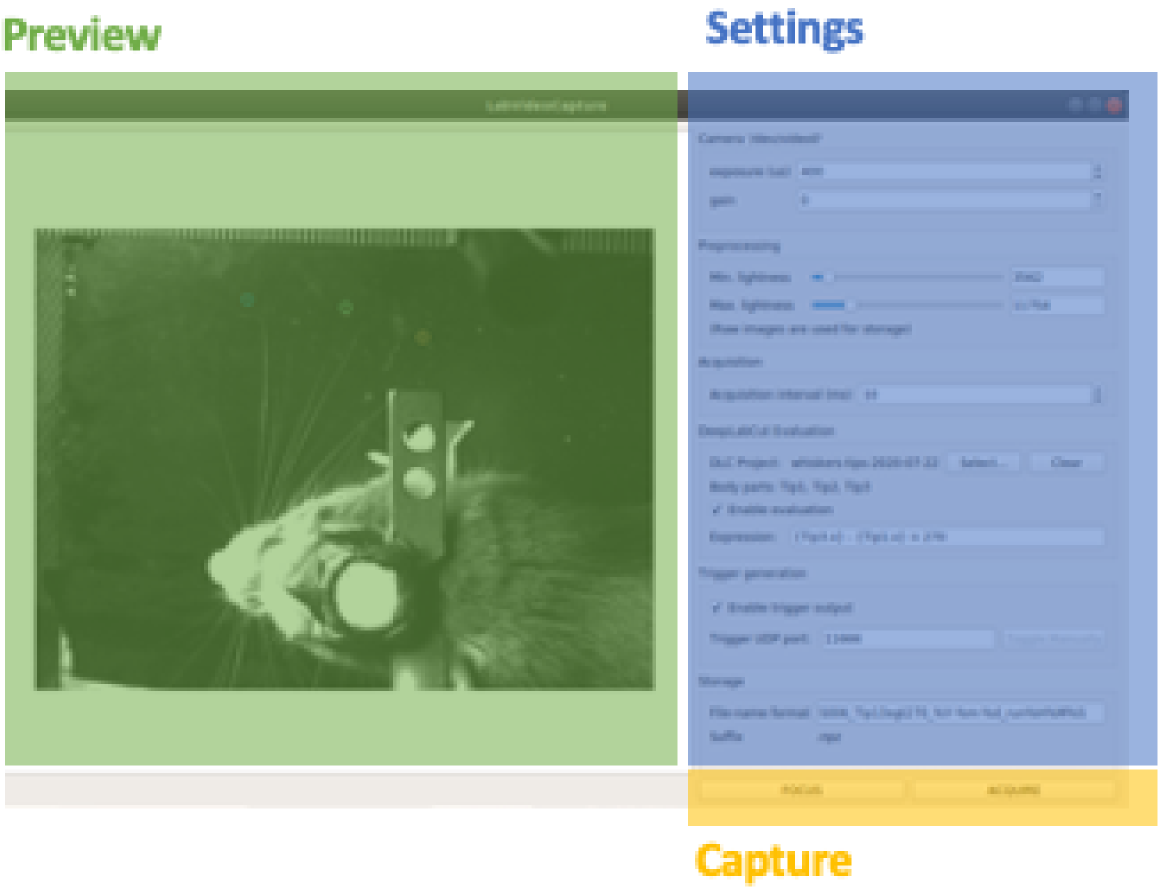
   ```
   $ pose-trigger
   ```

Note: When being run without a parameter, Pose-Trigger will use the device at `/dev/video0` by default. In case you want to use e.g. `/dev/video1`, specify the device as the parameter, i.e. run `pose-trigger /dev/video1`.

3.2 Organization of the main window

The Pose-Trigger main window can be divided into three groups:

- The **Capture** buttons (yellow) are for starting/stopping acquisition.
- The **Preview** panel (green) provides an on-line preview of the acquired video frames. If estimation of body-part positions is activated (refer to *DeepLabCut evaluation*), estimated positions will be shown as colored circles, too.
- In the **Settings** panel (blue), you can configure how acquisition is performed (refer to the *Panel-by-panel guide*).



Camera (described)

exposure (us)

gain

Preprocessing

Min. lightness

Max. lightness

(How images are used for storage)

Acquisition

Acquisition interval (ms)

DeepLabCut Evaluation

DLC Project: whiskers-tips-2020-07-22 Select... Clear

Body parts: Tip1, Tip2, Tip3

✓ Enable evaluation

Expression

Trigger generation

✓ Enable trigger output

Trigger UDP port

Storage

File name format

Suffix

Fig. 1: Overview of the main window

3.3 Capturing videos

3.3.1 Capture modes

There are two modes of running for Pose-Trigger:

- **FOCUS mode**: capturing video frames without storing them
- **ACQUIRE mode**: captures video frames *and* stores acquired data

You can start/stop either of the capturing modes by clicking on the button at the bottom of the main window.

Caution: **Pose-Trigger does !not! stream data into storage during acquisition!** During acquisition, it keeps all the data in-memory. The data will be written out to a file only *after* acquisition. The duration of acquisition will be thus limited to the order of 1–2 minutes.

Note: Currently, the following parameters are "hard-coded" and used as default:

- Image format: 640x480 pixels, 16-bit grayscale
- Timing generation: a busy-wait algorithm
- Storage format: the NumPy zip-file format (.npz)

3.3.2 Format of the saved files

The data are saved in the NumPy zip-file format (i.e. ".npz" file). Each file includes the following entries:

Table 1: Entries in saved files

Name	Always there?	Description
`frames`	Yes	the 3-D frame data, (frame-index, height, width)
`timestamps`	Yes	1-D array containing unix timestamps in seconds
`metadata`	Yes	a JSON-serialized text object containing information on acquisition configuration
`estimation`	No (Optional)	when a DeepLabCut project is selected; 3-D array with the (frame-index, parameter) shape
`trigger_status`	No (Optional)	when pose-evaluation is enabled; 1-D boolean array of evaluation results

TODO

add some examples for metadata (and probably for other entries, too)

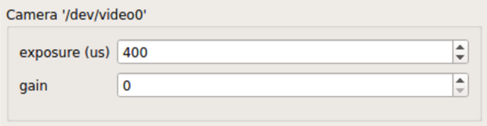
CHAPTER

FOUR

PANEL-BY-PANEL GUIDE

Contents

4.1 “Camera” panel



Camera '/dev/video0'

exposure (us) 400

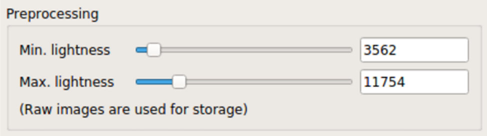
gain 0

Fig. 1: “Camera” panel for capture-parameter settings

Here, you can set the exposure and the gain of each video frame acquisition.

Note: For the time being, **the image format is restricted to 16-bit grayscale, with the 640x480 frame size** (otherwise there will be an unexpected behavior).

4.2 “Preprocessing” panel



Preprocessing

Min. lightness 3562

Max. lightness 11754

(Raw images are used for storage)

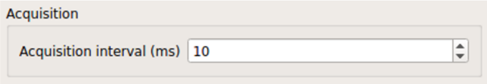
Fig. 2: “Preprocessing” settings

This controls the brightness/contrast settings for “live” video frames. It controls signal conditioning parameters for:

- Video-frame preview
- The images being fed to DeepLabCut (i.e. body-part position estimation)

On the other hand, **the raw, unconditioned images are used** for data storage.

4.3 “Acquisition” panel



Acquisition

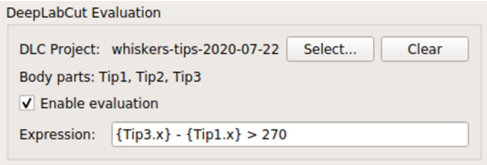
Acquisition interval (ms) 10

Fig. 3: “Acquisition” timing control

Here you can set the (targeted) acquisition intervals. For example, if you want to have Pose-Trigger running at 50 Hz, set this interval to 20 ms.

Note: For the time being, you can only choose to use the busy-wait timing-generation mechanism. This means that the *minimum* inter-frame interval is set to the value specified here.

4.4 “DeepLabCut evaluation” panel



DeepLabCut Evaluation

DLC Project: whiskers-tips-2020-07-22

Body parts: Tip1, Tip2, Tip3

☑ Enable evaluation

Expression: {Tip3.x} - {Tip1.x} > 270

Fig. 4: “Evaluation” mode control

Here, you can configure how DeepLabCut should work in real-time.

4.4.1 Project selection

By using the “Select” button, you can select your DeepLabCut project of choice. Conversely, by clicking on the “Clear” button, you can un-set the project.

When a project is selected, the panel shows the body-part labels being registered in the project.

In addition, as long as a project is selected here, body-part position estimation occurs during video-capture processes. Estimated positions will also be stored in the data file in the case of the *ACQUIRE mode*.

4.4.2 Pose evaluation

You can enable pose evaluation by ticking the “Enable evaluation” button. Evaluation occurs using **the boolean expression entered in the “Expression” field**. The “expression” can be any Python one-line expression, but it has to be evaluated to be a boolean.

When specifying the boolean expression, you can use a **placeholder-based reference** to body part positions. For example, by entering `{Tip1.x}`, you can use the X coordinate of `Tip1` as a parameter. Other than the `x` property, you can also use the `y` and `p` properties of a body part to refer to the Y coordinate and the probability.

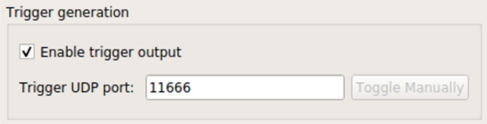
In computation of the expression, some major libraries can be used: use `math` for representing the `math` standard library, and use `np` to refer to the `numpy` library. For example, the expression below calculates the Euclidean distance between two body parts, `Tip1` and `Tip2`:

```
math.sqrt( ({Tip1.x} - {Tip2.x})**2 + ({Tip1.y} - {Tip2.y})**2 )
```

In addition, to enable testing of the output latency at the trigger-generation step, the custom placeholder, `{EVERY10}` is there. By using the following expression, you can toggle trigger output on and off every 10 frames:

```
{EVERY10}.get()
```

4.5 “Trigger generation” panel



Trigger generation

☑ Enable trigger output

Trigger UDP port: 11666

Fig. 5: “Trigger” mode control

Here, you can test and control trigger generation.

4.5.1 Enabling communication with FastEventServer

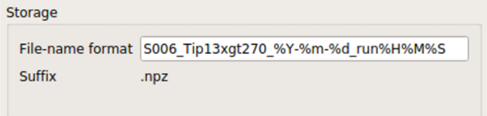
By ticking “Enable trigger output”, it starts sending the result of evaluation (true/false value) to FastEventServer. Receiving the result, FastEventServer, in turn, sends command to the Arduino-based output board to generate the corresponding output.

4.5.2 Manually toggling the trigger

When trigger-output based on evaluation results is disabled, you can manually toggle the trigger output on and off, using the “Toggle manually” button.

> **Caution:** For the time being, the “trigger UDP port” cannot be specified; if Pose-Trigger fails to connect to FastEventServer on port 11666 at the beginning of its running session, it disables the trigger-output functionality during the whole running session.

4.6 “Storage” panel



Storage

File-name format: S006_Tip13xgt270_%Y-%m-%d_run%H%M%S

Suffix: .npz

Fig. 6: “Storage” control

Here, you can control how acquired data are stored.

File names are automatically generated using the text entered in the “File-name format” field.

You can use the following **format directives**. These fields are passed on straight to the `datetime.strftime` method (refer to the python datetime module documentation on the specific format directives).

> **Caution:** Be cautious of Pose-Trigger **automatically overwriting existing files**! Try to include (at least) the minutes/seconds directive into the file-name format, so that you do not unexpectedly delete your previous videos.