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## pyPOCQuant - A tool to automatically quantify Point-Of-Care Tests from images

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The tool pyPOCQuant aims to automatically detect and quantify signal bands from lateral flow assays (LFA) or Point of Care tests (POC or POCT) from an image. It can batch analyze large amounts of images in parallel. An analysis pipeline can be run either from the command line (good for automating large numbers of analysis) or from a desktop application.
1.1 Stable release

1.1.1 As module

To install pyPOCQuantui, just run this command in your terminal:

```
$ pip install pyPOCQuant
```

Installing pyPOCQuantui this way ensures that you get always the latest release.

If you don’t have pip installed, this Python installation guide can guide you through the process.

1.1.2 As stand alone executable

If you want to install pyPOCQuantui on your system without installing Python yourself just download the pre-compiled executable matching your operating system:

Install tesseract following these instructions depending your operating system:

```
Warning: Make sure tesseract is on PATH of your environment.
```

pypocquantui can then be used trough its graphical user interface (GUI) directly.

1.2 From sources

1.2.1 All platforms

The latest sources for pypocquantui can be downloaded from the Github repo.

`pyPOCQuant` requires python 3.6. It is recommended to use miniconda. When miniconda is installed, start the terminal and type:

1. Install system `Python3` or `miniconda3`.
2. Create a new environment “pyPOCQuantEnv” with:

```
$ conda create -n pyPOCQuantEnv python=3.6
$ activate pyPOCQuantEnv
```
Note: More information about conda environments can be found [here](#).

3. You can clone the public repository:

```bash
$ git clone git://git.gitlab.com/csb.ethz/pypocquantui.git
```

Once you have a copy of the source, navigate into the directory `pypocquantui` and install dependencies with:

**Note:** `{platform}` is one of `win32.txt`, `linux.txt`, or `osx.txt`.

Then to start the UI run:

```bash
$ fbs run
```

If you use PyCharm make sure you open the project with its root folder and add

```
/pypocquantui/src/main/python/main.py
```

to the run configuration.

### 1.2.2 Windows

- Install tesseract

### 1.2.3 Linux

Install the following dependences (instructions for Ubuntu Linux):

```bash
$ sudo apt install libzmq3-dev, tesseract-ocr, libzbar0
```

### 1.2.4 macOS

To install the required dependencies we recommend to use the packaging manager `brew`. Install it from here if you have’t allready [Install brew](#).

```bash
$ brew install zbar
$ brew install tesseract
```

### 1.3 Build from source

To compile and create a pyPOCQuantUI installer, perform following steps. In the following `{ppcqui_root}` points to the root folder of the `pyPOCQuantUI` checked-out code.
1.3.1 Windows

```
$ cd ${ppcqui_root}
$ python ./make_build.py
```

You will find the installer in ${ppcqui_root}/target/pyPOCQuant.

1.3.2 Linux

```
$ sudo apt install ruby ruby-dev rubygems build-essential
$ sudo gem install --no-document fpm
$ cd ${ppcqui_root}
$ python ./make_build.py
```

This will create a ${ppcqui_root}/target/pyPOCQuant/pyPOCQuant.deb package that can be installed and redistributed.

```
$ sudo apt install ${ppcqui_root}/target/pyPOCQuant/pyPOCQuant.deb
```

Please notice that client machines will need to install also two dependences:

```
$ sudo apt install tesseract-ocr, libzbar0
$ sudo apt install ${ppcqui_root}/target/pyPOCQuant/pyPOCQuant.deb
```

1.3.3 macOS

```
$ cd ${ppcqui_root}
$ python ./make_build.py
```

Note:

- Depending on your Python installation, you may need to use pip3 instead of pip.
- For both running it from source or with the compiled binaries zbar and tesseract needs to be installed and be on PATH. On Windows zbar libs are installed automatically.
2.1 Introduction

The tool pyPOCQuant aims to automatically detect and quantify signal bands from lateral flow assays (LFA) or Point of Care tests (POC or POCT) from an image. It can batch analyze large amounts of images in parallel.

An analysis pipeline can be run either from the command line (good for automating large numbers of analysis) or from a desktop application.

2.2 Command line workflow

1. Split images by POCT manufacturer if needed
2. Copy all the images of the same kind into one folder
3. Prepare a settings (configuration) file
4. Run the pipeline

2.2.1 Split images by POCT manufacturer

This only applies if you collected many images using POCTs from different vendors and stored all the images in one common folder! Analysis settings would need to be slightly adapted for different POCTs shapes and sizes.

If you have many images in an unorganized way we provide a helper script to sort them by manufacturer into subfolders.

This can also be run from the UI, see below.

$ python ./split_images_by_strip_type_parallel.py -f /PATH/TO/INPUT/FOLDER -o /PATH/TO/OUTPUT/FOLDER -w ${{NUM_WORKERS}}

- /PATH/TO/INPUT/FOLDER: path to the folder that contains all images for a given camera.
- /PATH/TO/OUTPUT/FOLDER: path where all images will be organized into subfolders; one per each strip manufactured. Strip images that cannot be recognized (or do not contain any strip) will be moved to an UNDEFINED subfolder.
- Currently recognized manufacturers:
  * AUGURIX
  * BIOZAK
Please notice: the list of known manufacturers is defined in `pyPOCQuant.consts.KnownManufacturers`.

- NUM_WORKERS: number of parallel processes; e.g. 8.

### 2.2.2 Settings file preparation

You can prepare a default parameter file from the command line as follows:

```
$ python ./pypocquant/pyPOCQuant_FH.py -c /PATH/TO/INPUT/settings_file.conf
```

Open the file in a text editor and edit it.

```python
qc=True
verbose=True
sensor_band_names=('igm', 'igg', 'ctl')
peak_expected_relative_location=(0.25, 0.53, 0.79)
sensor_center=(178, 667)
sensor_size=(61, 249)
sensor_border=(7, 7)
perform_sensor_search=True
qr_code_border=40
subtract_background=True
sensor_search_area=(71, 259)
sensor_thresh_factor=2.0
raw_auto_stretch=False
raw_auto_wb=False
strip_try_correct_orientation=False
strip_try_correct_orientation_rects=(0.52, 0.15, 0.09)
strip_text_to_search='COVID'
strip_text_on_right=True
force_fid_search=True
```

Some of the parameter names contain the term `strip`: this is used to indicate the POCT. The prefix `sensor` indicates the measurement region within the `strip`.

See Explanations for detailed description of the parameters.

Please notice that some parameters are considered “Advanced”; in the user interface the parameters are separated into “Runtime parameters”, “Basic parameters”, and “Advanced parameters”.
How to determine the parameters manually

Open the settings file and adjust the parameters to fit your images.

Important parameters are the sensor_size, sensor_center, and sensor_search_area (the latter being an advanced parameter).

The user interface allows to easily define those parameters by drawing onto the extracted POCT image.

Sensor parameters are relative to the POCT image.

In the following we show how to obtain position and extent of the sensor areas in Fiji or ImageJ. Later we will see how to do the same in the pyPOCQuant user interface.

- When drawing a rectangular region of interest, the size is displayed in Fiji’s toolbar; e.g. x=539, y=145, w=230, h=62.
- When hovering over the central pixels in the top or left sides of the selection, the x, and y coordinates of the center, respectively, are show in Fiji’s toolbar; e.g. x=601, y=144, value=214 (and equivalently for y).

2.2.3 Run the pipeline

Run the analysis per manufacturer manually

$ python pyPOCQuant_FH.py -f /PATH/TO/INPUT/FOLDER/MANUFACTURER -o /PATH/TO/RESULTS/FOLDER -s /PATH/TO/CONFIG/FILE -w NUM_WORKERS

- /PATH/TO/INPUT/FOLDER/MANUFACTURER: path to the folder that contains all images for a given camera and manufacturer.
- /PATH/TO/RESULTS/FOLDER: path where the results (and the quality control images) for a given camera and manufacturer will be saved. The results are saved in a quantification_data.csv text file.
- /PATH/TO/CONFIG/FILE: path to the configuration file to be used for this analysis. Please see below. Notice that a configuration file will be needed per manufacturer and (possibly) camera combination.
- NUM_WORKERS: number of parallel processes; e.g. 8.

2.3 GUI workflow

1. Split images by POCT manufacturer if needed
2. Copy all the images of the same kind into one folder
3. Select the folder containing the images to be processed
4. Set all analysis parameters
5. Run the pipeline
2.3.1 Split images by POCT manufacturer

This only applies if you collected many images using POCTs from different vendors and stored all the images in one common folder! Analysis settings would need to be slightly adapted for different POCTs shapes and sizes.

To do so go to File -> Split images by type to open the dialog to split the images.

How to determine the parameters automatically using the GUI

A settings file must not necessarily be created in advance. The Parameter Tree can be edited directly. Optionally, settings can be loaded or saved from the UI.

How to estimate sensor parameters graphically in the UI:

- Select the input folder and click on one of the listed images to display it. The POCT region will be automatically extracted and shown in the view at the top. Please mind that this can take a few seconds. The lower view shows the whole image.

- Hit the Draw sensor outline icon (red arrow) in the toolbar. This will allow you to interactively define the sensor area and the peak_expected_relative_location parameters.

- Draw the four corners of the sensor and place the vertical bars on the bands. This will cause all relevant parameters to be populated in the Parameter Tree. Please notice that, by default, the sensor_search_area is set to be 10 pixels wider and taller than the sensor_size. This can be changed in the advanced parameters (but beware to keep it only slightly larger than the sensor_size: it is meant only for small refinements).

- You can test current parameters on one image by clicking the Test parameters button under the Parameter Tree.

- Optionally, you can save the settings file (Ctrl+S, File->Save settings file)

Run the analysis per manufacturer automatically using the GUI

Once the previous steps are done and all parameters are correctly set, you can hit the Run button to start the analysis.

Note: a step by step guide can be found under **Quick start* (Help -> Quick start)*

2.4 Settings

The following settings must be specified. These are default values and need to be adopted for a series of the same kind of images. Please note: in the following, strip is used to indicate the POCT, and sensor to indicate the measurement region within the strip.

qc=True
verbose=True
sensor_band_names=('igm', 'igg', 'ctl')
peak_expected_relative_location=(0.25, 0.53, 0.79)
sensor_center=(178, 667)
sensor_size=(61, 249)
sensor_border=(7, 7)
perform_sensor_search=True
qr_code_border=40
subtract_background=True
sensor_search_area=(71, 259)
sensor_thresh_factor=2.0
raw_auto_stretch=False
raw_auto_wb=False
strip_try_correct_orientation=False
strip_try_correct_orientation_rects=(0.52, 0.15, 0.09)
strip_text_to_search='COVID'
strip_text_on_right=True
force_fid_search=True

2.4.1 Explanations

Runtime parameters

max_workers

- The analysis can work in parallel. Specify the maximum number of images that are run in parallel. The maximum allowed value is the number of cores in your machine.

qc

- Toggle creation of quality control images.
- Possible values: True or False
- Recommended: True when testing parameters.

verbose

- Toggle extensive information logging.
- Possible values: True or False
- Recommended: True when testing parameters.

Basic parameters

number_of_sensor_bands

- It defines the number of test lines (TLs) to be expected in the POCT, including the control line. This parameter is used by the user interface to dynamically adapt the tree for related settings (see sensor_band_names and peak_expected_relative_location below), and is not part of the settings file, since it can be easily derived from those parameters.
- Possible values: 2 to 100
control_band_index

• Index of the control line.
• Possible values: 0, 1, ..., number_of_sensor_bands - 1; or -1 (last index).
• Default: -1 (in Python parlance, -1 means last index, or, the first index from the right).

sensor_band_names

• Custom name for the test lines (by default 3, needs to match the number of defined TLs number_of_sensor_bands) t2, t1 and ctl (e.g., IgM, IgG andCtl).

peak_expected_relative_location

• Expected relative peak positions as a function of the width of the sensor (= 1.0). These values can easily be set interactively using the UI.

sensor_center

• Coordinates in pixels of the center of the sensor with respect to the strip image: \((y, x)\).

sensor_size

• Area in pixels of the sensor to be extracted: \((height, width)\).

sensor_border

• Lateral and vertical sensor border in pixels to be ignored in the analysis to avoid border effects: \((lateral, vertical)\).

perform_sensor_search

• If True, the (inverted) sensor is searched within sensor_search_area around the expected sensor_center; if False, the sensor of size sensor_size is simply extracted from the strip image centered at the relative strip position sensor_center.
• Possible values: True or False
• Recommended: True
**qr_code_border**

- Lateral and vertical extension of the (white) border around each QR code.

**subtract_background**

- If True, estimate and subtract the background of the sensor intensity profile (bands).
- Possible values: True or False
- Recommended: True

**Advanced parameters**

These parameters will most likely work with the default values above.

**sensor_search_area**

- Search area in pixels around the sensor: (height, width).
- Used only if skip_sensor_search is False.
- Try to keep it just a bit larger than the sensor size: in particular, try to avoid picking up features (e.g. text) in close proximity of the sensor.

**sensor_thresh_factor**

- Set the number of (robust) standard deviations away from the median band background for a peak (band) to be considered valid.
- Recommended: 2, maybe 3.

**raw_auto_stretch**

- Whether to automatically correct the white balance of RAW images on load. This does not affect JPEG images!
- Possible values: True or False
- Recommended: False

**raw_auto_wb**

- Whether to automatically stretch image intensities of RAW images on load. This does not affect JPEG images!
- Possible values: True or False
- Recommended: False
**strip_try_correct_orientation**

- Whether to automatically try to rotate a POCT that was mistakenly placed on the template facing the wrong direction (and where the control band is on the left instead of on the right). The pipetting inlet will be searched in the POCT; the inlet is assumed to be found on the side opposite to the control band, and always on the left. If found on the right, the image will be rotated.
  
  - Possible values: True or False
  - Default: False
  - If set to True, make sure to properly set the strip_try_correct_orientation_rects parameters below!

**strip_try_correct_orientation_rects**

- Parameters for defining two rectangles left and right from the sensor center to be used to detect the pipetting inlet. The first parameter, Relative height factor, defines the relative height of the rectangles with respect to the strip. The second parameter, Relative center cut-off, defines the relative offset from the sensor center and therefore the width of the rectangle. Finally, the third parameter, Relative border cut-off, defines the relative offset from the strip's left and right borders and hence the width of the search rectangle.
  
  - Possible values: (0:1, 0:1, 0:1)
  - Default: (0.52, 0.15, 0.09)

**strip_text_to_search**

- Whether to use a specific text printed on the POCT to automatically try to rotate a POCT that was mistakenly placed on the template facing the wrong direction (and where the control band is on the left instead of on the right). Set to "" to skip search and correction. If the strip has some text printed on either side of the sensor, it can be searched to guess the orientation. See also strip_text_on_right.

**strip_text_on_right**

- Assuming the strip is oriented horizontally, whether the strip_text_to_search text is expected to be on the right. If strip_text_on_right is True and the text is found on the left hand-side of the strip, the strip will be rotated 180 degrees.
  
  - Ignored if strip_text_to_search is "".

**force_fid_search**

- If force fid search is activated, try hard (and slow!) to find an FID on a barcode or QR code label on the image identifying the sample.
  
  - Possible values: True or False
  - Recommended: False
2.5 Results

The analysis pipeline delivers a .csv that contains a relatively large table of results. The extracted features are explained in the following.

2.5.1 Result table

Structure and description of the result table:

- **fid**: patient FID in the form F5921788
- **fid_num**: just the numeric part of the FID (i.e., 5921788)
- **filename**: name of the analyzed image
- **extension**: extension (either *.JPG or *.ARW, *.CR2, *.NEF)
- **basename**: filename without extension
- **iso_date**: date of image acquisition in the form YYYY-MM-DD (e.g. 2020-04-14)
- **iso_time**: time of image acquisition in the form HH-MM-SS (24-h format)
- **exp_time**: camera exposure time
- **f_number**: aperture F number
- **focal_length_35_mm**: 35mm equivalent focal length
- **iso_speed**: camera ISO value
- **manufacturer**: POCT manufacturer
- **plate**: plate number
- **well**: well (e.g. A 01)
- **ctl**: 1 if the control band could be extracted, 0 otherwise.
- **t2**: 1 if the t2 band (e.g. IgM) could be extracted, 0 otherwise.
- **t1**: 1 if the t1 band (e.g. IgG) could be extracted, 0 otherwise.
- **ctl_abs**: absolute signal strength of the control band,
- **t2_abs**: absolute signal strength of the t2 band,
- **t1_abs**: absolute signal strength of the t1 band,
- **ctl_ratio**: relative signal strength of the control band (always 1.0 if detected)
- **t2_ratio**: relative signal strength of the t2 band with respect to the control band
- **t1_ratio**: relative signal strength of the t1 band with respect to the control band
- **issue**: if issue is 0, the image could be analyzed successfully, if issue > 0 it could not. See the list of issues below
- **user**: custom field

Note: expect small residual variations in the absolute signal strengths (ctl_abs, t2_abs, and t1_abs) across images in a batch due to inhomogeneities in acquisition.

Note 2: ctl, t1, and t2 in the column names will be replaced by the names defines in sensor_band_names. For example, t1_ratio may become igg_ratio.
Note 3: The number of test lines (TL) changes according to the parameter `number_of_sensor_bands`. By default, 3 TLs are defined including the ctl line. Changing the number of TLs also changes the number of columns in the results table.

**Analysis issues**

Each analyzed image is assigned an integer **issue**:

- 0: no issue, the analysis could be performed successfully
- 1: barcode extraction failed
- 2: FID extraction failed
- 3: strip box extraction failed
- 4: strip extraction failed
- 5: poor strip alignment
- 6: sensor extraction failed
- 7: peak/band quantification failed
- 8: control band missing

**2.5.2 Quality control images**

Types and examples’ of quality control images:

Raw image shown as comparison:

- `IMAGE_FILE_NAME_aligned_box`: Aligned raw image
- `IMAGE_FILE_NAME_box`: QR code box around the POCT oriented such that the control band is always on the right side.
- `IMAGE_FILE_NAME_rotated`: Raw image rotated such that the POCT is at the parallel to the bottom side of the image.
- `IMAGE_FILE_NAME_strip_gray_aligned`: Aligned POCT cropped around its outline such that it is parallel to the bottom side.
- `IMAGE_FILE_NAME_strip_gray_aligned_after_ocr`: Aligned POCT cropped around its outline such that it is parallel to the bottom side after OCR filtering such that the pipetting part is always left (for the cases where the POCT was not placed in the correct orientation in the template.)
- `IMAGE_FILE_NAME_strip_gray_hough_analysis`: Aligned POCT cropped around its outline such that it is parallel to the bottom side detecting the pipetting spot to identify wrongly oriented POCT in the strip box.
- `IMAGE_FILE_NAME_strip_gray_hough_analysis_candidates`: Hough analysis candidate results. The rectangles indicate the search areas while as the circles indicate potential hits for the pipetting spot. Red rectangle and magenta circles identifies the side where the pipetting spot was detected. Note it is assumed that the control band is always opposite of the pipetting area.
- `IMAGE_FILE_NAME_sensor`: Aligned sensor crop showing the bands.
- `IMAGE_FILE_NAME_peak_overlays`: Sensor crop with colored rectangle overlay(s) indicating the area(s) where the signal for each detected band is quantified. Notice that the rectangle extends to cover the whole area under the curve, from background level through peak and back to background level.
• IMAGE_FILE_NAME_peak_background_estimation: Control figure displaying the performance of the background estimation fit. Black dashed line is an estimation of the background level obtained by robust linear fit of the band profile. From the estimate background trend a constant value is subtracted (resulting red solid line). This is to make sure that the signal is flat after correction, but no values are clipped.

• IMAGE_FILE_NAME_peak_analysis: Control figure displaying the performance of the peak analysis. Red circle indicates the max peak height. The green dashed line is an estimate of the local background that is used to test all candidate local maxima against a threshold defined by the red dashed line. This line is calculated as the (median of the background values) + f * (median deviation of the background values). The factor f is a user parameter and defaults to 2. The solid blue, orange and green line under the curves indicate the local span of each of the bands and indicate which part of the signal is integrated.

2.5.3 Log file

The log file contains more detailed information for each processed image identified by its file name, such as IMG_8489.JPG.

It informs about barcode extraction and its rotation, QR code box rotation, FID extraction, actual sensor coordinates and the identified bands.

Example log:

<table>
<thead>
<tr>
<th>File = IMG_8489.JPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing IMG_8489.JPG</td>
</tr>
<tr>
<td>Best percentiles for barcode extraction: (0, 100); best scaling factor = 0.25; score = 6/6</td>
</tr>
<tr>
<td>File IMG_8489.JPG: best percentiles for barcode extraction after rotation: (0, 100); best scaling factor = 0.25; score = 6/6</td>
</tr>
<tr>
<td>File IMG_8489.JPG: Strip box image rotated by angle -0.9172186022623166 degrees using QR code locations.</td>
</tr>
<tr>
<td>File IMG_8489.JPG: FID = 'F5923994'</td>
</tr>
<tr>
<td>File IMG_8489.JPG: sensor coordinates = [140, 207, 523, 780], score = 1.0</td>
</tr>
<tr>
<td>Peak 69 has lower bound 48 (d = 21) with relative intensity 0.06 and upper bound 93 (d = 24) with relative intensity 0.00. Band width is 46. Band skewness is 1.14</td>
</tr>
<tr>
<td>Peak 138 has lower bound 104 (d = 34) with relative intensity 0.00 and upper bound 162 (d = 24) with relative intensity 0.10. Band width is 59. Band skewness is 0.71</td>
</tr>
<tr>
<td>Peak 203 has lower bound 170 (d = 33) with relative intensity 0.04 and upper bound 248 (d = 45) with relative intensity 0.00. Band width is 79. Band skewness is 1.36</td>
</tr>
<tr>
<td>File IMG_8489.JPG: the bands were 'normal'.</td>
</tr>
<tr>
<td>✓ File IMG_8489.JPG: successfully processed and added to results table.</td>
</tr>
</tbody>
</table>

2.5.4 Settings file

A settings file is created in the -o /PATH/TO/RESULTS/FOLDER with the actually used parameters for the analysis. It can be used to reproduce the obtained results.

See settings file section for detailed description.
2.6 Graphical user interface

The GUI offers several actions via the menu, the toolbar and buttons.

1. File menu:
   - File: Lets you load (File -> Load settings file) and save (File -> Save settings file) a settings file
   - Help: Get quick instructions and open this manual

2. Toolbar:
   - Load settings from file: Load settings from file into the Parameter Tree.
   - Save settings to file: Save current settings to file.
   - Draw sensor outline: Activates drawing a polygon by clicking into the corners of the sensor on the images.
   - Delete sensor: Deletes currently drawn sensor.
   - Mirror image vertically: Mirrors the displayed image vertically.
   - Mirror image horizontally: Mirrors the displayed image horizontally.
   - Rotate clockwise: Rotates the displayed image clockwise.
   - Rotate counter clockwise: Rotates the displayed image counter clock wise.
   - Set rotation angle in degrees: Specifies the rotation angle.
   - Zoom in: Zooms in the displayed image.
   - Zoom out: Zooms out the displayed image.
   - Reset zoom: Resets the zoom level.
   - Measure distance: Lets you draw a line on the image to measure distances. It will update the qr_border_distance parameter.
   - Show / hide console: shows or hides the console at the bottom of the UI.

3. Select input folder: Allows to specify the input folder.
   - Select output folder: (Optional) Lets you select a output folder. If left empty a output subfolder is automatically generated in the input folder.
   - Image list: Lists all available images in the input folder. Click onto the filename to display one in 5.

4. Parameter Tree: Adjust parameters manually if needed.

5. POCT area: Shows the extracted POCT and allows for drawing the sensor.

6. Display area: Shows the currently selected image.

7. Test parameters: Runs the pipeline on the selected image with current settings. The test folder will be opened automatically to inspect the control files.

8. Run: Runs the pipeline with the current settings**.

9. Log: Informs the user about performed actions.

10. Tools menu:
    - Save POCT template: Lets you save and print the POCT template to be used for the image acquisition.
- **Save QR labels template**: Lets you save an Excel template to be used to generate QR code labels for all your samples from a list.

- **Generate QR labels**: Lets you generate QR labels for your samples using the excel template or a csv file with a list of the names in the correct format: SAMPEID-MANUFACTURER-PLATE-WELL-USERDATA. You can use the USERDATA field for **very short** annotations; please make sure not to use dashes (-) in this field, but replace them with underscores (_). You can define the page size, label size, position and number per page to match the format for any printable label paper as, for instance, from AVERY.

- **Split images by type**: helps organizing mixtures of images from different POCT manufacturers stored in one and the same folder. The tool will analyze each of the images and attempt to extract the manufacturer information from the QR code (if present) or by searching for the name on the POCT itself (OCR). If the manufacturer can be resolved, the image is moved into a sub-folder with the name of the manufacturer, otherwise it will be moved into a subfolder called UNDEFINED. As long as the QR code structure is satisfied (which is guaranteed if using the **Generate QR labels** tool explained above), even previously unknown manufacturers can be recognized. Should the QR code detection fail, a fall-back OCR detection can use a comma-separated list of expected manufacturer names to potentially identify unknown manufacturers. The **input folder** defines the folder containing all the images to process, and **output folder** the location where the split images should be moved. The **number of cores** defines the number of images that will be processed in parallel.

11. **Help menu**:
   - **Quick instructions**: Shows the quick instructions dialog.
   - **Quick start**: Opens the quick start document describing how to set up the image acquisition setup, perform the acquisition and some potential problems and their solutions one might encounter.
   - **User manual**: Opens this document.
   - **About**: About the software and its dependencies.
The examples show the basic usage of pyPOCQuant to analyze images

3.1 pyPOCQuant quick start

For a reproducible and comparable analysis of your POCTs with pyPOCQuant, please carefully follow these instructions. They will show how to properly prepare the acquisition setup, the acquisition itself and the analysis of the images from lateral flow assays (LFA) / point of care tests (POCT).

This quick start guide focuses on the most relevant points. For detailed information read the relevant section in the user manual (Help -> Manual).

3.1.1 Preparation of the imaging acquisition setup

Materials needed:

- Camera, for example SLR/mirror less (recommended, use raw and jpg), pocket camera, mobile phone
- POCT Template / mount.
- A tripod to mount the camera above the POCT template and mount. Alternatively, a box (plastic box, or even a shoe box) can be used to mount the camera at a defined distance above the POCT template.
- Tape, glue, scissors or scalpel to fix and build the mounts.
- Printer to print the POCT template and the sample QR labels.
- Power bar to charge the camera batteries or power it directly.
- Desktop computer or laptop to transfer the images and run pyPOCQuant.

Instruction to build the POCT mount with the POCT template

Print our generic template (get it from Help -> POCT template) in black and white (ideally on non glossy paper to avoid disturbing reflections) and place the POCT to evaluate in the center of the QR code box. Cut out its cartridge outline with a scalpel or scissors (Fig. 1). The fine red grid will help you to align the POCT nicely with the QR code box border. Note: needs to be repeated for each cartridge design if its size changes.

Glue or stick the template on one or two cartons and again cut out the region to place the POCT (Fig. 2). Note: the narrower you cut the better it will hold the POCT at the exact same position.

The basis of the template mount could also be 3D printed or laser cut from any material and aligned with the POCT template to build a solid POCT mount.
Instructions to build the photo box / acquisition station

While setting up the imaging acquisition station there are three important points to consider.

- First, make sure that you have **constant lightning conditions**. If just using the POCT template and a tripod (Fig. 3) make sure you have a dark room otherwise daylight changes will influence the images. Best would be using a photo box (Fig. 4). *Note: Our POCT template changed over the course of the development but we don’t have images of the setup from each stage. Here you see a very early incomplete version of it. Please use the one presented in Fig. 1.*

- Second, make sure that during a series of tests of the same kind the **camera is well fixed on the tripod**. Ideally you use the camera timer option or a remote control to release the images to make sure that the distance between the camera and the POCT on the POCT template is constant.

- Third, make sure that the **field of view does not change during a series**. For this the POCT template is well fixed on the table and the tripod with camera is not moved. If this is not the case, you will need to create a configuration file for each image, and will not be able to easily batch process them!

3.1.2 Image acquisition

Do **not write to or stick anything on the POCT**. Use the QR code labels instead to allow for machine readable identification of the sample and place the QR above the QR code box in its dedicated place.

**Step 1:**
- Check that all QR codes on the template are in the field of view and on the image.

**Step 2:**
- Check that the light conditions are constant and there are no shadows on the POCT / sensor area and there are no reflections.

**Step 3:**
- Check that there are no vibrations during the acquisition which could lead to a bad or blurred image. If possible, use a remote control or computer control to take the images. If not available, use the timer option carefully to avoid moving the camera.

**Step 4:**
- Check that the image is sharp and in focus: in particular the POCT sensor area and the QR codes.

Example image meeting all criteria’s sufficiently except that the packaging is cut off. *Note: pyPOCQuant will detect the orientation of the image automatically. There is no need to rotate the images*
3.1.3 Analysis of the images with pyPOCQuant

- Follow the installer guide lines to install pyPOCQuant
- Install third-party dependences for your operating system.
  - Linux: zbar and tesseract.
    - In Ubuntu, you can install them with `sudo apt install libzbar0 tesseract-ocr`.
  - macOS: cairo, zbar and tesseract.
    - Using homebrew: `brew install cairo zbar tesseract`.

Note: For most images it is sufficient to just load an image (Step 3 & 4) and draw the sensor (Step 5) and then test the automatically determined & default parameters with (Step 7) and finally run it on all images (Step 8).

Step 1:
- Copy the images of the same kind (i.e., same POCT cartridge / manufacturer and/or same imaging station, objective, distance to the sample) into a folder. Note that the UI allows you to automatically split the images by manufacturer into subfolders (if included in the QR code labels); in addition, we provide a script to do so from the command line. For the details read the respective sections in the user manual (``Help -> User manual``).

Step 2:
- Start pyPOCQuant.

Step 3:
- Select the image folder you want to analyze. Click on `Browse input folder` (Ctrl+I).
- (Optional) Click on `Browse result folder` to select the folder where to save results, logs and quality control images. By default, a subfolder `pipeline` is created in the input folder.

Step 4:
- Click on one image (ideally one which shows all bands) to load it. After a while (green progress bar fully to the right) the POCT area will be extracted and displayed on the top-right canvas.

<table>
<thead>
<tr>
<th>Image selected - strip extraction pending</th>
<th>Image selected - strip extraction done and displayed</th>
</tr>
</thead>
</table>

Step 5:
- Hit the draw sensor icon in the toolbar and click into the image to draw a rectangle around the sensor area.
  
  The parameters `sensor_center`, `sensor_size` and `sensor_search_area` will be set automatically in this step.

| Click into the corners of the sensor to draw the sensor outline | Drawing finished. Parameters `sensor_center`, `sensor_size` and `sensor_search_area` have now been set automatically |

Step 6:
- Adjust the expected position of the bands by clicking on the vertical violet lines and move them in place such that they are centered and overlapping with the bands on the test. Optionally, you can also fine-adjust by changing the parameters in the tree.

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3.1. pyPOCQuant quick start
Step 7

- Change the band labels for t2, t1 and ctl band according to the test analyzed. For example sensor_band_names=(IgG, IgM, Ctl). These names will be used as prefixes in the header of the result table.

Step 8:

- Hit Test parameters and check the result based on the quality control images. If you get false positive detections for weak signals increase the advanced parameter sensor_thresh_factor and hit test again.
- If the result looks good (check the quality control images IMAGE_NAME_peak_overlays control image, and IMAGE_NAME_peak_analysis control image and the entries in the quantification data.csv file), you can continue. Otherwise adjust the parameters further, look up the advanced parameters in the manual, or check the common problems and solutions below.

Step 9:

- Hit Run to batch analyze all images in the folder in parallel.

Repeat the procedure for all other folders. *Note: if the POCT cartridge design changes or a different camera with a different perspective is used, a new configuration file has to be generated and tested. Otherwise, one can load the same configuration file also for other / new images. To load a configuration file just double-click on it if it is in the same folder as the input images, or hit Ctrl+O or select File -> Load settings from file*

3.1.4 Potential problems and their solution:

**Problem**: There are artifacts / weak signals that get quantified wrongly as a band (Fig. 5)

**Solution**: Increase the sensor threshold factor (Fig. 6)

![Fig 5](sensor_threshold_factor=1) ![Fig 6](sensor_threshold_factor=2)

**Problem**: One or more bands were missed or the wrong band(s) were extracted (Fig. 7)

**Solution**: Adjust the Peak expected relative location parameter for the band(s) which were not detected. If that did not solve the problem check the quality-control images if the sensor was detected correctly. If not adjust the sensor position and its size (Fig. 8).

![Fig 7](Fig 7) ![Fig 8](Fig 8)

**Problem**: Almost no pixels are considered for quantification (Fig. 9)
**Solution:** Reduce the sensor border x|y values to consider more pixels of the sensor (Fig. 10). If it considers too many pixels increase the parameter values.

**Problem:** I have a lot of images to be processed and it is slow.

**Solution:** Increase the Number of cores parameter to the maximum of your computer. Use a more powerful station or cluster.

**Problem:** By accident, the image was taken with the POCT wrongly oriented and the control band is left (Fig. 11).

**Solution:** Select the checkbox try to correct strip orientation. This will try to rotate the image correctly for the analysis (Fig 12). The qc image lets you verify if the correction works. If it does not work modify the parameters (Relative height factor, Relative center cut-off, Relative border cut-off) defining the size and position of the search rectangles. The red rectangle (Fig. 11) indicates where the inlet was found and will rotate the image such that the inlet is left and the control band on the right (Fig. 12). The search rectangles should only include the region around the pipetting inlet. If it still does not work, the last chance is to try and search for some text printed on one side of the POCT. Add the prominent text (for example, “COVID” as in Figg. 11 or 12) to the Strip text to search (orientation) parameter and select if the text is on the right or not (check or uncheck the Strip text is on the right parameter). If this still fails, the image will have to be discarded and a new one will need to be reacquired.

**Problem:** I have a lot of images from with different POCT cartridge designs from different manufacturers taken with the same camera but my configuration file does only work for one type.

**Solution:** Split the images into a subfolder for each cartridge design / manufacturer. If you used the QR code sample labels you can use the script described in the manual to do this automatically for you.

**Problem:** I have a lot of images with different POCT cartridge designs from different manufacturers. Do I really need a separate configuration for each design?

**Solution:** Unfortunately yes. As they come in any shape the software needs some specific guidance to know where to search for the bands and to allow for robust and reproducible results. One solution to relax this assumption would be to change the POCT cartridge design by including small qr codes directly next to the sensor. That would allow us also to get rid of the QR code template. If you have a direct contact to your favorite manufacturer, tell them about it and their potential competitive advantage in the market (Fig 13)!

**3.2 Command line usage**

**pyPOCQuant** can be used trough its command line interface (cli). It is convenient to process a large amount of different folder trough i.e a bash script.

To show the usage type:

```
python -m pypocquant.pyPOCQuant --help
```

To run the pipeline for a given folder and config type:

```
python -m pypocquant.pyPOCQuant_FH -f path/to/images -s path/to/config.conf -w 10
```

To split and organize images of different kinds in one folder type:
3.3 Scripting

**pyPOCQuant** can be used directly from within python scripts and therefore being part of a larger workflow. It is convenient to process a large amount of different folder automatically. Or further automatically process results and generation of reports.

Minimal example with default settings. Add the following code to a file such as *example.py* wile replacing the *input_folder_path* and *results_folder_path* to the example or your images:

```python
from pypocquant.lib.pipeline import run_pipeline
from pypocquant.lib.settings import default_settings

# Get the default settings
settings = default_settings()

# Change settings manually as needed
settings['sensor_band_names'] = ('igm', 'igg', 'ctl')

# Alternatively, load existing settings file
# from pypocquant.lib.settings import load_settings
# settings = load_settings('full/path/to/settings/file.conf')

# Set final argument
input_folder_path = 'full/path/to/input/folder'
results_folder_path = 'full/path/to/results/folder'
max_workers = 8

# Run the pipeline
run_pipeline(
    input_folder_path,
    results_folder_path,
    **settings,
    max_workers=max_workers
)
```

and run it with:

```bash
python -m example.py
```

3.4 pyPOCQuant with Jupyter

Demo notebook to show the usage of **pyPOCQuant** using a Jupyter/IPython notebook.

This is a convinient way to automate the execution of multiple folders and directly analize and plot the results.

```python
# Load the relevant dependencies
import os
import sys
```
```python
import pandas as pd
sys.path.append('..\..')
from pypocquant.lib.pipeline import run_pipeline
from pypocquant.lib.settings import load_settings
from pathlib import Path
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from IPython.display import Image, display

Next lets load and print the example config

```python
[8]: p = Path(os.path.abspath('images'))
settings_file_path = Path(p.parent / 'config.conf')
print('The pipeline will be run with the following configuration')
f = open(str(settings_file_path), "r")
print(f.read())

The pipeline will be run with the following configuration
max_workers=4
qc=True
verbose=True
control_band_index=-1
sensor_band_names=('igm', 'igg', 'ctl')
peak_expected_relative_location=(0.31, 0.53, 0.75)
sensor_center=(147, 522)
sensor_size=(45, 215)
sensor_border=(7, 7)
perform_sensor_search=True
qr_code_border=40
subtract_background=True
sensor_search_area=(55, 225)
sensor_thresh_factor=2.0
raw_auto_stretch=False
raw_auto_wb=False
strip_try_correct_orientation=False
strip_try_correct_orientation_rects=(0.52, 0.15, 0.09)
strip_text_to_search=''
strip_text_on_right=False
force_fid_search=False

```python
[9]:
if settings_file_path.exists():
    input_folder_path = Path(p)
    results_folder_path = Path(input_folder_path / 'pipeline')
    results_folder_path.mkdir(parents=True, exist_ok=True)
    print(f'RUN pipeline for {p}"

## Load the settings
settings = load_settings(settings_file_path)

## Run the pipeline
run_pipeline(
    input_folder_path,
    results_folder_path,
    **settings
)
```
3.4.1 Read and plot the results

```python
[10]: results = pd.read_csv(str(Path(p / 'pipeline/quantification_data.csv')))
results
```

```
   fid   fid_num   filename  extension  basename  \
0  H01601828610122  1601828610122  IMG_9067.JPG  .JPG  IMG_9067
1    F5921394       5921394  IMG_9068.JPG  .JPG  IMG_9068
2    F5922180       5922180  IMG_9069.JPG  .JPG  IMG_9069
3    F5922944       5922944  IMG_9070.JPG  .JPG  IMG_9070

    iso_date  iso_time  exp_time  f_number  focal_length_35_mm  ...
  igm  0  2020-06-21  12-14-03  [1/10]  [63/10]       -1  ...  0
   1  2020-06-21  12-14-46  [1/10]  [63/10]       -1  ...  1
   2  2020-06-21  12-15-07  [1/10]  [63/10]       -1  ...  1
   3  2020-06-21  12-15-28  [1/10]  [63/10]       -1  ...  0

   igm_abs  igm_ratio  igg  igg_abs  igg_ratio  ctl  ctl_abs  \
   0  0.000000  0.000000  0  0.000000  0.000000  1  1087.000925
   1  1443.824091  822.735949  1  1443.824091  1.414340  1  1020.846550
   2  1029.903783  200.968865  1  1029.903783  0.998311  1  1031.645989
   3  405.080753  0.000000  1  405.080753  0.403488  1  1003.946928

cTL_ratio  user
   0  1.0  CUNYA
   1  1.0  CUNYA
   2  1.0  CUNYA
   3  1.0  CUNYA
[4 rows x 25 columns]
```

```python
[11]: %matplotlib inline
    dm = pd.melt(results, id_vars=['fid'], value_vars=['igm', 'igg', 'ctl', 'igm_abs',
        'igg_abs', 'ctl_abs', 'igm_ratio', 'igg_ratio', 'ctl_ratio'])
    g = sns.catplot(x="fid", y="value", hue="fid", col='variable', col_wrap=6, data=dm,
        sharey=False, height=1, aspect=1.6)
    g.set_xticklabels(rotation=90)
    axes = g.axes.flatten()
```

(continues on next page)
3.4.2 Check the qc images

```
[i1, i2, i3, i4] = display(Image(filename=str(Path(p / 'pipeline/IMG_9068_JPG_peak_analysis.PNG'))),
                      Image(filename=str(Path(p / 'pipeline/IMG_9068_JPG_peak_overlays.PNG'))),
                      Image(filename=str(Path(p / 'pipeline/IMG_9068_JPG_strip_gray_aligned.PNG'))),
                      Image(filename=str(Path(p / 'pipeline/IMG_9068_JPG_rotated.JPG'))))
```

3.4.3 Inspect the log file

```python
f = open(str(Path(p / 'pipeline/log.txt')), "r")
print(f.read())
f.close()
```

File = 20210105_config_run_1.conf

File = IMG_9067.JPG
Processing IMG_9067.JPG
Best percentiles for barcode extraction: (0, 100); best scaling factor = 0.25; score = 6/6
Detected FIDs for rotated image: H01601828610122 H01601828610122
File IMG_9067.JPG: best percentiles for barcode extraction after rotation: (0, 100); best scaling factor = 0.5; score = 6/6
File IMG_9067.JPG: Strip box image rotated by angle -0.285863954857813 degrees using QR code locations.
File IMG_9067.JPG: FID = 'H01601828610122'
File IMG_9067.JPG: sensor coordinates = [126, 171, 423, 638], score = 1.0
Peak 143 has lower bound 99 (d = 44) with relative intensity 0.00 and upper bound 166 (d = 23) with relative intensity 0.00. Band width is 68. Band skewness is 0.52
File IMG_9067.JPG: the bands were 'normal'.
^ax File IMG_9067.JPG: successfully processed and added to results table.

File = IMG_9068.JPG

(continues on next page)
Processing IMG_9068.JPG
Best percentiles for barcode extraction: (0, 100); best scaling factor = 0.25; score = 6/6
Detected FIDs for rotated image: F5921394 F5921394
File IMG_9068.JPG: best percentiles for barcode extraction after rotation: (0, 100);
→best scaling factor = 0.25; score = 6/6
File IMG_9068.JPG: Strip box image rotated by angle -0.32740089084438817 degrees
→using QR code locations.
File IMG_9068.JPG: FID = 'F5921394'
File IMG_9068.JPG: sensor coordinates = [126, 171, 416, 631], score = 1.0
Peak 65 has lower bound 45 (d = 20) with relative intensity 0.00 and upper bound 83
→(d = 18) with relative intensity 0.01. Band width is 39. Band skewness is 0.90
Peak 112 has lower bound 90 (d = 22) with relative intensity 0.01 and upper bound 142
→(d = 30) with relative intensity 0.00. Band width is 53. Band skewness is 1.36
Peak 159 has lower bound 138 (d = 21) with relative intensity 0.00 and upper bound 201 (d = 42) with relative intensity 0.00. Band width is 64. Band skewness is 2.00
File IMG_9068.JPG: the bands were 'normal'.
^ae" File IMG_9068.JPG: successfully processed and added to results table.

File = IMG_9069.JPG
Processing IMG_9069.JPG
Best percentiles for barcode extraction: (0, 100); best scaling factor = 0.5; score = 6/6
Detected FIDs for rotated image: F5922180 F5922180
File IMG_9069.JPG: best percentiles for barcode extraction after rotation: (0, 100);
→best scaling factor = 0.5; score = 6/6
File IMG_9069.JPG: Strip box image rotated by angle -0.28627203365974213 degrees
→using QR code locations.
File IMG_9069.JPG: FID = 'F5922180'
File IMG_9069.JPG: sensor coordinates = [126, 171, 416, 631], score = 1.0
Peak 65 has lower bound 43 (d = 22) with relative intensity 0.00 and upper bound 79
→(d = 20) with relative intensity 0.03. Band width is 37. Band skewness is 0.64
Peak 112 has lower bound 89 (d = 23) with relative intensity 0.00 and upper bound 143
→(d = 31) with relative intensity 0.00. Band width is 55. Band skewness is 1.35
Peak 158 has lower bound 133 (d = 25) with relative intensity 0.00 and upper bound 200 (d = 42) with relative intensity 0.00. Band width is 68. Band skewness is 1.68
File IMG_9069.JPG: the bands were 'normal'.
^ae" File IMG_9069.JPG: successfully processed and added to results table.

File = IMG_9070.JPG
Processing IMG_9070.JPG
Best percentiles for barcode extraction: (0, 100); best scaling factor = 0.25; score = 6/6
Detected FIDs for rotated image: F5922944 F5922944
File IMG_9070.JPG: best percentiles for barcode extraction after rotation: (0, 100);
→best scaling factor = 0.5; score = 6/6
File IMG_9070.JPG: Strip box image rotated by angle -0.4086648209901469 degrees using
→QR code locations.
File IMG_9070.JPG: FID = 'F5922944'
File IMG_9070.JPG: sensor coordinates = [126, 171, 424, 639], score = 1.0
Peak 96 has lower bound 76 (d = 20) with relative intensity 0.01 and upper bound 122
→(d = 26) with relative intensity 0.00. Band width is 47. Band skewness is 1.30
Peak 141 has lower bound 122 (d = 19) with relative intensity 0.01 and upper bound 190 (d = 49) with relative intensity 0.00. Band width is 69. Band skewness is 2.58
File IMG_9070.JPG: the bands were 'normal'.
^ae" File IMG_9070.JPG: successfully processed and added to results table.
File = pipeline
File = test

```python
"""Entry point for launching an IPython kernel.
"""
```
pyPOCQuant is released under the GPL v3 license:

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**Version 3, 29 June 2007**


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@article{cuny2020,
    author = {Andreas P. Cuny and Fabian Rudolf and Aaron Ponti},
    title = {A tool to automatically quantify Point-Of-Care Tests from images},
    journal = {MedRxiv},
    year = {2020},
    doi = {10.1101/2020.11.08.20227470}
}
This page contains auto-generated API reference documentation¹.

## 7.1 pypocquant

### 7.1.1 Subpackages

**pypocquant.lib**

**Submodules**

**pypocquant.lib.analysis**

### Module Contents

#### Functions

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<td>Determine the minimal euclidean distance of a set of coordinates.</td>
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¹ Created with sphinx-autoapi
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```python
from pypocquant.lib.analysis import get_min_dist

get_min_dist(xy1, xy2)
```

Determine the minimal euclidean distance of a set of coordinates.

**Parameters**

- `xy1` – First set of coordinates
- `xy2` – Second set of coordinates

**Returns** Minimal distance

**Return type** `tuple`

```python
from pypocquant.lib.analysis import identify_bars_alt

identify_bars_alt(peak_positions, profile_length, sensor_band_names, expected_relative_peak_positions, tolerance)
```

Assign the peaks to the corresponding bar based on the known relative position in the sensor.

**Parameters**

- `peak_positions` – list List of absolute peak positions in pixels.
- `profile_length` – Length of the profile in pixels.
• **sensor\_band\_names** – Tuple[str, ...] Tuple of sensor band names.

• **expected\_relative\_peak\_positions** – Tuple[float, ...] Tuple of expected relative (0.0 -> 1.0) peak positions.

• **tolerance** – Distance tolerance between peak position and expected position for assignment.

**Returns** dictionary of band assignments: {bar\_name: index}

```python
pytocquant.lib.analysis.invert\_image(image, bit\_depth=8)
```

Inverts an image.

**Parameters**

• **image** – Image to be inverted

• **bit\_depth** – Bit depth of image

**Returns** image\_inv: Inverted image.

**Return type** uint8

```python
pytocquant.lib.analysis.local\_minima(array, min\_distance=1)
```

Find all local minima of the array, separated by at least min\_distance.

**Parameters**

• **array** – Signal array

• **min\_distance** – Minimal distance for local minima seperation

**Returns** array: Array with local minimas

**Return type** np.array

```python
pytocquant.lib.analysis._find\_lower\_background(profile: np.ndarray, peak\_index: int, lowest\_bound: int, max\_skip: int = 1)
```

This method is used by find\_peak\_bounds() and is not meant to be used as a standalone method.

**Parameters**

• **profile** (np.ndarray) – Signal profile

• **peak\_index** (int) – Index of the peak

• **lowest\_bound** (int) – Highest bound

• **max\_skip** (int) – Max skip

**Returns** current\_lower\_bound: Upper bound

**Returns** current\_lower\_background: Upper background

**Returns** d\_lower:

```python
pytocquant.lib.analysis._find\_upper\_background(profile: np.ndarray, peak\_index: int, highest\_bound: int, max\_skip: int = 1)
```

This method is used by find\_peak\_bounds() and is not meant to be used as a standalone method.

**Parameters**

• **profile** (np.ndarray) – Signal profile

• **peak\_index** (int) – Index of the peak

• **highest\_bound** (int) – Highest bound

• **max\_skip** (int) – Max skip
pyPOCQuant

    Returns current_upper_bound: Upper bound
    Returns current_upper_background: Upper background
    Returns d_upper:

    pypocquant.lib.analysis.find_peak_bounds(profile, border, peak_index, image_log, verbose=False)
    Find the lower and upper bounds of current band.

    Parameters
    • profile (np.ndarray) – Signal profile
    • border (int) – Border offset
    • peak_index (int) – Index of the peak
    • image_log (list) – Image log
    Returns current_lower_bound: Lower bound
    Returns current_upper_bound: Upper bound
    Returns image_log: Log for this image

    pypocquant.lib.analysis.fit_and_subtract_background(profile, border, subtract_offset=10)
    Use a robust linear estimator to estimate the background of the profile and subtract it.

    Parameters
    • profile (np.ndarray) – Signal profile
    • border (int) – Border offset
    • subtract_offset (int) – Fixed offset to be used for substraction.
    Returns profile: Background corrected profile.
    Returns background: Estimated background.
    Returns background_offset: Background offset.

    pypocquant.lib.analysis.estimate_threshold_for_significant_peaks(profile, border_x, thresh_factor)
    Estimate threshold for significant peaks in sensor signal.

    Parameters
    • profile (np.ndarray) – Signal profile
    • border_x (int) – Border offset in x
    • thresh_factor (float) – Threshold factor for estimation.
    Returns peak_threshold:
    Returns loc_min_indices
    Returns md
    Returns lowest_background_threshold
Quantify the band signal across the sensor.

Notice: the expected relative peak positions for the original strips were: [0.30, 0.52, 0.74]

**Parameters**

- `window (np.ndarray)` – Window (image) to be analyzed.
- `border_x (int)` – Border offset in x from window.
- `border_y (int)` – Border offset in y from window.
- `thresh_factor (float)` – Threshold factor from background.
- `peak_width (int)` – Minimal width of a peak.
- `sensor_band_names ([str, ...])` – Names of the sensor bands (test lines TL).
- `peak_expected_relative_location (tuple[float, ...])` – Tuple of relative expected peak positions in respect to the window.
- `control_band_index (int)` – Index of the control band for the list sensor_band_names.
- `subtract_background (bool)` – Bool to substract background.
- `qc (bool)` – Bool to retrun qc image.
- `verbose (bool)` – Bool to return verbose logging information
- `out_qc_folder (Path)` – QC image output folder
- `basename (str)` – Basename
- `image_log (list)` – Image log list.

**Returns**

- `merged_results (list)` – Merged results
- `image_log (Image log)` – Image log

**pypocquant.lib.analysis.extract_inverted_sensor (gray, sensor_center=(119, 471), sensor_size=(40, 190))**

Returns the sensor area at the requested position without searching.

**Parameters**

- `gray` – Gray image.
- `sensor_center` – Sensor center coordinate on gray image.
- `sensor_size` – Sensor size on gray image.
Returns inverted_image Returns the extracted sensor on an inverted image.

```python
pypocquant.lib.analysis.get_sensor_contour_fh(strip_gray, sensor_center, sensor_size, sensor_search_area, peak_expected_relative_location, control_band_index=-1, min_control_bar_width=7)
```

Extract the sensor area from the gray strip image.

**Parameters**

- `strip_gray` – np.ndarray Gray-value image of the extracted strip.
- `sensor_center` – Tuple[int, int] Coordinates of the center of the sensor (x, y).
- `sensor_size` – Tuple[int, int] Size of the sensor (width, height).
- `sensor_search_area` – Tuple[int, int] Size of the sensor search area (width, height).
- `peak_expected_relative_location` – list[float, ...] List of expected relative peak (band) positions in the sensor (0.0 -> 1.0).
- `control_band_index` – int Index of the control band in the peak_expected_relative_location. (Optional, default -1 := right-most)
- `min_control_bar_width` – int Minimum width of the control bar (in pixels). (Optional, default 7)

**Returns**

- Realigned sensor: np.ndarray
- Sensor coordinates: [y0, y, x0, x]
- sensor_score: score for the sensor extracted (obsolete: fixed at 1.0)
- Return type tuple

```python
pypocquant.lib.analysis.extract_rotated_strip_from_box(box_gray, box)
```

Segments the strip from the box image and rotates it so that it is horizontal.

**Parameters**

- `box_gray` – Gray image of QR code box containing strip
- `box` – RGB image of QR code box containing strip

**Returns**

- strip_gray Extracted gray strip from box
- strip Extracted RGB strip from box

```python
pypocquant.lib.analysis.adapt_bounding_box(bw, x0, y0, width, height, fraction=0.75)
```

Make the bounding box come closer to the strip by remove bumps along the outline.

**Parameters**

- `bw` – Binary mask of an image.
- `x0` – Top left corner in x.
- `y0` – Top left corner in y
- `width` – Mask width
- `height` – Mask height
- `fraction` –

**Returns**

- `new_y0:`
- `new_y:`
Returns new_x0:

Returns new_x:

`pypocquant.lib.analysis.point_in_rect(point, rect)`
Check if the given point (x, y) is contained in the rect (x0, y0, width, height).

Parameters point – Point to be checked if in rectangle

:param rect Rectangle defined by (x0, y0, width, height)

returns bool: :rtype: bool

`pypocquant.lib.analysis.get_rectangles_from_image_and_rectangle_props(img_shape, rectan- 
gle_props=(0.52, 0.15, 0.09))`  
Calculate the left and right rectangles to be used for the orientation analysis using the Hough transform.

Parameters img_shape – tuple

Image shape (width, height)

Parameters rectangle_props – tuple Tuple containing information about the relative position of the two rectangles to be searched for the inlet on both sides of the center of the image:

rectangle_props[0]: relative (0..1) vertical height of the rectangle with respect to the image height.

rectangle_props[1]: relative distance of the left edge of the right rectangle with respect to the center of the image.

rectangle_props[2]: relative distance of the left edge of the left rectangle with respect to the center of the image.

Returns left_rect: Left rectangles

Returns right_rect: Right rectangles

Return type tuple

`pypocquant.lib.analysis.use_hough_transform_to_rotate_strip_if_needed(img_gray, rectan- 
gle_props=(0.52, 0.15, 0.09), stretch=False, img=None, qc=False)`  
Estimate the orientation of the strip looking at features in the area around the expected sensor position. If the orientation is estimated to be wrong, rotate the strip.

Parameters

- img_gray – np.ndarray Gray-scale image to be analyzed.

- rectangle_props – tuple Tuple containing information about the relative position of the two rectangles to be searched for the inlet on both sides of the center of the image:
rectangle_props[0]: relative (0..1) vertical height of the rectangle with respect to the image height.

rectangle_props[1]: relative distance of the left edge of the right rectangle with respect to the center of the image.

rectangle_props[2]: relative distance of the left edge of the left rectangle with respect to the center of the image.

• **stretch** – bool Set to True to apply auto-stretch to the image for Hough detection (1, 99 percentile). The *original* image will be rotated, if needed.

• **img** – np.ndarray or None (default) Apply correction also to this image, if passed.

• **qc** – bool If True, create quality control images.

**Returns**
- img_gray: Gray image.
- img: RGB Image.
- qc_image QC image.
- rotated Bool; true if was rotated
- left_rect: Left rectangles
- right_rect: Right rectangles

**Return type** tuple

```python
pypocquant.lib.analysis.use_ocr_to_rotate_strip_if_needed(img_gray, img=None, text='COVID', on_right=True)
```

Try reading the given text on the strip. The text is expected to be on one side of the strip; if it is found on the other side, rotate the strip.

We apply the same rotation also to the second image, if passed.

**Parameters**
- **img_gray** – Gray input image to be potentially rotated.
- **img** – RGB input image to be potentially rotated.
- **text** – Text to be identified by OCR.
- **on_right** – Position of text to be identified in respect to the strip orientation.

**Returns**
- img_gray: Gray image.
- img: RGB Image.
- rotated Bool; true if was rotated

```python
pypocquant.lib.analysis.read_patient_data_by_ocr(image, known_manufacturers=consts.KnownManufacturers)
```

Try to extract the patient data by OCR.

**Parameters**
- **image** – Input image to be read with OCR.
- **known_manufacturers** – List with known manufacturers.

**Returns** fid: FID number.

**Returns** manufacturer: manufacturer name.
pyPOCQuant

pyPocquant.lib.barcode

Module Contents

Classes

Barcode

- **Barcode**
  - Pythonic barcode object.

Functions

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<td>Detect the barcode in the image.</td>
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<tr>
<td><code>get_fid_numeric_value</code></td>
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```python
class pypocquant.lib.barcode.Barcode(top: int, left: int, width: int, height: int, data: Union[bytes, str], symbol: str):
    Bases: object

    Pythonic barcode object.

classmethod from_barcode(cls, barcode)
    Initialize from pyzbar barcode object.

    Parameters barcode – A barcode (QR, CODE39, CODE128).

    scale(self, factor: float)
    Scale the barcode object by given factor.

    The (top, left) is scaled accordingly.

    Parameters factor – Scaling factor for the barcode.

    __str__ (self)
    Return str(self).

    __repr__ (self)
    Return repr(self).

pypocquant.lib.barcode.detect (image: np.ndarray, expected_area=22000, expected_aspect_ratio=7.5, barcode_border=75, blur_size=(3, 3), morph_rect=(9, 3), mm_iter=1, qc=True, verbose=False)
```

Detect the barcode in the image.

Adapted from: https://www.pyimagesearch.com/2014/11/24/detecting-barcodes-images-python-opencv/

Returns the extracted barcode image, the coordinates of the extracted rectangle, the (possibly rotated) image, and (if qc is True) a copy of the (possibly rotated) image with the extracted rectangle coordinates overlaid on it.

Parameters

- `image (np.ndarray)` – Image from which barcode should be read
- `expected_area (int)` – Expected area for barcode.
- `expected_aspect_ratio (float)` – Aspect ratio for barcode.
- `barcode_border (int)` – Border of the barcode.
- `blur_size (tuple)` – Kernel (3, 3) by default for bluring the image.
• **morph_rect (tuple)** – Kernel (9,3) by default for morph rect.
• **mm_iter (int)** – Dilation & Eroding iterations.
• **qc (bool)** – Bool, if true quality control images will be saved.
• **verbose (bool)** – Bool, if true additional loggin info will be displayed.

Returns barcode_img: The image of the barcode.
Returns coordinates: The position and size coordinates of the barcode (x,y, w, h)/
Return type coordinates: tuple
Returns image: The image.
Returns mask_image: The mask of the image.
Return type tuple

**pypocquant.lib.barcode.rotate (image, angle)**

Rotate the image by given angle in degrees.

Parameters

• **image** – The image to be rotated.
• **angle** – Rotation angle in degrees for the image.

Returns image: Rotated image.

**pypocquant.lib.barcode.calc_area_and_approx_aspect_ratio (contour)**

Calculate area and approximate aspect ratio of a contour.

Parameters **contour** – cv2.Contour.

Returns area: Area of the contour.
Returns aspect_ratio: Aspect ratio of the contour.

**pypocquant.lib.barcode.rotate_90_if_needed (image)**

Try to estimate the orientation of the image, and rotate if needed.

@TODO: This is not very robust so far.

Parameters **image** – Image to be rotated by 90 degrees.

Returns image: By 90 degrees rotated image.

**pypocquant.lib.barcode.read_FID_from_barcode_image (image)**

Read the FID string from the barcode image using pytesseract and decode the barcode itself using pyzbar.

Parameters **image** – Image to read FID from barcode.

Returns fid_tesseract: FID detected by tesseract (OCR).
Returns fid_pyzbar: FID detected by pyzbar (barcode).

Returns score: Score how well FID detection worked. For more details about the score read the manual.

**pypocquant.lib.barcode.get_fid_from_barcode_data (barcode_data, **
barcode_type='CODE128')**

Parse the output of pyzbar and retrieve the FID.

Parameters

• **barcode_data** – Barcode data (zbar).
• **barcode_type** – Type of barcode (CODE39, CODE128, QRCODE).
pyPQQuan

**Returns** barcode: Decoded barcode as utf8.

```python
py pocquant.lib.barcode.get_fid_from_box_image_using_ocr(box_img)
```

Use pytesseract to retrieve FID from the strip box image.

**Parameters**
- **box_img** – Image of the QR code box.

**Returns** fid_tesseract: FID detected by tesseract from image using OCR.

```python
py pocquant.lib.barcode.try_extracting_barcode_from_box_with_rotations(box,
scaling=(1.0, 0.5, 0.25),
verbose=False, log_list=None)
```

Try extracting barcode from QR code box while scaling it for different orientations [0, 90, 180, -90].

**Parameters**
- **box** – QR code box
- **scaling** – Scaling factors.
- **verbose** – Display additional logging information to the console.
- **log_list** – Log list.

**Returns** fid: FID number

**Returns** log_list Appended Log list with current log information.

```python
py pocquant.lib.barcode.try_extracting_barcode_with_rotation(image,
angle_range=15, verbose=True, log_list=None)
```

Try extracting barcode from QR code box for a list of angles in the range of `angle_range`.

**Parameters**
- **image** – Input image
- **angle_range** (`int`) – Range of angles to rotate input images in degrees.
- **verbose** – Display additional logging information to the console.
- **log_list** – Log list.

**Returns** fid: Extracted FID

**Returns** angle: Rotation angle that led to FID detection

**Returns** log_list: Appended log list.

```python
py pocquant.lib.barcode.find_strip_box_from_barcode_data_fh(image, barcode_data,
qr_code_border=30, qc=False)
```

Extract the box around the strip using the QR barcode data.

**Parameters**
- **image** – Strip image.
- **barcode_data** – Barcode data.
• **qr_code_border** – Border around QR codes.
• **qc** – Bool, if true quality control image will be saved.

**Returns**

- box: Strip box.
- qr_code_size: The size of the QR codes (qr_code_width, qr_code_height).
- qc_image: Quality control image.
- box_rect: Rectangle of the QR box.

```python
find_strip_box_from_barcode_data(image, barcode_data, qr_code_border=30, qr_code_spacer=40, barcode_border=80, qc=False)
```

Extract the box around the strip using the QR barcode data.

**Parameters**

- **image** – Input image.
- **barcode_data** – Barcode data
- **qr_code_border** – Border around QR code on image.
- **qr_code_spacer** – Spacer around QR code.
- **barcode_border** – Border around barcode such as CODE128.
- **qc** – Bool, if true quality control image will be saved.

**Returns**

- box QR code box around strip
- x_barcode Return the (x) coordinate of the left edge of the barcode rectangle.
- qr_code_size: The size of the QR codes (qr_code_width, qr_code_height).
- qc_image Quality control image.

```python
try_extracting_barcode_with_linear_stretch(image, lower_bound_range=(25), upper_bound_range=(98))
```

Try to extract the barcodes from the image by rescaling the intensity of the image with a linear stretch.

**Parameters**

- **image** – Input image
- **lower_bound_range** – Lower bound range.
- **lower_bound_range** – tuple
- **upper_bound_range** – Upper bound range.
- **upper_bound_range** – tuple

**Returns**

- gray

```python
try_getting_fid_from_code128_barcode(barcode_data)
```

Try finding a CODE 128 barcode in barcode data that should contain the patient FID.

**Parameters**

- **barcode_data** – Barcode data
pyPQQuant

Returns barcode: Decoded CODE128 barcode.

pyPQQuant.lib.barcode.try_get_fid_from_rgb(image)
Extract FID from rgb image.

Parameters

- **image** – RGB image with FID.

Returns fid: Detected FID as string.

pyPQQuant.lib.barcode.try_extracting_fid_and_all_barcodes_with_linear_stretch_fh(image,
lower_bound_range=(0, 5, 15, 25, 35),
upper_bound_range=(100, 98, 95, 92, 89),
scaling=(1.0))

Try extracting the fid and all barcodes from the image by rescaling the intensity of the image with a linear stretch.

Parameters

- **image** – Input image
- **lower_bound_range** – Lower bound range.
- **lower_bound_range** – tuple
- **upper_bound_range** – Upper bound range.
- **upper_bound_range** – tuple
- **scaling** – Scaling factor
- **scaling** – tuple

Returns barcodes: Barcode object

Returns fid: FID number

Returns manufacturer: Manufacturer name.

Returns plate: Plate info.

Returns well: Well info.

Returns user: Additional user data.

Returns best_lb: Best lower bound.

Returns best_ub: Best upper bound

Returns best_score: Best score.

Returns best_scaling_factor: Best scaling factor

Returns fid_128: FID 128 code.
Try extracting all barcodes from the image by rescaling the intensity of the image with a linear stretch.

**Parameters**
- `image` – Input image.
- `lower_bound_range` – Lower bound range.
- `upper_bound_range` – Upper bound range.

**Returns**
- `best_barcode_data` – Returns barcode data.
- `best_lb` – Returns best lower bound.
- `best_ub` – Returns best upper bound.
- `best_score` – Returns best score.

Rotate the image if the orientation is not the expected one.

**Parameters**
- `image` – Input image.
- `barcode_data` – Barcode data.
- `image_log` – Image log list.
- `verbose` (bool) – Bool, if true displays additional information to the console.

**Returns**
- `image_was_rotated` – Bool, true if image was rotated.
- `image` – Rotated image.
• **verbose (bool)** – Bool, if true displays additional information to the console.

**Returns** image_was_rotated: Bool, true if image was rotated.

**Return type** image_was_rotated: bool

**Returns** image: Rotated image.

**Returns** image_log: Log for this image

**Return type** tuple

```python
pypocquant.lib.barcode.pick_FID_from_candidates(fid_pyzbar, fid_tesseract)
```

Selection of FID from candidates depending on if candidates contain a FID.

**Parameters**

• **fid_pyzbar** – FID string determined with pyzbar.

• **fid_tesseract** – FID string determined with tesseract.

**Returns** fid FID number

**Returns** score Score for the candidate determination.

```python
pypocquant.lib.barcode.mask_strip(strip_gray, x_barcode, qr_code_extents)
```

Hide the barcode on the strip image.

**Parameters**

• **strip_gray** – Image of the strip (POCT).

• **x_barcode** – X coordinate of the barcode on the strip.

• **qr_code_extents** – QR code extents on the strip.

**Returns** strip_gray_masked Strip with QR code masked away.

**Returns** background_value Background value used for strip masking.

```python
pypocquant.lib.barcode.extract_strip_from_box(box, qr_code_width, qr_code_height, qr_code_spacer=40, slack=0)
```

Extract the strip from the strip box.

**Parameters**

• **box** – Image of the QR code box.

• **qr_code_width** – Width of the QR code

• **qr_code_height** – Height of the QR code

• **qr_code_spacer** – Horizontal and vertical distance between the internal edge of the QR codes and the beginning of the strip.

• **slack** – Some buffer (subtracted from qr_code_spacer) to avoid cropping into the strip

**Returns** strip Returns the extracted POCT strip as image matrix.

```python
pypocquant.lib.barcode.get_fid_numeric_value_fh(fid)
```

Return the numeric value of the FID (as string).

A FID could be in the form ‘F0123456’. We want to preserve the leading 0 after we removed the ‘F’.

**Parameters** **fid** (str) – FID number

**Returns** fid:

```python
pypocquant.lib.barcode.get_fid_numeric_value(fid)
```

Return the numeric value of the FID.
Parameters $\text{fid} (\text{str})$ – FID number

Returns filtered_fid: FID number as numeric

`pypocquant.lib.barcode.get_box_rotation_angle(pt1, pt2, pt3)`
Determine the QR code box rotation angle

Parameters

- $\text{pt1}$ – Coordinate corner 1
- $\text{pt2}$ – Coordinate corner 2
- $\text{pt3}$ – Coordinate corner 3

Returns rot_angle Rotation angle in degree.

`pypocquant.lib.barcode.align_box_with_image_border_fh(barcode_data, image)`
Method to align QR code box with image border of the full image (old pipeline).

Parameters

- $\text{barcode_data}$ – QR code data
- $\text{image}$ – Image

Returns image_rotated: Rotated image

Returns angle Rotation angle in degrees.

`pypocquant.lib.barcode.align_box_with_image_border(barcode_data, image)`
Method to align QR code box with image border of the full image.

Parameters

- $\text{barcode_data}$ – QR code data
- $\text{image}$ – Image

Returns image_rotated: Rotated image

Returns angle Rotation angle in degrees.

`pypocquant.libconsts`

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<thead>
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<th>Issue</th>
<th>Issues detected during image processing.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SymbolTypes</td>
<td>SymbolTypes of zbar. Currently we support CODE39, CODE128 and QRCODE detection.</td>
</tr>
</tbody>
</table>

**class** `pypocquant.libconsts.Issue`

Bases: `enum.Enum`

Issues detected during image processing.

Returns Issue code

- `NONE = 0`
- `BARCODE_EXTRACTION_FAILED = 1`
**FID_EXTRACTION_FAILED** = 2
**STRIP_BOX_EXTRACTION_FAILED** = 3
**STRIP_EXTRACTION_FAILED** = 4
**POOR_STRIP_ALIGNMENT** = 5
**SENSOR_EXTRACTION_FAILED** = 6
**BAND_QUANTIFICATION_FAILED** = 7
**CONTROL_BAND_MISSING** = 8

class pypocquant.libconsts.SymbolTypes
    Bases: enum.Enum
    SymbolTypes of zbar. Currently we support CODE39, CODE128 and QR CODE detection. :param Enum:
    Returns TYPES
    Return type list

TYPES

pypocquant.libconsts.KnownManufacturers = ['AUGURIX', 'BIOZAK', 'CTKBIOTECH', 'DRALBERMEXACARE', 'LUMIRATEK', 'NTBIO', 'SUREBIOTECH', 'TAMIRNA']

pypocquant.libconsts.BAND_COLORS

Module Contents

Functions

```python
load_and_process_image(full_filename: str, raw_auto_stretch: bool = False, raw_auto_wb: bool = False, to_rgb: bool = False) # Load a supported (standard) image file format such as '.jpg', '.tif', '.png' and
is_raw(filename: str) -> bool # Check whether the image is one of the supported RAW
```

```python
pypocquant.lib.io.load_and_process_image (full_filename: str, raw_auto_stretch: bool = False, raw_auto_wb: bool = False, to_rgb: bool = False) # Load a supported (standard) image file format such as '.jpg', '.tif', '.png' and some RAW file formats ('.nef', '.cr2', '.arw').
```

Parameters

- **full_filename** *(str)* – Full path to the file to open.
- **raw_auto_stretch** *(bool)* – (Only applies to RAW image file formats). Set to True to automatically stretch image intensities (default = False).
- **raw_auto_wb** *(bool)* – (Only applies to RAW image file formats). Set to True to automatically apply white-balancing (default = False).
- **to_rgb** *(bool)* – Set to True to convert from BGR (openCV standard, used in processing) to RGB (for display, default = False).

Returns image: Loaded (and possibly processed) image, or None if the image could not be opened.
Return type  cv2.Image

pypocquant.lib.io.is_raw(filename: str) → bool

Check whether the image is one of the supported RAW images (by checking the file extension.

Parameters filename (str) – Full file name.

Returns bool  True if the image is RAW, false otherwise.

Return type  bool

pypocquant.lib.pipeline

Module Contents

Functions

run_pool(files, raw_auto_stretch, raw_auto_wb, input_folder_path, results_folder_path, strip_try_correct_orientation, strip_try_correct_orientation Rects, strip_text_to_search, strip_text_on_right, min_sensor_score, qr_code_border, perform_sensor_search, sensor_size, sensor_center, sensor_search_area, sensor_thresh_factor, sensor_border, peak_expected_relative_location, control_band_index, subtract_background, force_fid_search, sensor_band_names, verbose, qc, max_workers=4)

Run a thread pool for the analysis.

run_pipeline(input_folder_path: Path, results_folder_path: Path, raw_auto_stretch: bool = False, raw_auto_wb: bool = False, strip_try_correct_orientation: bool = False, strip_try_correct_orientation Rects: tuple = (0.52, 0.15, 0.09), strip_text_to_search: str = 'COVID', strip_text_on_right: bool = True, min_sensor_score: float = 0.85, qr_code_border: int = 30, perform_sensor_search: bool = True, sensor_size: tuple = (61, 249), sensor_center: tuple = (178, 667), sensor_search_area: tuple = (71, 259), sensor_thresh_factor: float = 2, sensor_border: tuple = (7, 7), peak_expected_relative_location: tuple = (0.25, 0.53, 0.79), control_band_index: int = -1, subtract_background: bool = True, force_fid_search: bool = False, sensor_band_names: tuple = ('igm', 'igg', 'ctl'), verbose: bool = False, qc: bool = False, max_workers: int = 2)

Run the whole processing and analysis pipeline.

continues on next page
**pyPOCQuant**

Table 6 – continued from previous page

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>`run(filename, raw_auto_stretch, raw_auto_wb, input_folder_path: Path, results_folder_path: Path, strip_try_correct_orientation: bool, strip_try_correct_orientation_rects: tuple, strip_text_to_search: str, strip_text_on_right: bool, min_sensor_score: float = 0.85, qr_code_border: int = 30, perform_sensor_search: bool = False, sensor_size: tuple = (37, 185), sensor_center: tuple = (119, 471), sensor_search_area: tuple = (50, 195), sensor_thresh_factor: float = 2, sensor_border: tuple = (7, 7), peak_expected_relative_location: tuple = (0.27, 0.55, 0.79), control_band_index: int = -1, subtract_background: bool = True, force_fid_search: bool = False, sensor_band_names: tuple = ('igm', 'igg', 'ctl'), verbose: bool = False, qc: bool = False)</td>
<td>Runnable which runs the analysis on a worker</td>
</tr>
</tbody>
</table>

Run a thread pool for the analysis.

**Parameters**

- **files (list)** – List with image file names to be processed
- **raw_auto_stretch (bool)** – Whether to automatically correct the white balance of RAW images on load. This does not affect JPEG images!
- **raw_auto_wb (bool)** – Whether to automatically stretch image intensities of RAW images on load. This does not affect JPEG images!
- **input_folder_path (str)** – Folder with the raw images to process.
- **results_folder_path (str)** – Target folder, where all results and quality control figures are written.
- **strip_try_correct_orientation (bool)** – Try to assess and possibly correct for wrong orientation of the strip by searching for the position of the injection inlet.
- **strip_try_correct_orientation_rects (tuple)** – Tuple containing information about the relative position of the two rectangles to be searched for the inlet on both sides of the center of the image:

  - `rectangle_props[0]`: relative (0..1) vertical height of the rectangle with respect to the image height.
  - `rectangle_props[1]`: relative (0..1) distance of the left edge of the right rectangle with respect to the center of the image.
  - `rectangle_props[2]`: relative (0..1) distance of the left edge of the left rectangle with respect to the center of the image.
**strip_text_to_search**(str) – Text to search on the strip to assess orientation. Set to "" to skip.

**strip_text_on_right**(bool) – Assuming the strip is oriented horizontally, whether the ‘strip_text_to_search’ text is assumed to be on the right. If ‘strip_text_on_right’ is True and the text is found on the left hand-side of the strip, the strip will be rotated 180 degrees. Ignored if strip_text_to_search is "".

**min_sensor_score**(float) – Minimum segmentation score for the sensor to be considered peak analysis (0.0 <= min_sensor_score <= 1.0). This is currently ignored.

**qr_code_border**(int) – Lateral and vertical extension of the (white) border around each QR code.

**perform_sensor_search**(bool) – If True, the (inverted) sensor is searched within ‘sensor_search_area’ around the expected ‘sensor_center’; if False, the sensor of size ‘sensor_size’ is simply extracted from the strip image centered at the relative strip position ‘sensor_center’.

**sensor_size**(tuple) – Area of the sensor to be extracted (height, width).

**sensor_center**(tuple) – Coordinates of the center of the sensor with respect to the strip image (y, x).

**sensor_search_area**(tuple) – Search area around the sensor (height, width). Used only if ‘skip_sensor_search’ is False.

**sensor_thresh_factor**(int) – Set the number of (robust) standard deviations away from the median band background for a peak to be considered valid.

**sensor_border**(tuple) – Lateral and vertical sensor border to be ignored in the analysis to avoid border effects.

**peak_expected_relative_location**(tuple) – Expected relative peak positions as a function of the width of the sensor (= 1.0)

**control_band_index**(int) – Index of the control band in the peak_expected_relative_location. (Optional, default -1 := right-most)

**subtract_background**(bool) – If True, estimate and subtract the background of the sensor intensity profile.

**force_fid_search**(bool) – If True, apply a series of search fall-back approaches to extract patient data from the image. Only use this if the expected QR code with patient data was not added to the image or could not be extracted.

**sensor_band_names**(tuple) – Names of the bands for the data frame header. Please notice: the third ([2]) band is always the control band.

**verbose**(bool) – Toggle verbose output.

**qc**(bool) – Toggle creation of quality control figures.

**max_workers**(int) – Number of max cores to use for running the pipeline

Returns  res
Return type  list
Returns  log_list
Return type  list
Run the whole processing and analysis pipeline.

**Parameters**

- `input_folder_path (str)` – Folder with the raw images to process.
- `results_folder_path (str)` – Target folder, where all results and quality control figures are written.
- `raw_auto_stretch (bool)` – Whether to automatically correct the white balance of RAW images on load. This does not affect JPEG images!
- `raw_auto_wb (bool)` – Whether to automatically stretch image intensities of RAW images on load. This does not affect JPEG images!
- `strip_try_correct_orientation (bool)` – Try to assess and possibly correct for wrong orientation of the strip by searching for the position of the injection inlet.
- `strip_try_correct_orientation_rects (tuple)` – Tuple containing information about the relative position of the two rectangles to be searched for the inlet on both sides of the center of the image:
  
  rectangle_props[0]: relative (0..1) vertical height of the rectangle with respect to the image height.

  rectangle_props[1]: relative (0..1) distance of the left edge of the right rectangle with respect to the center of the image.

  rectangle_props[2]: relative (0..1) distance of the left edge of the left rectangle with respect to the center of the image.
- `strip_text_to_search (str)` – Text to search on the strip to assess orientation. Set to “” to skip.
- `strip_text_on_right (bool)` – Assuming the strip is oriented horizontally, whether the ‘strip_text_to_search’ text is assumed to be on the right. If ‘strip_text_on_right’ is True and the text is found on the left hand-side of the strip, the strip will be rotated 180 degrees. Ignored if strip_text_to_search is “”.
- `min_sensor_score (float)` – Minimum segmentation score for the sensor to be considered peak analysis (0.0 <= min_sensor_score <= 1.0). **This is currently ignored.**
- `qr_code_border (int)` – Lateral and vertical extension of the (white) border around each QR code.
• **perform_sensor_search**(bool) – If True, the (inverted) sensor is searched within ‘sensor_search_area’ around the expected ‘sensor_center’; if False, the sensor of size ‘sensor_size’ is simply extracted from the strip image centered at the relative strip position ‘sensor_center’.

• **sensor_size**(tuple) – Area of the sensor to be extracted (height, width).

• **sensor_center**(tuple) – Coordinates of the center of the sensor with respect to the strip image (y, x).

• **sensor_search_area**(tuple) – Search area around the sensor (height, width). Used only if ‘skip_sensor_search’ is False.

• **sensor_thresh_factor**(int) – Set the number of (robust) standard deviations away from the median band background for a peak to be considered valid.

• **sensor_border**(tuple) – Lateral and vertical sensor border to be ignored in the analysis to avoid border effects.

• **peak_expected_relative_location**(tuple) – Expected relative peak positions as a function of the width of the sensor (= 1.0)

• **control_band_index**(int) – Index of the control band in the peak_expected_relative_location. (Optional, default -1 := right-most)

• **subtract_background**(bool) – If True, estimate and subtract the background of the sensor intensity profile.

• **force_fid_search**(bool) – If True, apply a series of search fall-back approaches to extract patient data from the image. Only use this if the expected QR code with patient data was not added to the image or could not be extracted.

• **sensor_band_names**(tuple) – Names of the bands for the data frame header. Please notice: the third ([2]) band is always the control band.

• **verbose**(bool) – Toggle verbose output.

• **qc**(bool) – Toggle creation of quality control figures.

• **max_workers**(int) – Number of max cores to use for running the pipeline

```python
pypocquant.lib.pipeline.run(filename, raw_auto_stretch, raw_auto_wb, input_folder_path: Path, results_folder_path: Path, strip_try_correct_orientation: bool, strip_try_correct_orientation_rects: tuple, strip_text_to_search: str, strip_text_on_right: bool, min_sensor_score: float = 0.85, qr_code_border: int = 30, perform_sensor_search: bool = False, sensor_size: tuple = (37, 185), sensor_center: tuple = (119, 471), sensor_search_area: tuple = (50, 195), sensor_thresh_factor: float = 2, sensor_border: tuple = (7, 7), peak_expected_relative_location: tuple = (0.27, 0.55, 0.79), control_band_index: int = -1, subtract_background: bool = True, force_fid_search: bool = False, sensor_band_names: tuple = ('igm', 'igg', 'ctl'), verbose: bool = False, qc: bool = False)
```

Runnable which runs the analysis on a worker

**Parameters**

• **filename**(list) – Image file name to be processed

• **raw_auto_stretch**(bool) – Whether to automatically correct the white balance of RAW images on load. This does not affect JPEG images!
• `raw_auto_wb (bool)` – Whether to automatically stretch image intensities of RAW images on load. This does not affect JPEG images!

• `input_folder_path (str)` – Folder with the raw images to process.

• `results_folder_path (str)` – Target folder, where all results and quality control figures are written.

• `strip_try_correct_orientation (bool)` – Try to assess and possibly correct for wrong orientation of the strip by searching for the position of the injection inlet.

• `strip_try_correct_orientation_rects (tuple)` – Tuple containing information about the relative position of the two rectangles to be searched for the inlet on both sides of the center of the image:
  
  rectangle_props[0]: relative (0..1) vertical height of the rectangle with respect to the image height.
  
  rectangle_props[1]: relative (0..1) distance of the left edge of the right rectangle with respect to the center of the image.
  
  rectangle_props[2]: relative (0..1) distance of the left edge of the left rectangle with respect to the center of the image.

• `strip_text_to_search (str)` – Text to search on the strip to assess orientation. Set to “” to skip.

• `strip_text_on_right (bool)` – Assuming the strip is oriented horizontally, whether the ‘strip_text_to_search’ text is assumed to be on the right. If ‘strip_text_on_right’ is True and the text is found on the left hand-side of the strip, the strip will be rotated 180 degrees. Ignored if strip_text_to_search is “”.

• `min_sensor_score (float)` – Minimum segmentation score for the sensor to be considered peak analysis (0.0 <= min_sensor_score <= 1.0). This is currently ignored.

• `qr_code_border (int)` – Lateral and vertical extension of the (white) border around each QR code.

• `perform_sensor_search (bool)` – If True, the (inverted) sensor is searched within ‘sensor_search_area’ around the expected ‘sensor_center’; if False, the sensor of size ‘sensor_size’ is simply extracted from the strip image centered at the relative strip position ‘sensor_center’.

• `sensor_size (tuple)` – Area of the sensor to be extracted (height, width).

• `sensor_center (tuple)` – Coordinates of the center of the sensor with respect to the strip image (y, x).

• `sensor_search_area (tuple)` – Search area around the sensor (height, width). Used only if ‘skip_sensor_search’ is False.

• `sensor_thresh_factor (int)` – Set the number of (robust) standard deviations away from the median band background for a peak to be considered valid.

• `sensor_border (tuple)` – Lateral and vertical sensor border to be ignored in the analysis to avoid border effects.

• `peak_expected_relative_location (tuple)` – Expected relative peak positions as a function of the width of the sensor (= 1.0)

• `control_band_index (int)` – Index of the control band in the peak_expected_relative_location. (Optional, default -1 := right-most)
• **subtract_background**(bool) – If True, estimate and subtract the background of the sensor intensity profile.

• **force_fid_search**(bool) – If True, apply a series of search fall-back approaches to extract patient data from the image. Only use this if the expected QR code with patient data was not added to the image or could not be extracted.

• **sensor_band_names**(tuple) – Names of the bands for the data frame header. Please notice: the third ([2]) band is always the control band.

• **verbose**(bool) – Toggle verbose output.

• **qc**(bool) – Toggle creation of quality control figures.

Returns row_data

Returns image_log

**pypocquant.lib.processing**

**Module Contents**

**Functions**

```python
phase_only_correlation(in1: np.ndarray, in2: np.ndarray) → np.ndarray
```
Calculate phase-only correlation of two numpy arrays.

```python
find_position_in_image_using_phase_corr(in1: np.ndarray, in2: np.ndarray) → tuple
```
Find phase-only correlation to find the coordinates in in2 where in1 can be found.

```python
find_position_in_image_using_norm_xcorr(in1: np.ndarray, in2: np.ndarray) → tuple
```
Find normalized cross-correlation to find the coordinates in in2 where in1 can be found.

```python
correlation_coefficient(image_1, image_2)
```
Create the normalized correlation coefficient (scalar) of two images.

```python
crop_image_around_position_to_size(image, y, x, size)
```
Crop an image to given size centered at coordinates (y, x).

```python
create_rgb_image(red, green, blue=None)
```
Merge three single channels into an RGB image.

```python
find_features(image, detector='surf', num_features=1000, hessian_threshold=10, use_latch_descriptor=False)
```
Find features in of a template inside a larger image.

```python
find_position_of_template_in_image_using_descriptors(template_kps, template_des, image_kps, image_des, template_size)
```
Find the template in the image using the extracted feature descriptors.

```python
register_images_opencv_features(source, target, detector='surf', use_latch_descriptor=False, perspective=True, affine=False, rigid=False, num_features=1000, hessian_threshold=10, control_image=False)
```
Register 2 images using image features.

```python
apply_transformation_to_image(image, transformation_type, transformation_matrix, target_height=None, target_width=None)
```
Apply a transformation to an image.

```python
display_matches(img1, img2, sel_matches, k1, k2, max_matches=None)
```
Displays the matches on a control image and returns it.

```python
add_border(images: list, border: int, fill_value: int = -1) → list
```
Add a border to each of the images in a list and sets the border values to a given fill value.

```python
BGR2Gray(image, to_lightness=False)
```
Convert a BGR image to gray or lightness.
pyPOCQuant

pyPocquant.lib.processing.phase_only_correlation \( (\text{in1}: \text{np.ndarray}, \text{in2}: \text{np.ndarray}) \rightarrow \text{np.ndarray} \)

Calculate phase-only correlation of two numpy arrays.

**Parameters**
- \text{in1} – 2D numpy array.
- \text{in2} – 2D numpy array.

**Returns** 2D np.float64 numpy array.

pyPocquant.lib.processing.find_position_in_image_using_phase_corr \( (\text{in1}: \text{np.ndarray}, \text{in2}: \text{np.ndarray}) \rightarrow \text{tuple} \)

Uses phase-only correlation to find the coordinates in \text{in2} where \text{in1} can be found.

**Parameters**
- \text{in1} – 2D numpy array (must be strictly smaller, i.e. completely contained) in \text{in2}.
- \text{in2} – 2D numpy array.

**Returns** tuple with (y = row, x = column) location of the center of \text{in1} in \text{in2}.

**Return type** tuple

pyPocquant.lib.processing.find_position_in_image_using_norm_xcorr \( (\text{in1}: \text{np.ndarray}, \text{in2}: \text{np.ndarray}) \rightarrow \text{tuple} \)

Uses normalized cross-correlation to find the coordinates in \text{in2} where \text{in1} can be found.

**Parameters**
- \text{in1} – 2D numpy array (must be strictly smaller, i.e. completely contained) in \text{in2}.
- \text{in2} – 2D numpy array.

**Returns** tuple with (y = row, x = column) location of the center of \text{in1} in \text{in2}.

**Return type** tuple

pyPocquant.lib.processing.correlation_coefficient \( (\text{image\_1}, \text{image\_2}) \)

Create the normalized correlation coefficient (scalar) of two images.

**param image\_1**: np image1
**param image\_2**: np image2

**Returns** product:

pyPocquant.lib.processing.crop_image_around_position_to_size \( (\text{image}, \text{y}, \text{x}, \text{size}) \)

Crop an image to given size centered at coordinates (y, x).

If the original image is too small, a cropped version will be returned.

**Parameters**
- \text{image} – Image to be cropped
- \text{y} – y center coordinate
- \text{x} – x center coordinate
- \text{size} – size of the crop
**Returns** out: Cropped image

`pypocquant.lib.processing.create_rgb_image(red, green, blue=None)`

Merge three single channels into an RGB image.

**Parameters**
- `red` – Red channel
- `green` – Green channel
- `blue` – Blue channel

**Returns** view: RGB image

`pypocquant.lib.processing.find_features(image, detector='surf', num_features=1000, hessian_threshold=10, use_latch_descriptor=False)`

Find features in of a template inside a larger image.

**Parameters**
- `image` –
- `detector` –
- `num_features` –
- `hessian_threshold` –
- `use_latch_descriptor` –

**Returns** `kp`  

**Returns** `des`

`pypocquant.lib.processing.find_position_of_template_in_image_using_descriptors(template_kps, template_des, image_kps, image_des, template_size)`

Find the template in the image using the extracted feature descriptors.

**Parameters**
- `template_kps` –
- `template_des` –
- `image_kps` –
- `image_des` –
- `template_size` –

**Returns** coordinates  
**Return type** tuple
pyPocQuant

pypocquant.lib.processing.register_images_opencv_features(source, target, detector='surf', use_latch_descriptor=False, perspective=True, affine=False, rigid=False, num_features=1000, hessian_threshold=10, control_image=False)

Register 2 images using image features.

Keyword arguments: 
:param source: source image to be registered (must be grayscale) 
:param target: target image (must be grayscale) 
:param detector: one of “ orb”, “ kaze”, “ akaze”, “ brisk”, “ surf”, “ sift” (default if surf) 
:param use_latch_descriptor: True to use the new LATCH descriptor (requires openCV 3.1), False to use the default descriptors provided by the detectors (default is False)

Parameters

- **num_features** – number of features (used only by the “orb” and “sift” detectors, default is 1000)
- **hessian_threshold** – threshold of the hessian of the images (used only by the “surf” detector, default is 10)
- **perspective** – register the image using a perspective transformation (optional, default=True).
- **affine** – register the image using an affine transformation (optional, default=False).
- **rigid** – register the image using a rigid transformation (optional, default=False).
- **control_image** – set to True to create a quality control image (default is False).

Returns results (aligned: aligned image, M : transformation matrix, mask: mask returned by cv2.findHomography()).

Return type dict

Returns view: quality control image,

Returns source_descr: list of source descriptors,

Returns target_descr: list of target descriptors).

pypocquant.lib.processing.apply_transformation_to_image(image, transformation_type, transformation_matrix, target_height=None, target_width=None)

Apply a transformation to an image.

Parameters

- **image** – image to be transformed.
- **transformation_type** – type of transformation. One of: “perspective”: register the image using a perspective transformation. “affine”: register the image using an affine transformation. “rigid”: register the image using a rigid transformation.
- **transformation_matrix** –
transformation matrix, must be: "perspective": (3x3) “affine”: (2x3) “rigid”: (2x3)

- **target_height** – (optional) number of rows of the transformed image. If not set, the transformed image will have the same size as the source image.
- **target_width** – (optional) number of columns of the transformed image. If not set, the transformed image will have the same size as the source image.

**Returns** transformed: transformed image.

```python
pypocquant.lib.processing.display_matches(img1, img2, sel_matches, k1, k2, max_matches=None)
```

Displays the matches on a control image and returns it.

**Parameters**

- **img1** – First image
- **img2** – Second image
- **sel_matches** – Selected matches
- **k1** –
- **k2** –
- **max_matches** –

**Returns** view

```python
pypocquant.lib.processing.add_border(images: list, border: int, fill_value: int = -1) → list
```

Add a border to each of the images in a list and sets the border values to a given fill value. If the fill_value is omitted, the median of all pixel intensities will taken.

**Parameters**

- **images** (list) – List of images
- **border** (int) – Border to be added to image
- **fill_value** – (optional) If omitted the median of all pixel intensities will taken.

**Returns** out: List of images with added border.

**Return type** list

```python
pypocquant.lib.processing.BGR2Gray(image, to_lightness=False)
```

Convert a BGR image to gray or lightness.

**Parameters**

- **image** – Image to be converted
- **to_lightness** – To lightness bool

**Returns** l

**Return type** cv2.Image
pyPOCQuant

pypocquant.lib.settings

Module Contents

Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>default_settings()</td>
<td>Return a dictionary containing the default settings.</td>
</tr>
<tr>
<td>load_settings(filename)</td>
<td>Loads settings from file and returns them in a dictionary.</td>
</tr>
<tr>
<td>save_settings(settings_dictionary, filename)</td>
<td>Save settings from a dictionary to file.</td>
</tr>
<tr>
<td>load_list_file(filename)</td>
<td>Loads list from file and returns them as list.</td>
</tr>
</tbody>
</table>

```python
pypocquant.lib.settings.default_settings()
Return a dictionary containing the default settings.
pypocquant.lib.settings.load_settings(filename)
Loads settings from file and returns them in a dictionary.
Parameters
filename (str) – Name of the settings file.
Returns
settings_dictionary
Return type
dict
pypocquant.lib.settings.save_settings(settings_dictionary, filename)
Save settings from a dictionary to file.
Parameters
• settings_dictionary – Settings dictionary
• filename (str) – Filename of the settings file to be saved.
pypocquant.lib.settings.load_list_file(filename)
Loads list from file and returns them as list.
Parameters
filename (str) – Filename of the settings file to be loaded.
Returns
file_content_list
Return type
list
```

pypocquant.lib.tools

Module Contents

Functions

```python
extract_strip(image, qr_code_border,
strip_try_correct_orientation,
strip_try_correct_orientation_rects=(0.52, 0.15, 0.09),
stretch_for_hough=False,
strip_text_to_search=',
strip_text_on_right=True)
Attempts to extract the strip from the original image.
```
pypocquant.lib.tools.extract_strip(image, qr_code_border, strip_try_correct_orientation, 
strip_try_correct_orientation_rects=(0.52, 0.15, 0.09), 
stretch_for_hough=False, strip_text_to_search='', 
strip_text_on_right=True)

Attempts to extract the strip from the original image.

Parameters

• **image** *(numpy array)* – RGB image to be processed.

• **qr_code_border** *(int)* – Lateral and vertical extension of the (white) border around each QR code.

• **strip_try_correct_orientation** *(bool)* – Try to assess and possibly correct for wrong orientation of the strip by searching for the position of the injection inlet.

• **strip_try_correct_orientation_rects** *(tuple)* – Tuple containing information about the relative position of the two rectangles to be searched for the inlet on both sides of the center of the image:

  rectangle_props[0]: relative (0..1) vertical height of the rectangle with respect to the image height.

  rectangle_props[1]: relative (0..1) distance of the left edge of the right rectangle with respect to the center of the image.

  rectangle_props[2]: relative (0..1) distance of the left edge of the left rectangle with respect to the center of the image.

• **stretch_for_hough** *(bool (default, False))* – Set to True to apply auto-stretch to the image for Hough detection (1, 99 percentile).

• **strip_text_to_search** *(str)* – str Text to search on the strip to assess orientation. Set to "" to skip.

• **strip_text_on_right** *(bool)* – Assuming the strip is oriented horizontally, whether the ‘strip_text_to_search’ text is assumed to be on the right. If ‘strip_text_on_right’ is True and the text is found on the left hand-side of the strip, the strip will be rotated 180 degrees. Ignored if strip_text_to_search is "".

Returns

• **strip_for_analysis** : Strip image (RGB) or None if extraction fails.

• **error_msg** : If strip is None, the cause of failure will be stored in error_message.

• **left_rect** : Detected Hough circles in left_rect.

• **right_rect** : Detected Hough circles in right_rect.

Return type  tuple
create_quality_control_images(results_folder_path: str, basename: str, map_of_images: dict, extension: str = '.png', quality: int = 100)

Save the list of requested quality control images.

**Parameters**

- **results_folder_path (str)** – Full path to the folder where to save the quality control images.
- **basename (str)** – Common base name for all quality control images.
- **map_of_images (dict)** – Dictionary of keys to be appended to the base name with the corresponding image as value.
- **extension (str)** – File extension (format). Optional, default is `.png`.
- **quality (int)** – Image compression quality. Optional, default is 100. This is only considered if format is “.jpg”.

get_project_root() → Path

Returns project root folder.

Returns **project_root**

Return type **Path**

get_data_folder() → Path

Returns the value of the environment variable DATA_FOLDER or, if not found, the value if get_project_root().

Returns **data_folder**

Return type **Path**

image_format_converter(directory, filename, output_dir=None, image_format='tif')

Converts a image in raw format (”.nef”) to the specified open format. Default is ‘.tif’.

get_iso_date_from_image(image_path)

Returns the date in iso-date format for the image at the given path.

get_exif_details(image_path)

Returns the Exif metadata for the image at the given path. In particular EXIF ExposureTime, EXIF FNumber,

get_orientation_from_image(image_path)

Returns the image orientation for the image at the given path from the EXIF metadata.

is_on_path(prog)

Returns true if a certain program is on the environment variable PATH.

set_tesseract_exe()

Sets the path to the executable of tesseract.

remove_filename_duplicates(data_frame)

Removes duplicates entry from a pandas data frame based on the column NAME.

**Parameters**

- **directory** – Image directory
- **filename** *(str)* – Filename of the image to be converted
- **output_dir** – Output directory to write the converted image to.
- **image_format** *(str)* – Format of the image such as i.e. tif

```python
pypocquant.lib.utils.get_iso_date_from_image(image_path)
```

Returns the date in iso-date format for the image at the given path.

**Parameters**

- **image_path** *(str)* – Path to an image.

**Returns**

- iso_date
- iso_time

```python
pypocquant.lib.utils.get_exif_details(image_path)
```

Returns the Exif metadata for the image at the given path. In particular EXIF ExposureTime, EXIF FNumber, EXIF FocalLengthIn35mmFilm, EXIF ISOSpeedRatings.

**Parameters**

- **image_path** *(str)* – Path to an image.

**Returns**

- exp_time
- f_number
- focal_length_35_mm
- iso_speed

```python
pypocquant.lib.utils.get_orientation_from_image(image_path)
```

Returns the image orientation for the image at the given path from the EXIF metadata.

**Parameters**

- **image_path** *(str)* – Path to an image.

**Returns**

orientation

```python
pypocquant.lib.utils.is_on_path(prog)
```

Returns true if a certain program is on the environment variable PATH.

**param prog** Name of a program

**type prog** str

**Return type** boolean

```python
pypocquant.lib.utils.set_tesseract_exe()
```

Sets the path to the executable of tesseract.

```python
pypocquant.lib.utils.remove_filename_duplicates(data_frame)
```

Removes duplicates entry from a pandas data frame based on the column NAME.

**param data_frame**

Pandas data frame

**Returns**

data_frame

**Return type** pd.DataFrame
This repository contains the implementation of *pyPOCQuant* to automatically detect and quantify test line (TL) signal bands from lateral flow assays (LFA) images, as described in the paper:


Please cite the paper(s) if you are using this code in your research or work.

### 8.1 Overview

The above figure shows an image of a POCT placed on our QR code template as well as a QR code label providing metadata about the sample and test. The POCT gets extracted from the QR code box and finely aligned prior to the detection of the test lines (TLs) from the sensor area. The TLs and their signal strength get quantified after a background subtraction and the results are compiled in a table along with the metadata of the tests automatically for each image.

For a more detailed description please read the user manual or the paper.

### 8.2 Installation

This package requires Python 3.6 and runs on various platforms. If not explicitly stated differently all the steps below are the same on each platform.
8.2.1 Install | run compiled binaries

The easiest way to run pyPOCQuant is to use the compiled binaries which includes everything (except tesseract and zbar, see below) ready to be used.

- download pyPOCQuantUI binaries

8.2.2 Install python and all requirements | run from source

Windows

Install tesseract.

Linux

Install the following dependences (instructions for Ubuntu Linux):

```
$ sudo apt install libzmq3-dev, tesseract-ocr, libzbar0
```

macOS

To install the required dependencies we recommend to use the packaging manager brew. Install it from here if you have’t already Install brew.

```
$ brew install zbar
$ brew install tesseract
```

All platforms

pyPOCQuant requires python 3.6. It is recommended to use miniconda: https://docs.conda.io/en/latest/miniconda.html. When miniconda is installed, start the terminal and type:

```
# Create and activate an environment
$ conda create -n pypocquant python=3.6
$ conda activate pypocquant
```

Clone the repo.

```
git clone git://git.gitlab.com/csb.ethz/pypocquantui.git
```

Then, install all requirements.

```
$ cd ${pyPOCQuantUI_root_folder}
$ pip install -r requirements/${platform}
```

where ${platform} is one of win32.txt, linux.txt, or osx.txt.

Run the GUI with (from within ${pyPOCQuantUI_root_folder}):

```
$ fbs run
```

For other ways to use pyPOCQuant please read the documentation.
8.2.3 Build pyPOCQuantUI

To compile and create a pyPOCQuantUI installer, perform following steps. In the following `{ppcqui_root}` points to the root folder of the pyPOCQuantUI checked-out code.

**Windows**

```
$ cd ${ppcqui_root}
$ python ./make_build.py
```

You will find the installer in `{ppcqui_root}/target/pyPOCQuant`.

**Linux**

```
$ sudo apt install ruby ruby-dev rubygems build-essential
$ sudo gem install --no-document fpm
$ cd ${ppcqui_root}
$ python ./make_build.py
```

This will create a `{ppcqui_root}/target/pyPOCQuant/pyPOCQuant.deb` package that can be installed and redistributed.

```
sudo apt install ${ppcqui_root}/target/pyPOCQuant/pyPOCQuant.deb
```

Please notice that client machines will need to install also two dependences:

```
sudo apt install tesseract-ocr, libzbar0
sudo apt install ${ppcqui_root}/target/pyPOCQuant/pyPOCQuant.deb
```

**8.2.4 macOS**

```
$ cd ${ppcqui_root}/
$ python ./make_build.py
```

**Notes**

- Depending on your Python installation, you may need to use `pip3` instead of `pip`.
- For both running it from source or with the compiled binaries `zbar` and `tesseract` needs to be installed and be on PATH. On Windows `zbar` libs are installed automatically.
8.3 Usage

We provide an example workflow in a Jupyter notebook that illustrate how this library can be used as well as a step by step QuickStart (add link) guide in the documentation.

8.3.1 Example data

We provide example data as well as an example configuration in this repo under:

```
examples/config.conf
examples/images
```

8.3.2 Creating a config file

In the following we present a brief overview how to create a working config file for your images. Detailed instructions and the definition of each parameter can be found in detail in the manual and documentation. We show how to obtain position and extent of the sensor areas in Fiji or ImageJ. Later we will see how to do the same in the pyPOCQuant user interface (GUI).

Important parameters are the `sensor_size`, `sensor_center`, and `sensor_search_area` (the latter being an advanced parameter).

```
src/main/resources/base/img/strip_annotated.png
```

Creating a config file with Fiji

1. Open a settings file (i.e default settings) and adjust the parameters to fit your images.
2. Load an image with Fiji and crop it to the size of the POCT

```
src/main/resources/base/img/fiji_selection.png
```

1. After drawing a rectangular region of interest, the size is displayed in Fiji’s toolbar; e.g. `x=539, y=145, w=230, h=62`.
   - When hovering over the central pixels in the top or left sides of the selection, the `x`, and `y` coordinates of the center, respectively, are show in Fiji’s toolbar; e.g. `x=601, y=144, value=214` (and equivalently for `y`).
2. With the line tool the distance from the border to the test lines (TLs) can be measured and expressed as relative ration (distance to TL from left border / w) to obtain the `peak_expected_relative_location`.
Creating a config file with the GUI

A settings file must not necessarily be created in advance. The Parameter Tree can be edited directly. Optionally, settings can be loaded or saved from the UI.

1. Select the input folder and click on one of the listed images to display it. The POCT region will be automatically extracted and shown in the view at the top. The lower view shows the whole image.

2. Hit the Draw sensor outline icon (red arrow) in the toolbar. This will allow you to interactively define the sensor area and the peak_expected_relative_location parameters.

<table>
<thead>
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<th>Drawing sensor by clicking into the corners</th>
<th>Drawing finished with aligned test lines (vertical lines)</th>
</tr>
</thead>
</table>

1. Draw the four corners of the sensor and place the vertical bars on the test lines (TLs). This will cause all relevant parameters to be populated in the Parameter Tree. Please notice that, by default, the sensor_search_area is set to be 10 pixels wider and taller than the sensor_size. This can be changed in the advanced parameters (but beware to keep it only slightly larger than the sensor_size: it is meant only for small refinements).

src/main/resources/base/img/ui_new_settings.JPG

1. Save the settings file (Ctrl+S, File->Save settings file) or test current parameters on one image by clicking the Test parameters button under the Parameter Tree.

8.3.3 Minimal example

Create a Python script or Jupyter notebook cell with the following code to run the pipeline on all images for a given input_folder_path.

```python
from pypocquant.lib.pipeline import run_pipeline
from pypocquant.lib.settings import default_settings

# Get the default settings
settings = default_settings()

# Change settings manually as needed
settings["sensor_band_names"] = ('igm', 'igg', 'ctl')

# Alternatively, load existing settings file
# from pypocquant.lib.settings import load_settings
# settings = load_settings('full/path/to/settings/file.conf')

# Set final argument
input_folder_path = 'full/path/to/input/folder'
results_folder_path = 'full/path/to/results/folder'
max_workers = 8

# Run the pipeline
run_pipeline(
    input_folder_path,
    results_folder_path,
    max_workers,
)
```

(continues on next page)
8.3.4 Command line interface (CLI)

Running *pyPOCQuant* from the CLI is best suited when automating the processing of large amounts of images and folders.

To create a default configuration from the CLI, use the `-c` flag of pyPOCQuant.py.

```bash
python pyPOCQuant.py c /PATH/TO/CONFIG/FILE.conf
```

By far the easiest approach is to use the *pyPOCQuantUI* (GUI) for this purpose, but it could also be done with other tools, such as Fiji (as described in the manual).

Once the configuration file is ready, a full study can be started by running pyPOCQuant on a full folder of images:

The analysis is performed in parallel, and the number of concurrent tasks can be adjusted by the `-w` (`--workers`) argument.

```bash
python pyPOCQuant.py f /PATH/TO/INPUT/FOLDER o /PATH/TO/RESULTS/FOLDER s /PATH/TO/CONFIG/FILE w $\{NUMWORKERS\}
```

- **-f** /PATH/TO/INPUT/FOLDER/MANUFACTURER: path to the folder that contains all images for a given camera and manufacturer.
- **-o** /PATH/TO/RESULTS/FOLDER: path where the results (and the quality control images) for a given camera and manufacturer will be saved. The results are saved in a *quantification_data.csv* text file.
- **-s** /PATH/TO/CONFIG/FILE: path to the configuration file to be used for this analysis. Note that a configuration file will be needed per manufacturer and (possibly) camera combination.
- **-w** NUM_WORKERS: number of parallel processes; e.g. 8.
- **-v**: VERSION: displays current version of *pyPOCQuant*.
- **-h** HELP: displays the CLI arguments and their usage.

To run it with the provided example data type:

```bash
python pyPOCQuant.py f examples/images o examples/images/results s examples/config.conf w 4
```

8.3.5 Graphical user interface (GUI)

We also provide a graphical user interface *pyPOCQuantUI* that enables interactive parameter configuration, parameter testing, and parallel processing of all files in a folder. The UI also offers a graphical tool to create custom sample identifier QR codes, and another to split images by vendor (either by keyword or QR code tag).

Detailed installation and usage instructions can be found in the manual and documentation.

To start the GUI from source navigate into the *pyPOCQuantUI* root folder and run:

```
fbs run
```
or double click on the pyPOCQuant icon installed by the installer or directly on the downloaded binaries.

After selecting the **INPUT FOLDER** and clicking on an image (e.g. IMG_9068.JPG in the figure below), the POCT gets extracted and displayed on the right top. Clicking on the **Draw sensor** button (red arrow) allows to identify the sensor area by clicking into its corners. After aligning the relative position of the test lines (TLs) by dragging the vertical lines the button **Test parameters** will open the **OUTPUT FOLDER** and show the results for the selected image. Clicking the button **Run** will apply the parameters to all images in the selected folder and process each image in parallel.

![ui_drawing_arrow.JPG](src/main/resources/base/img/ui_drawing_arrow.JPG)

### 8.4 Troubleshooting

Installation requires Python 3.6, PyQt 5 and fbs 0.9 with PyInstaller 3.4. We have tested the package on (macOS, Linux, Windows 7 and 10) Please open an issue if you have problems that are not resolved by our installation guidelines above.

### 8.5 Contributors

pyPOCQuant is developed by Andreas P. Cuny and Aaron Ponti. If you want to contribute and further develop the project feel free to do so!

### 8.6 How to cite

```latex
@article{cuny2020,
    author = {Andreas P. Cuny and Fabian Rudolf and Aaron Ponti},
    title = {A tool to automatically quantify Point-Of-Care Tests from images},
    journal = {MedRxiv},
    year = {2020},
    doi = {10.1101/2020.11.08.20227470}
}
```
• genindex
• modindex
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