LUT Computer Vision and Pattern Recognition

BM40A1201 Digital Imaging and Image Preprocessing

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Practical Assignment, Imaging Measurements.

1 Problem Statement

The task is to carry out an imaging measurement with an imaging setup characterized or calibrated for the measurement task. The measurement equipment (camera, etc.), the measured target (the object being measured) and the purpose of the measurement (which characteristics are measured from the object) are fixed. The equipment will be available for extra measurements. The goal of the assignment is to implement a system that can estimate the number of various coins in the image.

The purpose of the assignment is the following:

1. Study and practice the basics of imaging setup[1] characterization/calibration for a specific measurement purpose.
2. Use the given data for system implementation.
3. Design an experiment for the extra measurements. The extra measurements may be needed due to the changes in the illumination conditions or in the imaging system (e.g. focal length). (the data distributed in Moodle.)
4. Collect extra experimental data. (the data distributed in Moodle.)
5. Correct the data by using the information from the characterization/calibration of the imaging setup.
6. Evaluate the measurement error/uncertainty based on the corrected measurement result and reference data.
7. Document the work in a report.

Your task is to realise a suitable MATLAB implementation for the measurement task. It is possible to use software implemented by someone else for some subtasks. However, if using such software is desired, you have to agree about this with the supervisor of the practical assignment before doing so.

1 An imaging setup typically consists of a light source, optics and a camera, and some mechanics can be also involved.

It is preferred to make your own implementation, but some procedures related, for example, to the calibration might require some extra work.

2 Requirements

The practical assignment is meant to be done in freely selected groups of two students. If someone wants to work alone, this is also possible (but not a preferable or recommended option).

To carry out the *programming task*, you must obey the following rules:

- Allowed: Use of MATLAB toolbox functions available at LUT University.
- Not allowed: Use of any MATLAB examples directly for the purpose. Use of any other source codes or software tools, for example from Internet, is not allowed unless explicitly agreed with the supervisor.

To prepare the *documentation* of your work, you must obey the following rules:

- Allowed: You should use references as long as you acknowledge them (proper citation to the reference used) and do not directly copy text from the reference[2].
- Not allowed: Use of any material (e.g. program codes) prepared by others (without properly acknowledging the source), or direct copying of sentences or their parts from a reference (without properly acknowledging the source).

By returning the assignment you assure that i) you acknowledge all sources (no plagiarism), and ii) you have not used any forbidden materials.

2.1 Implementation

The practical results of the assignment are i) Matlab source code/software implementation and ii) documentation of the work and the results. The tasks related to the implementation of the assignment are as follows:

1. Since the given set of images is taken in a constant environmental setting then extra measurements are needed for different environmental conditions (e.g. illumination changes, changes in camera parameters). (the data distributed in Moodle.)
2. Prepare a plan about the measurement setup/environment and consider how to use the equipment. Consider the need for image pre-processing for the measurement. (the data distributed in Moodle.)
3. Design the experiment(s).
4. Characterize/calibrate the equipment for the selected measurements.
5. Produce the measurement results and analyse them.
6. Document all the subtasks of the assignment.
7. Implement in MATLAB one function called estim_coins which is called as

   ```
   >> [coins] = estim_coins(measurement, bias, dark, flat);
   ```

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2 If this is absolutely needed, proper quotation of the text and a citation must be used.

where the output coins contains the number of various coins found from the measurement image measurement.

The input for the estim_coins(measurement, bias, dark, flat) are the four images (measurement, bias, dark, flat). No other images are needed to find the coins in the measurement image. Naturally the diameters and size of the coins are needed and this information is provided in millimeters, see[3]. From the image you can find the sizes in pixels, from the coins you know the sizes in millimeters and then the geometric calibration will find the mapping between the millimeters and pixels. The other inputs are bias, dark, flat images which contain the bias, dark, and flat images, respectively. The output coins is a six-element vector with the first element corresponding to the number of 5 cent-coins in the image and the last element corresponding to the number of 2 euro-coins in the image. The image measurement is one image only, the same applies to the images bias, dark and flat, they are the mean images $\hat{B}, \hat{D}, \hat{F}$ for the intensity calibration for as the image measurement R as

$$R = \frac{R - \hat{B} - \hat{D}}{\hat{F}} \tag{1}$$

where $\hat{F}$ needs to be scaled such that the $\hat{F}$ =1. In many cases $\hat{F}$ consists of one image F only, it is the flat field in the measurement and as such $\hat{F} = F$.

Inside the function estim_coins you should define two calibrations, first the calibration of the intensity and then also the geometric calibration for the input image. Typically, the output from the geometric calibration is a two-element vector containing the 2D-mapping from millimeters to pixels (the first element is corresponding to the horizontal domain and the second element to the vertical domain of the image).

A general objective is that all the above tasks are to some extent treated in the work and its documentation, or you document why a certain subtask is not needed.

Remember to properly document your work and comment your software implementation. Write also a short help section to your functions that tells the purpose of the function, usage, and explanation of the parameters. In MATLAB, comments following the first line of a function will show when the help command is used with the name of the function. You can see an example, if you type following command in MATLAB:

```
>> help mean
>> doc mean
```

2.2 Documentation

Write a report about your project in English. The documentation should include a cover page where you give the course number and name, project title, date, and the names and student numbers of the team. The LATEX template for the LUT MSc. thesis is the correct starting point.

Describe the methods used in such detail that a reader would be able to implement similar functions for the same purpose just based on your documentation and the cited references. Presenting an algorithm and explaining it in words can be used to describe the principles of methods. Justify your choices, that is, present grounds for selecting the methods for your solution.

Include in the report the measurement results with the data produced in the experiments. Present also results related to the measurement error, and comment on or quantify the measurement uncertainty.

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3 https://economy-finance.ec.europa.eu/euro/euro-coins-and-notes/euro-coins/common-sides-euro-coins_en

At the end of your documentation, you should list all the references used. Note that you are allowed to use any references/information you wish. The standard functions of the official MATLAB toolboxes available at the university can be used, but it is preferred that you write the method implementations by yourself. If you wish to use an implementation by someone else, ask the permission to do so from the supervisor.

3 Deadline and submission

The deadline of submitting the results of your work is given in the course web pages in Moodle. There is also the submission system established.

The results of the work containing the pdf document (the report) and all relevant codes (calibration, measurement, evaluation) must be packed into a single file using tar and gzip. The file name of the package must be STNUM.zip where STNUM is the student number of one of the students in the group. When STNUM.tar.gz is extracted, it should create a single directory STNUM. This directory should contain a file README.txt shortly describing the other files (except any standard MATLAB functions), as well as your report.

In the package DO NOT INCLUDE any images that can be downloaded from Moodle. I.e., the package contains only the report (in pdf format) and the MATLAB codes.

4 Grading

The work will be evaluated based on the submitted report and implementation according to the following criteria:

1. Measurement purpose selected: The objective of the measurement should be clearly described and defined in the report.
2. Measurement setup planned: The equipment and setup to collect the images for the measurement and its evaluation are described understandably in the report.
3. Equipment calibrated: The calibration of the equipment, including the collection of calibration data and protocol used, (or the grounds why calibration is not needed in this case) is clearly described in the report.
4. Successful implementation: Based on the results presented in the report, the implementation works for the selected purpose.
5. Experiments planned: The plan for the data collection related to the accuracy evaluation is well defined in the report.
6. Analysis of the results: The measurement results are clearly presented in the report.
7. Evaluation of accuracy/quality: Accuracy of the measurement based on the evaluation, that is, comparison to a reference measurement and presenting the measurement error.
8. How correctly your implementation is able to estimate the number of coins from the images in a test set.
9. Documentation: The report includes all the parts mentioned above.

If there are minor shortcomings with respect to the before-mentioned criteria, the following characteristics of the implementation and documentation will be taken into account in the evaluation to compensate the lacking items:

- Measurement purpose.
- The difficulty of implementing the selected objective of the measurement. Remember that the measurement should be successful, that is, it is not beneficial to select an objective which is too difficult to handle.
- It is an advantage if the group is able to demonstrate the measurement to an interested party.

Based on the evaluation, the work will be graded using the scale 0, 1, ..., 5. **To pass the course, the grade of the practical assignment must be at least 1 (one).**

5 Notes and tips

There exists a large variety of purposes for which it is possible to use an image-based measurement. During the course lectures, the following topics have been considered:

1. Measuring intensity: for example, the intensity of ambient light in an environment, or the intensity of emitted light from a light source could be measured.
2. Measuring colour: for example, image-based measurement of colour correctness (against some reference measurement) or colour differences could be implemented.
3. Measuring geometry: for example, the physical dimensions or the angles between straight edges of an object could be measured.
4. Measuring image objects: for example, the image could be segmented and the characteristics of several objects in the scene could be measured/compared.

Many of these measurement purposes do not require deep background knowledge on image processing nor machine vision. However, if there are problems selecting a suitable measurement purpose it is recommended to discuss with the supervisor of the assignment.

In general, it is a good practice to make initial experiments with some equipment to gain confidence in the practicality of an idea. Also in the case of a new idea for an image-based measurement, it is appropriate to carry out initial tests to see whether the measurement can be performed.

If there are any problems with this description of the assignment, contact the supervisor of the practical assignment before making your own interpretations or too radical assumptions. **Pay attention to the deadlines.**