MINT 카메라 캘리브레이션 툴박스

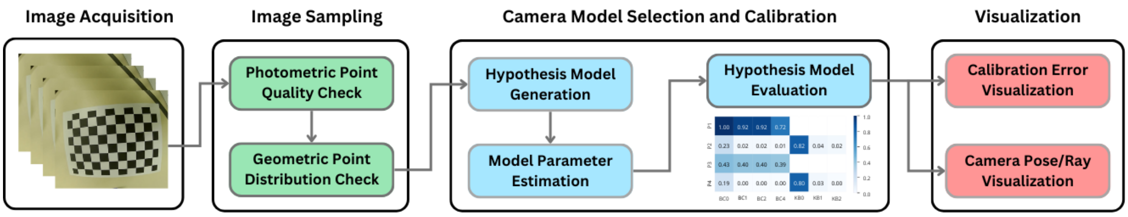
MINT Camera Calibration Toolbox

응우옌 콩꾸이[1], 최성록[1†]

Quy Nguyen Cong[1] and Sunglok Choi[1†]

Abstract: Calibration is a crucial part and a prerequisite step for implementing various computer vision applications such as 3D reconstruction, autonomous driving, image stitching, robot vision, augmented reality, and more. The current diversity of camera models makes calibration more challenging, as it requires selecting a suitable model that ensures simplicity while delivering good calibration results. To address these challenges, in this paper, we introduce an open-source tool for the auto-calibration process. Our framework can perform calibration across a variety of proposed camera models, then each model will be evaluated and automatically selected based on model selection criteria. Additionally, it facilitates the creation of a reliable dataset for calibration through effective image sampling methods. Designed for ease of use, the system streamlines the calibration process, making it more accessible and efficient for users working with diverse camera models. The most appropriate models proposed by our framework are reliable in terms of both model configuration and the quality of the calibration results. All our source code is available at https://github.com/mint-lab/mint_camera_calib

Keywords: Camera Calibration, Image Sampling, Model Selection Criteria, Camera Model Slection, Open-Source Library.



[Fig. 1]: The process for calibration and model selection.

1. Introduction

Determining camera parameters, such as intrinsic parameters (including focal length, principal point, and distortion coefficients) and extrinsic parameters (comprising the rotation matrix and translation vector), is crucial. Accurately estimating these parameters significantly enhances the performance of subsequent tasks. Recent years, numerous methods have been proposed for performing calibration, ranging from traditional approaches to modern techniques leveraging deep learning models. However, during the calibration process, we often face uncertainty regarding several key factors: the optimal number of images needed for accurate calibration, the best viewpoints for capturing images that form a comprehensive dataset, the required quality of calibration images for building a reliable dataset, and the most suitable camera model to use. Although some existing research has explored choosing the most suitable camera model, it often focuses on separate criteria for selecting projection models [1] or distortion models [2], rather than providing a comprehensive approach that integrates both aspects.

To address the challenges outlined above, this work introduces the generalized camera calibration framework, which incorporates three essential components: image sampling, model selection, and model parameter estimation. Our approach automates the creation of reliable datasets, calibrates camera parameters across a variety of models, and

※This research was supported by MSIT/NRF Grant for Bridge Convergence R&D Program (AI-based Localization and Path Planning on 3D Building Surfaces, 2021M3C1C3096810).

1. Computer Science and Engineering Department, Seoul National University of Science and Technology (SEOULTECH) Seoul, Korea.
† Corresponding author (sunglok@seoultech.ac.kr)

determines the most optimal model. In addition, the framework includes three visualization tools: model-wise heatmaps, point-wise heatmaps, and camera pose visualizations that effectively display calibration results. We also offer an open-source platform designed to simplify the camera calibration process, enabling researchers to quickly identify the most reliable model that strikes the right balance between accuracy and computational efficiency.

2. Overall Procedure of the Toolbox

An overview of the entire process is depicted in Fig. 1, outlining the four key steps involved.

2.1 Image Acquisition

A sequence of images is captured using a chessboard pattern for calibration, resulting in a dataset that will be used for further processing.

2.2 Image Sampling

Image sampling involves two key checks: the Photometric Point Quality Check, which ensures the visual consistency and clarity of reference points in the captured images, and the Geometric Point Distribution Check, which verifies that the points are uniformly distributed and well-spaced, thereby improving the dataset's reliability.

2.1 Camera Model Selection and Calibration:

The process includes several steps: First, multiple candidate models are generated by combining different projection models and distortion models. Next, the camera parameters, including intrinsic and extrinsic matrices, are estimated. Finally, each model is evaluated by assessing reprojection errors and model complexity to determine the optimal camera model.

2.2 Visualization

Two types of visualizations are offered to enhance the calibration process. The first, calibration error visualization, presents point-wise heatmaps of calibration errors for each sample, offering valuable insights into how to improve images with high reprojection errors; or model-wise heatmaps, simplifying the comparison and selection of the most suitable models. The second type, camera pose/ray visualization, illustrates the camera's position and orientation relative to the reference objects, enabling a thorough review of the constructed dataset and aiding in the development of strategies to enhance data quality.

3. Usage Guide of the Toolbox

The tool has minimal requirements, with the only prerequisite being the installation of OpenCV. Once installed, users can simply execute the command line to launch the tool.

3.1 Image Sampling

```
python image_sampling.py  video_path out_dir
                          [-c config_file.json]
```

Arguments:

- **`video_path:`** Specify the video path from which images will be extracted.
- **`out_dir:`** Specify the directory where the selected images will be saved.
- **`-c (or --config_file):`** Specify a configuration file that allows modification of the chessboard properties.

3.2 Camera Model Selection and Calibration

```
python cam_cali_select.py img_dir out_dir
                          [-c config_file.json]
```

Arguments:

- **`img_dir:`** Specify the dataset path that contains the samples for calibration.
- **`out_dir:`** Specify the directory where the calibration results will be saved.
- **`-c (or --config_file):`** Specify a configuration file that allows modification of the chessboard properties and model selection criteria.

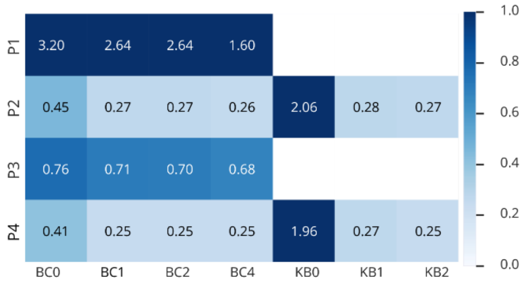
3.3 Visualization

```
python visualize.py result_dir [-t visual_type]
                               [-c config_file.json]
```

Arguments:

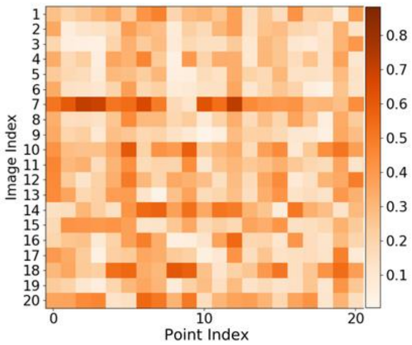
- **`result_dir:`** Specify the directory where the calibration results are stored.
- **`-t (or --visual_type):`** Select the type of visualization.
- **`-c (or --config_file):`** Specify a configuration file that allows modification of the chessboard properties and or visualization type.

  User can select the desired type of visualization through the **`visual_type`** argument:
- The *model_wise_score* option generates heatmaps to visualize the evaluated scores after applying the selection criteria, while the *model_wise_rms* option displays RMSE values for each model after calibration.



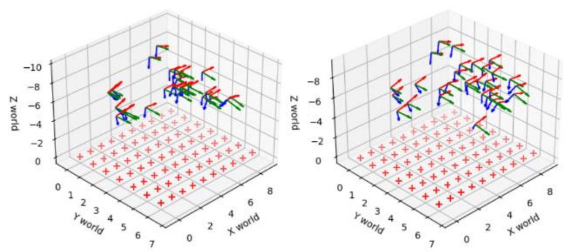
[Fig. 2]: Model wise score visualization

- The *point_wise* option analyzes individual samples within the dataset, displaying the reprojection error for each chessboard corner in every image.



[Fig. 3]: Point wise visualization

- The *cam_pose* option illustrates camera positions and orientations relative to captured images, highlighting spatial distribution and alignment with reference objects



[Fig. 4]: Camera pose visualization. A randomly selected dataset (left) is compared with our dataset (right), which is built using a proposed effective image sampling method.

References

[1] K. Kinoshita and L. Lindenbaum, “Camera model selection based on geometric AIC,” in Proceedings the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), vol. 2, 2000.

[2] V. Orekhov, B. Abidi, C. Broaddus, and M. Abidi, “Universal camera calibration with automatic distortion model selection,” in Proceedings of the IEEE International Conference on Image Processing (ICIP), vol. 6, 2007.