User Documentation - Automated Hand-Eye Calibration Application

Introduction

This document provides user instructions for the Automated Hand-Eye Calibration Application developed as part of a Master's thesis at Brno University of Technology, Faculty of Mechanical Engineering, in collaboration with INTEMAC. The application enables precise calibration of robot-camera systems using machine vision techniques, supporting both eye-in-hand and eye-to-hand configurations.

The complete source code and additional technical documentation are available on GitHub: https://github.com/plisnik/visual_inspection_cell_project.git

Application Overview

The application features a tab-based graphical interface with four main sections:

- **Home**: Displays calibration results and provides access to saving/loading functions
- **Calibration**: Contains settings and controls for the calibration process
- **Test**: Offers validation tools to verify calibration accuracy
- **Settings**: Provides system configuration options for robot and camera setup

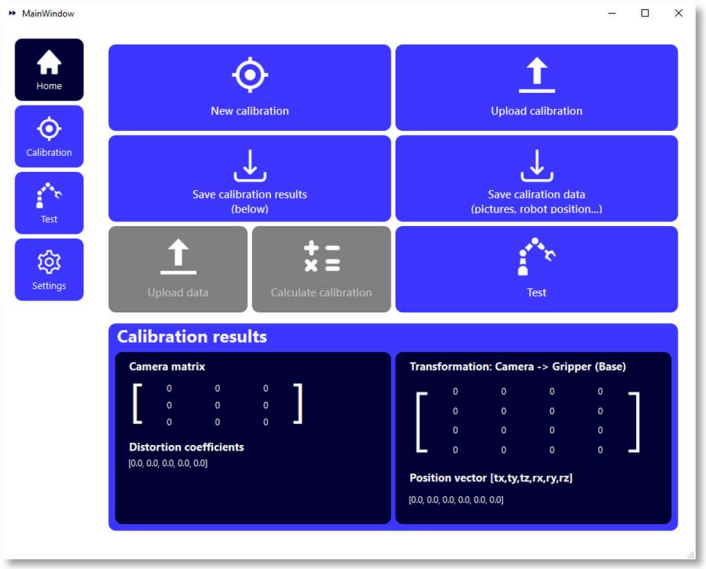
Getting Started

After installing the application and required dependencies (refer to the README.md file on GitHub), follow these steps to begin:

1. Launch the application from the command line:

   python scripts/main.py

2. The application will open with the Home tab active.



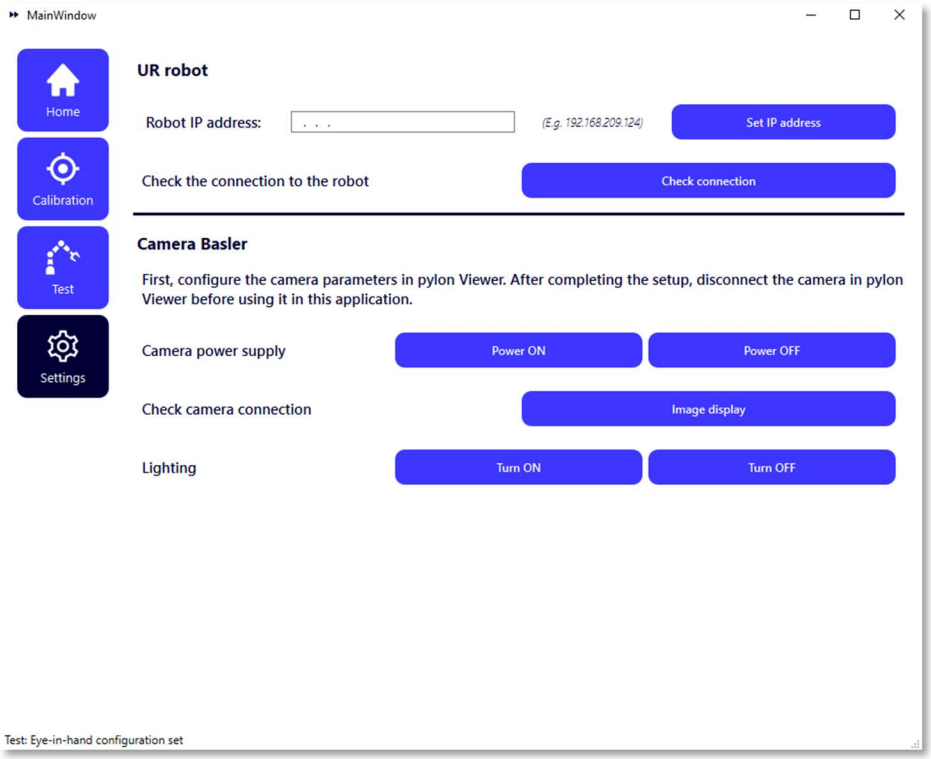
Basic Setup

Connecting to the Robot

1. Navigate to the **Settings** tab.
2. Enter the robot's IP address in the designated field.
3. Click "Check Robot" to verify the connection.
4. If successful, a confirmation message will appear in the status bar.

Camera Setup

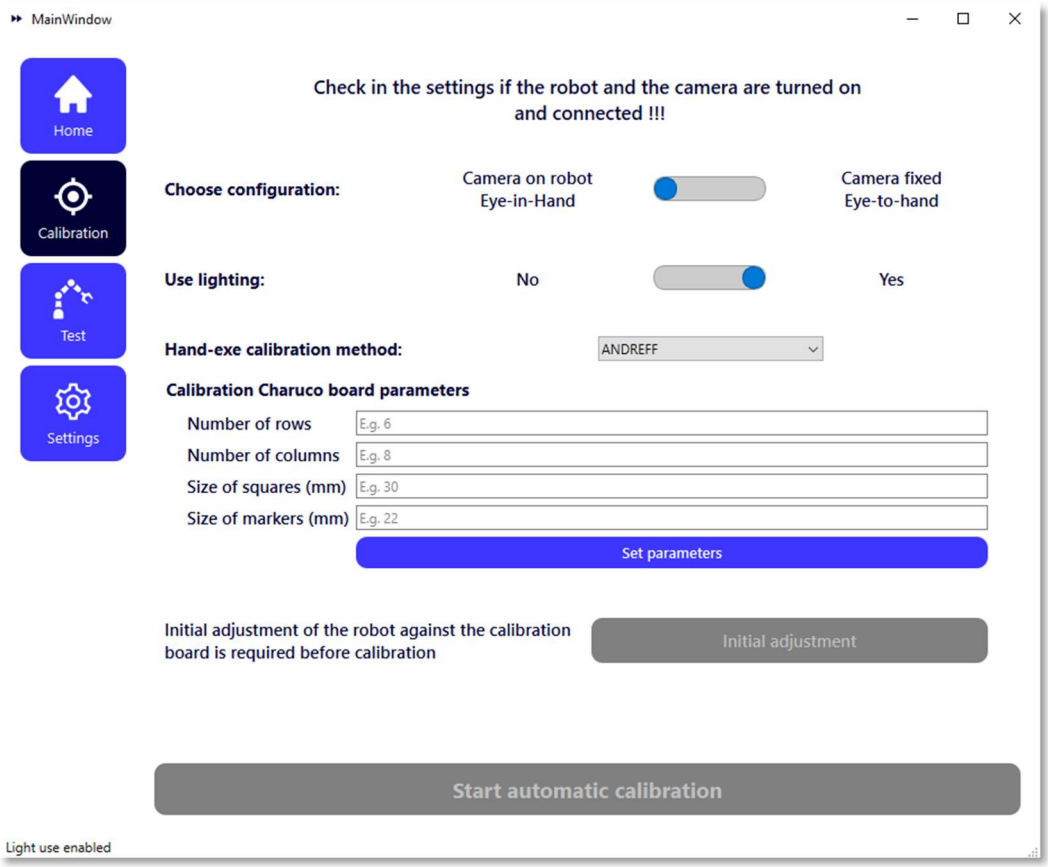
1. While in the **Settings** tab, click "Check Camera" to verify camera connection.
2. Use the "Camera ON" and "Camera OFF" buttons to control camera power.
3. If lighting is required, use the "Light ON" and "Light OFF" buttons.



Performing Calibration

Step 1: Configure Calibration Parameters

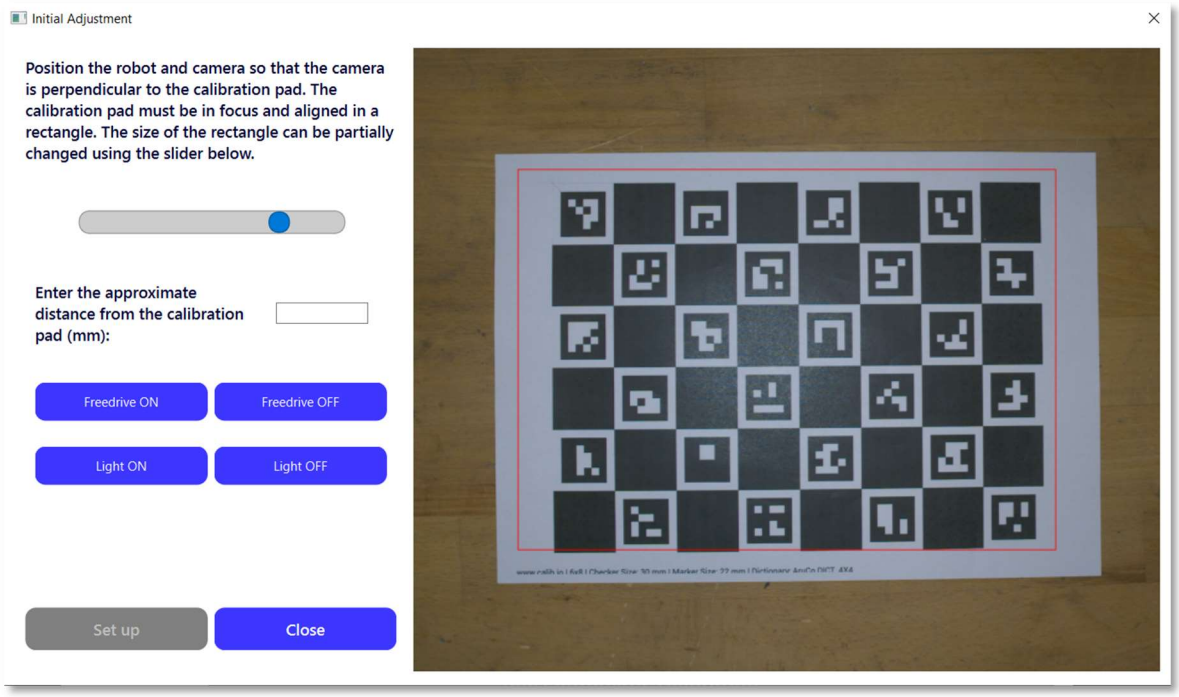
1. Navigate to the **Calibration** tab.
2. Select the appropriate configuration using the slider:
    - **Eye-in-Hand**: Camera mounted on the robot
    - **Eye-to-Hand**: Stationary camera observing the robot workspace
3. Toggle the light setting if required.
4. Select a calibration method from the dropdown menu.
5. Configure the ChArUco board parameters:
    - Number of rows and columns
    - Size of squares (in mm)
    - Size of markers (in mm)



Step 2: Initial Adjustment

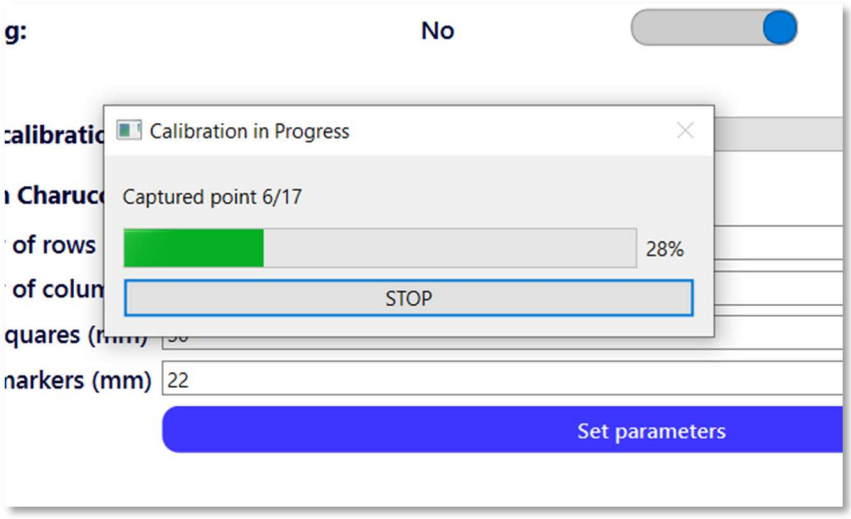
1. Click the "Initial Adjustment" button.
2. A new dialog will open showing the camera feed with a rectangle overlay. Use the slider to adjust the size of the rectangle.
3. Enter the approximate distance between the camera and calibration board (in mm).

4. Use the "Freedrive ON" button to manually position the robot/camera.
5. Ensure the calibration board is visible and roughly centered in the rectangle.
6. Click "Setup" to confirm the position.



Step 3: Start Calibration

1. Click the "Start Calibration" button to begin the automated process.
2. The system will:
    - Move the robot to multiple predefined positions
    - Capture images of the calibration pattern at each position
    - Process the images to detect the pattern
    - Calculate the calibration parameters
3. A progress dialog will show the current status.
4. The process can be stopped at any time by clicking "Stop". Attention, when the "Stop" button is pressed, the robot stops only after the current movement is performed before next movement. To stop the robot immediately, use the red emergency-stop button on the robot.



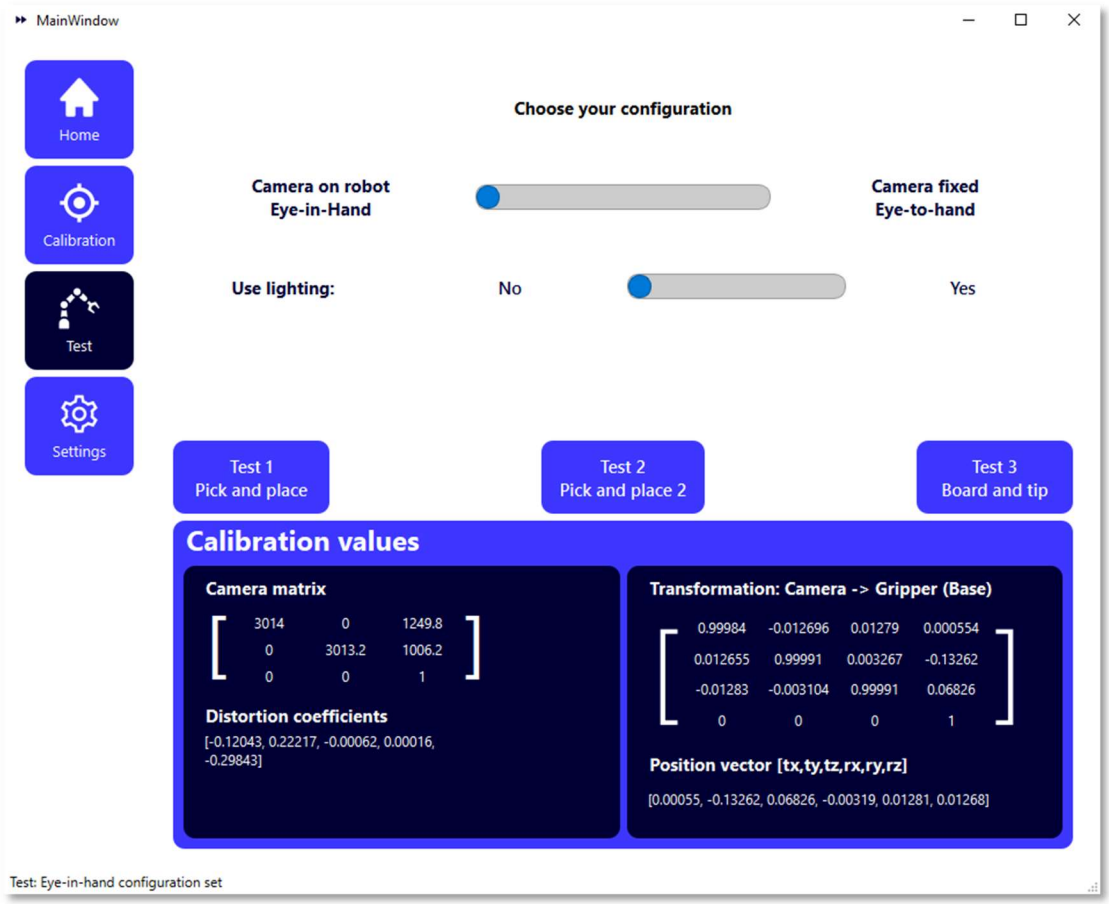
Step 4: Review Results

1. After calibration completes, the application automatically returns to the Home tab.
2. Review the calibration results displayed in the matrices and parameter fields.
3. Save the calibration by clicking "Save Calibration Results".
4. Optionally, save the complete dataset by clicking "Save Dataset".

Testing Calibration Results

After completing calibration, validate its accuracy using the testing tools:

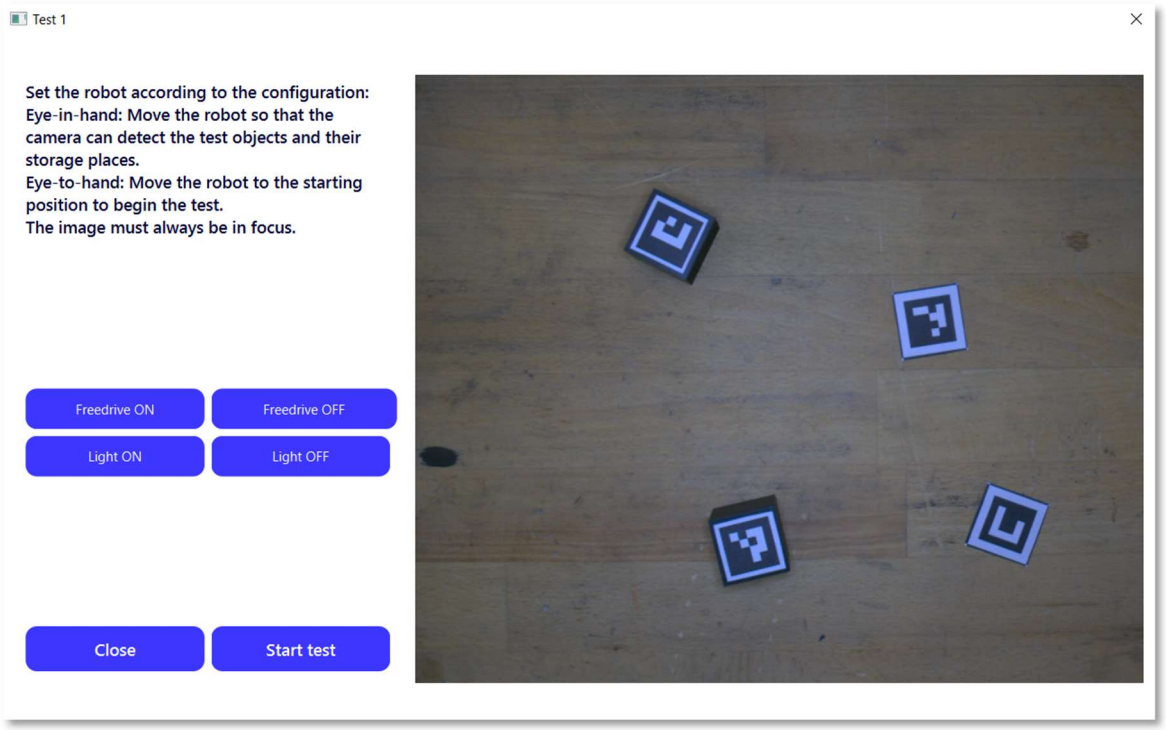
1. Navigate to the **Test** tab.
2. Select the configuration (eye-in-hand or eye-to-hand) using the slider.
3. Choose whether to use lighting.
4. Select one of the three test types:



Test 1: Marker-Based Pick and Place

This test verifies positioning accuracy by picking up objects marked with ArUco markers and placing them at target positions.

1. Click "Test 1" button.
2. In the initialization dialog, use freedrive to position the robot.
3. Click "Start Test" to begin.
4. The robot will:
    - Detect markers for objects and target positions
    - Pick up each object
    - Place it at the corresponding target position



Test 2: Form Manipulation

This test verifies relative positioning accuracy using a form with predefined positions.

1. Click "Test 2" button.
2. Use freedrive to position the robot in the initialization dialog.
3. Click "Start Test" to begin.
4. The robot will detect the form and place objects in the designated positions.

Test 3: Precision Pointing

This test verifies absolute positioning accuracy using a calibration needle.

1. Click "Test 3" button.
2. In the initialization dialog, prepare the test environment.
3. Click "Start Test" to begin.
4. The robot will move to precisely point at predefined locations.

Saving and Loading Calibration Data

Save Calibration Results

1. From the Home tab, click "Save Calibration Results".
2. Choose a location and filename in the save dialog.
3. The calibration parameters will be saved in YAML format.

Load Calibration Results

1. From the Home tab, click "Upload Calibration".
2. Select a previously saved calibration file in the open dialog.
3. The calibration parameters will be loaded and displayed.

Save Complete Dataset

1. From the Home tab, click "Save Dataset".
2. Choose a location in the folder selection dialog.
3. The complete dataset (images, robot positions, etc.) will be saved as a ZIP archive.

Troubleshooting

Connection Issues

If unable to connect to the robot:

1. Verify the IP address is correct
2. Ensure the robot is powered on and available on the network
3. Check network cables and connections

Camera Issues

If the camera doesn't respond:

1. Ensure the camera is properly configured in Pylon Viewer first:
    - Set the correct IP address in Pylon Viewer
    - Verify the camera works properly in Pylon Viewer
    - Make sure to disconnect the camera from Pylon Viewer before using the application
2. Try turning the camera power off and on using the application controls

Calibration Failures

If calibration results are poor or the process fails:

1. Ensure the calibration board is clearly visible in all positions
2. Check lighting conditions - avoid reflections and ensure even illumination
3. Verify that the board parameters are entered correctly
4. Try a different calibration method