# *The Diameter Measurement Tool Handbook*

## 1. Scripts Overview

1) main_calib_snap.py: This script is the entry script for capturing calibration images.
2) main_measure.py: Second running script for processing calibration images and algorithm to obtain calibration results and then using them to perform real-time measurements.
3) alg_calibration.py: camera calibration algorithm, to get intrinsic and extrinsic parameters, along with pixel_to_micron_factor.npy, used in alg_measure.py for measurements.
4) alg_camera.py: initializes the camera for the Windows system.
5) picamera.py: initializes the camera for the Raspberry Pi system.
6) alg_measure.py: measuring and calculating algorithm.
7) Ui_calibrator.py and Ui_page1_calib.py: UI design for capturing and measuring processes.

## 2. Python Env Setup on Raspberry Pi

1) Make sure your Raspberry Pi system is up to date:
    a. sudo apt update
    b. sudo apt upgrade
2) Install Python 3 and pip
    a. sudo apt install python3
    b. sudo apt install python3-pip
3) Install common Python libraries such as NumPy, matplotlib, Pillow, etc.
    a. pip install numpy
    b. pip install pillow
    c. pip install PyQt5
    d. pip install matplotlib
4) Install python libraries for image processing and PiCamera
    a. pip install opencv-python
    b. pip install python3-picamera

# 3. Capturing environmental setup:

The environmental requirements for non-contact precision measurement are high. Before starting, please check if the environment follows these requirements:

8) Stable Light Source: Lighting should be stable and uniform to avoid shadows and insufficient lighting.
9) Background Setup: Avoid cluttered backgrounds as they can interfere with edge detection and measurement. Additionally, there should be a contrast between the background and the object being captured to satisfy the requirements of the measuring algorithm for object edge recognition.
10) Stable Camera Position: Throughout the measurement process, the camera's position should remain the same. Mount the camera to prevent image blurring or moving

# 4. Calibrate & Measure

Once the environment is prepared, non-contact precision measurement typically involves two steps: calibration and measurement.

### 4.1 Calibration Principle:

Establish the relationship between the camera's internal parameters and its coordinates in the real world. This process corrects distortions and accurately determines the factors for converting pixels into physical dimensions. With the intrinsic and extrinsic parameters obtained through calibration, along with the conversion factor, precise measurements of diameters or other dimensions in captured images can be achieved.

### 4.2 Calibration Steps:

1) Prepare the calibration board: Based on the camera parameters and the required field of view (FOV) for capturing objects, prepare a calibration board of appropriate size. The calibration board should be rigid; you can print the required size of the calibration board from websites (such as https://calib.io/pages/camera-calibration-pattern-generator) and then paste it onto a board. Choose a “checkboard” pattern for our project.


Figure 1: Generation of Calibration board Pattern

2) Before starting calibration, adjust the background and lighting for shooting, as well as find a distance to ensure the object appears clearly in the center of the shot and forms a distinct contrast with the background, allowing the measurement algorithm to better identify the object's edges.
3) Capture calibration images: First, run "main_calib_snap.py", and select the folder to save the calibration images. Start capturing calibration images from a close place to the actual object getting from step 2). Capture the calibration board from different angles. Each time you click the "snapshot" button, the number of calibration images will increase, and the number of captured images will be displayed on the interface. Capture approximately 20 to 30 calibration images. Ensure that the calibration board occupies more than 80% of the camera's view, and all corners need to be fully visible.

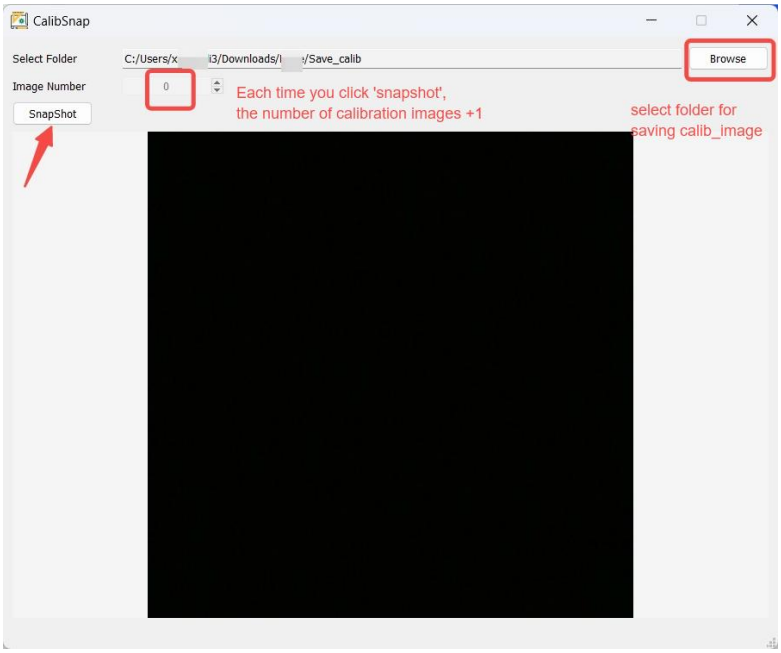


Figure 2: Interface for Capturing Calibration Images

4) Calibrate: Run the “main_measure.py script”. Click "Browse" to select the folder where the calibration images are captured from step 3). Modify the corresponding parameters for the calibration board: column, row, and checkerboard size.
   After inputting the parameters of the calibration board, click "calibrate" to start. The calibration window will scan each calibration image, and calibration is considered successful only when all inner points are scanned. The calibration results will be displayed below the window.

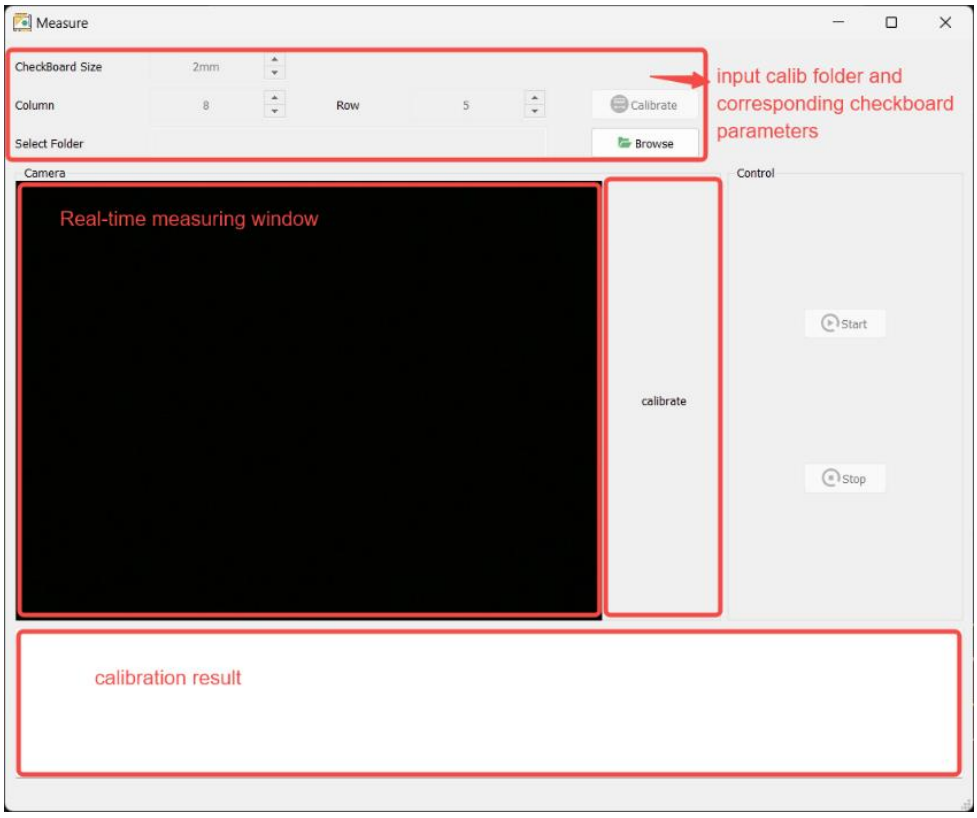


Figure 3: Real time Measurement Interface

Note that the number of columns and rows corresponds to the number of inner points. For example, if the calibration board has a grid number of 6 x 9, here it should be 5 x 8. Size refers to the size of each grid on the checkerboard. If the input parameters for the calibration board are incorrect, the calibration will not proceed successfully.

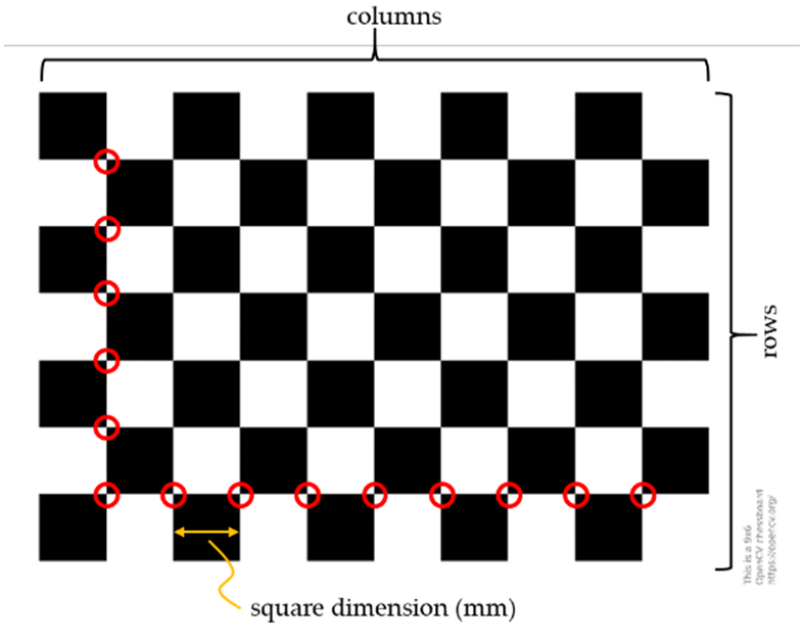


Figure 4: Schematic Diagram of Calibration Board Parameters

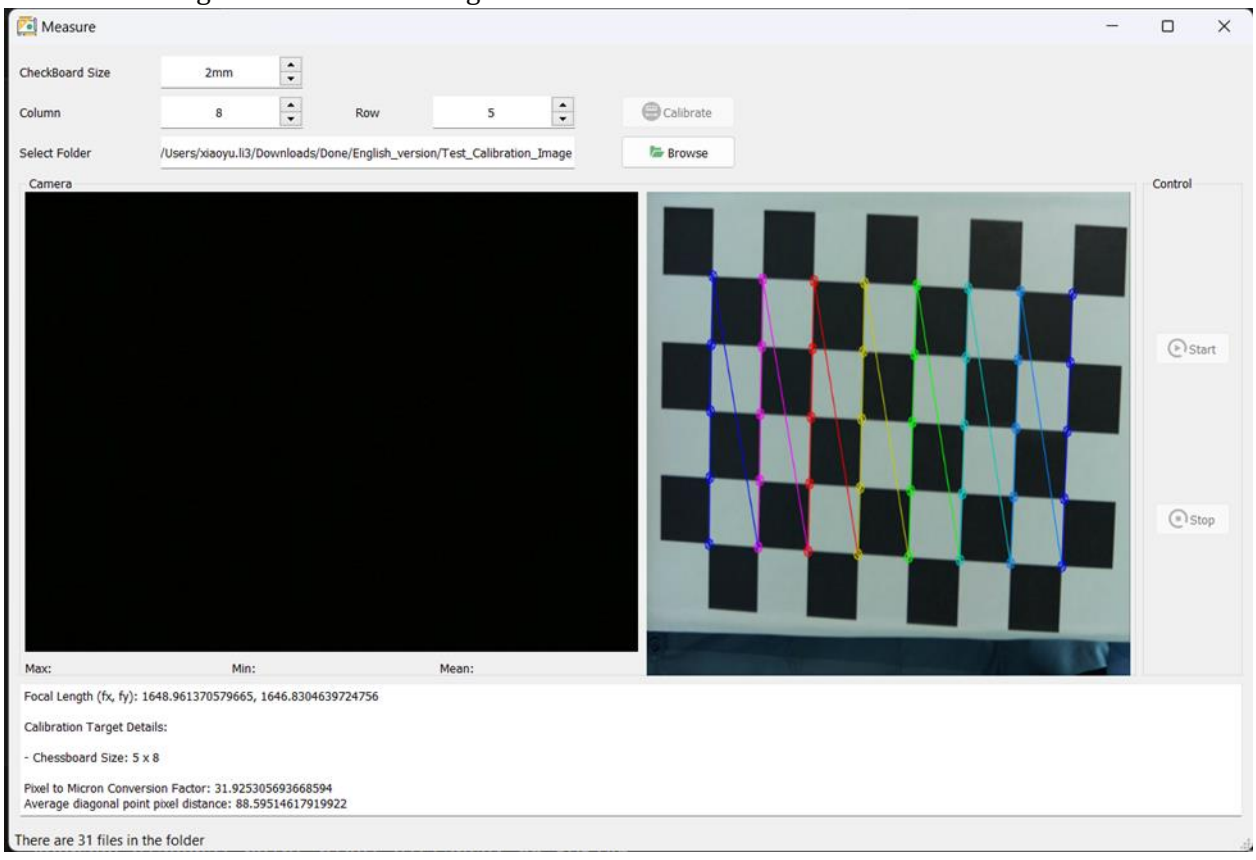


Figure 5: Illustration of Calibration Process After Inputting Calibration Images. After Calibration Completion, the Start Button on the Right Turns Blue, Allowing Real-Time Measurements to Begin.

### 4.3 Measurement:

After obtaining the calibration results, click the "start" button on the right side of the window to start the measurement. The maximum, minimum, and average values should ideally be measured, and they will appear below the window.

## 5. URL Reference

Tutorial on how to enable Internet and SSH on a Raspberry Pi:

- https://www.seeedstudio.com/blog/2021/01/25/three-methods-to-configure-raspberry-pi-wifi/
- https://phoenixnap.com/kb/enable-ssh-raspberry-pi#ftoc-heading-9

When there is no monitor available, use the VNC server to access the Raspberry Pi system on your laptop or for remote control:

- https://www.youtube.com/watch?v=Zoxus1QoEZo

Camera Documentation:

- Raspberry Pi High Quality Camera
- Raspberry Pi Camera Documentation
- Raspberry Pi High Quality Camera Lens Mount Drawing
- Camera Calibration Pattern Generator

Calibration tutorial:

- https://calib.io/pages/camera-calibration-pattern-generator
- Calibration Method (Starts at 6 minutes 40 seconds)