Camera Calibration

Applied Physics 167

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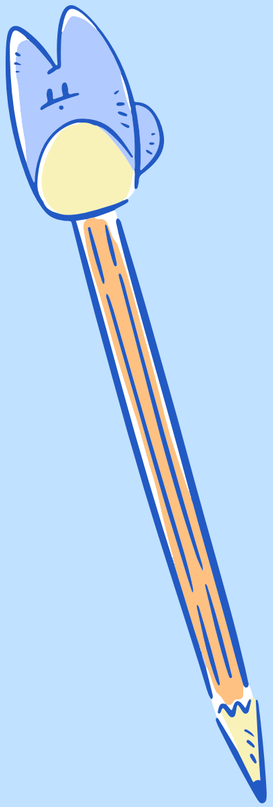
Objectives

1. Model the physical processes involved in the geometric aspects of image formation.
2. Perform image calibration using Tsai grid and a phone camera.
3. Verify the camera calibration by predicting the image coordinates of some corner points.



Introduction

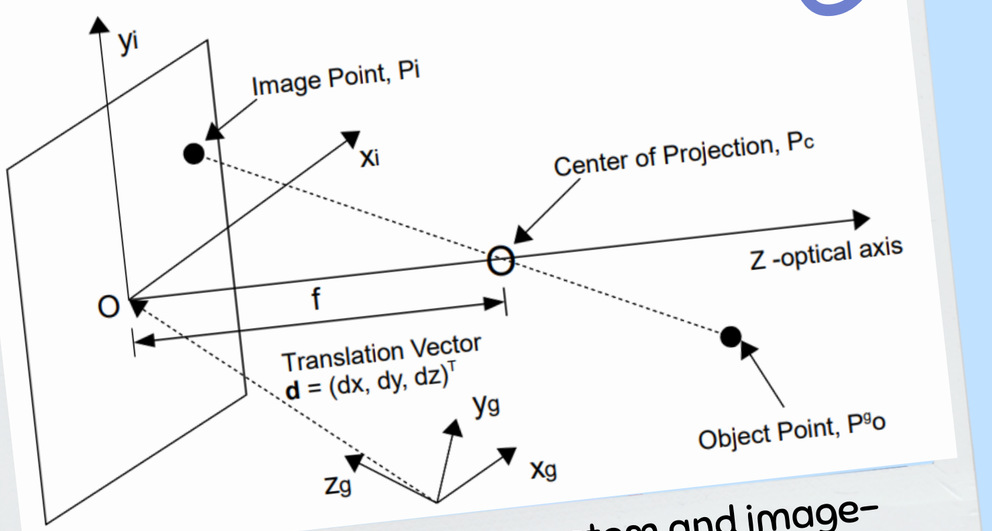


Figure 1. Global coordinate system and image-plane coordinate system

source:https://uvle.upd.edu.ph/pluginfile.php/990439/mod_resource/content/1/Camera%20Calibration%20Lecture.pdf

Modeling the physical processes inherent to the geometric aspects of image formation is imperative for various reasons. Consider the example of a pinhole camera model, which employs an image plane-centered coordinate system, but this approach proves impractical. Hence, we adopt a user-defined global coordinate system for our purposes, which can be transformed to align with the image-plane centric coordinate system, as illustrated in Figure 1 [1].

Introduction

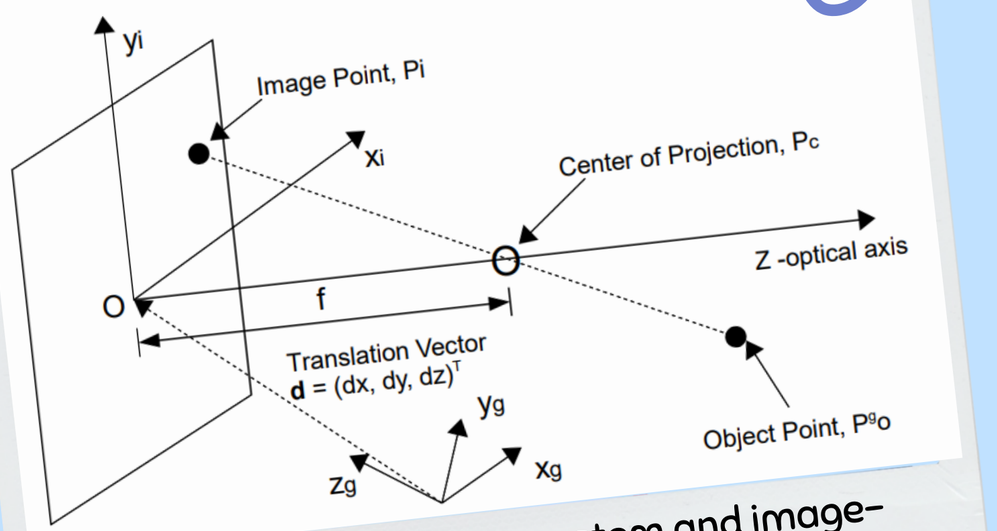


Figure 1. Global coordinate system and image-plane coordinate system

source:https://uvle.upd.edu.ph/pluginfile.php/990439/mod_resource/content/1/Camera%20Calibration%20Lecture.pdf

This transformation comprises multiple translations and rotations, collectively forming matrix A with its components denoted as a_ij, representing the camera parameters we aim to determine. This procedure is referred to as camera calibration.

In this activity, we perform camera calibration using a constructed Tsai grid and a phone camera.

Methodology

1

We constructed a Tsai grid with 1-inch by 1-inch squares on an illustration board, ensuring perpendicular alignment between the boards. I used my phone camera to capture the image. The global coordinate system, defined by the x-y-z axes shown in Figure 2, was selected for reference.

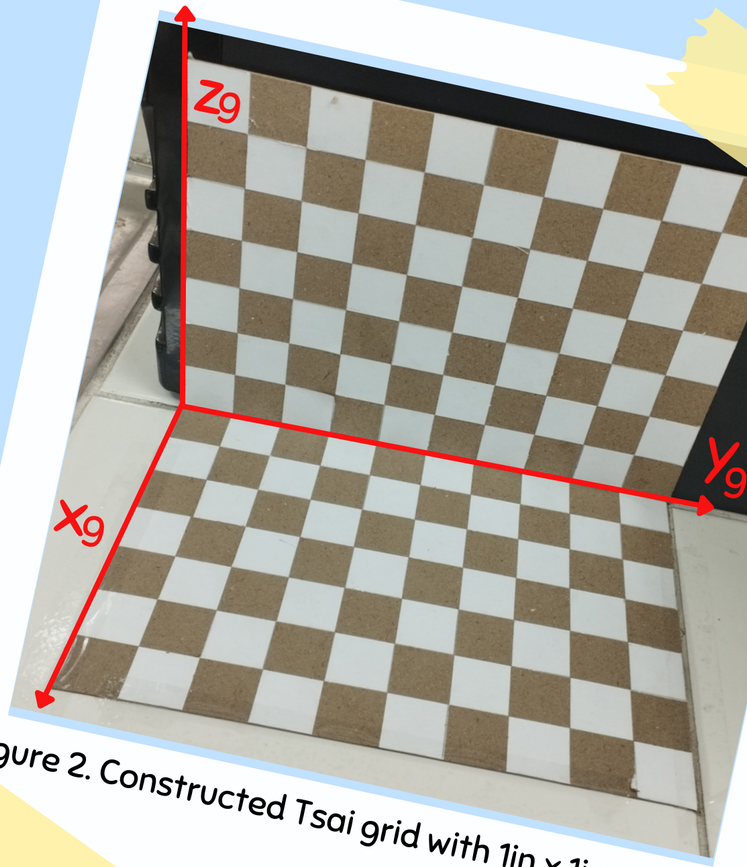


Figure 2. Constructed Tsai grid with 1in x 1in squares.

Methodology

I selected 25 corner points from the grid and recorded their global coordinates along with corresponding image coordinates using the paint software. Care was taken to encompass a substantial portion of the available corner points on the grid.

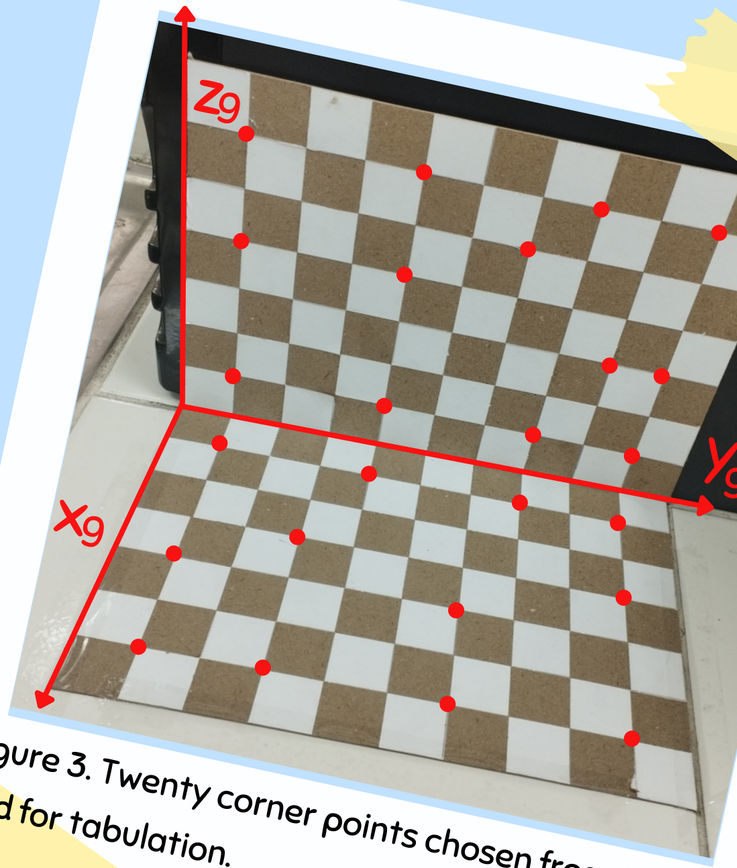


Figure 3. Twenty corner points chosen from the Tsai grid for tabulation.

click to see the data points

Methodology

I imported the data into MATLAB and developed a code to compute the elements of matrix A. Following this computation, I selected various test points and used the camera parameters obtained to predict their respective image coordinates, thereby validating the camera calibration.

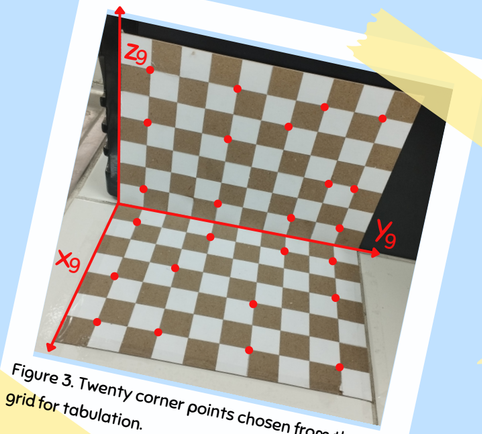


Figure 3. Twenty corner points chosen from the Tsai grid for tabulation.

3

click to see the code

MATLAB

Results

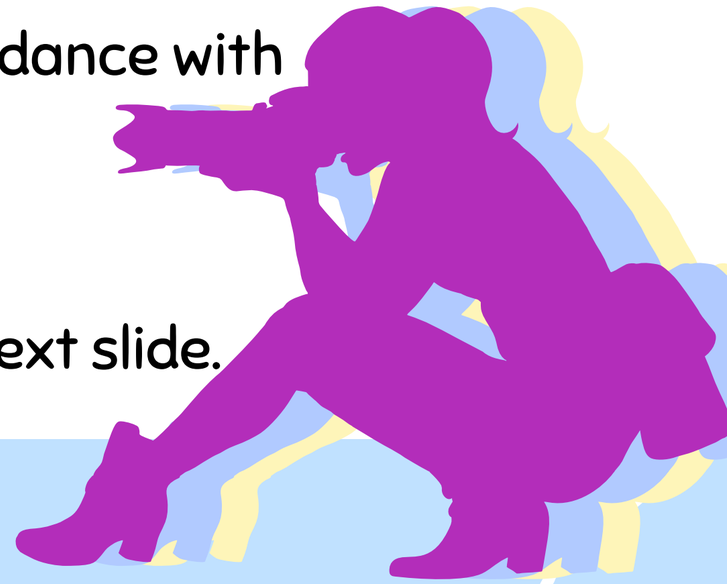
11x1 double

	1
1	-70.6448
2	160.0442
3	-64.5640
4	1.2807e+03
5	44.3749
6	-1.1060
7	-168.6670
8	1.5888e+03
9	-0.0365
10	0.0011
11	-0.0314

Figure 3. Screenshot of matrix A obtained from MATLAB

Upon executing the MATLAB code, the elements of matrix A were successfully derived, as depicted in Figure 3. Utilizing these camera parameters, I attempted to predict the image coordinates of randomly selected corner points. The calculation of image coordinates was executed in accordance with Equations (29) and (30).

The result of the prediction is shown in the next slide.



Predictions

	(x9, y9, z9)	xi	yi
1	(2,8,0)	2587	1783
2	(0,8,1)	2554	1443
3	(0,7,4)	1427	621
4	(2,2,0)	15708	1803
5	(0,3,2)	1734	1327

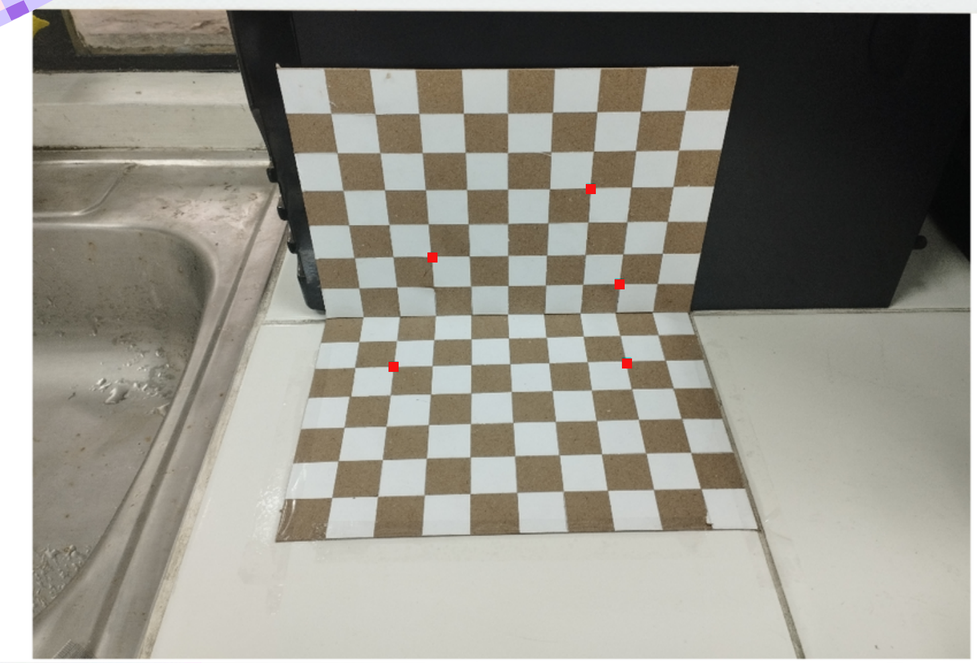


Figure 4. Image coordinate predictions of randomly selected corner points.

Analysis

Figure 4. Image coordinate predictions of randomly selected corner points.

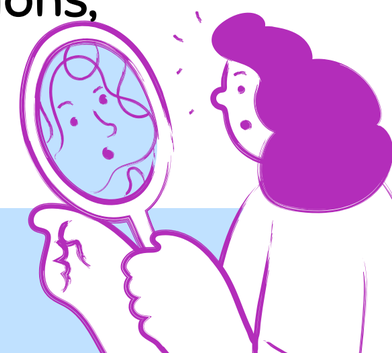
As observed, we successfully estimated the image coordinates of randomly selected corner points, albeit with some degree of inaccuracy. Several factors may have contributed to this slight error, including the measurement uncertainty associated with the image coordinates of the reference corner points employed in the camera parameter calculation.

Conclusions

The camera calibration using a Tsai grid and a phone camera was successfully executed. To evaluate its accuracy, I conducted a verification by predicting the image coordinates of specific corner points. While minor discrepancies were noted, this process underscored the utility of the calibration procedure. In summary, this activity has enhanced my understanding of image formation and calibration techniques.

Reflection

I thoroughly enjoyed every aspect of this activity, ranging from the initial creation of the Tsai grid, the execution of MATLAB code to obtain image parameters, to the subsequent prediction of image coordinates. During the course of this activity, I did encounter a setback in my initial attempt to predict the image coordinates. However, I reevaluated all the components involved and identified an error in the matrix Q, which had caused some confusion and mixing up of image coordinates. Upon solving this issue and confirming the accuracy of my approach, I achieved the desired results. It was particularly gratifying to witness the correctness of the predictions, providing a sense of fulfillment (*kilig*) and accomplishment in the process.



Self-Grade

CRITERIA	perfect score	my score
Technical correctness	30	30
Quality of presentation	30	30
Reflection	30	30
Ownership	10	10
TOTAL	100	100

I give myself a perfect score for this activity due to my active participation in all its facets. I collaborated with my fellow labmates, namely Jonabel, Julian, and Nic, in the creation of the Tsai grid. Additionally, as this report was intended to be an individual effort, I developed my own MATLAB code to derive matrix A and conduct the necessary predictions. Most notably, I achieved a significant milestone by accurately estimating the image coordinates of several corner points.

References:

1. Soriano, M. N. (2023). A Geometric Model for 3D Imaging. uvle.upd.edu.ph. https://uvle.upd.edu.ph/pluginfile.php/990439/mod_resource/content/1/Camera%20Calibration%20Lecture.pdf