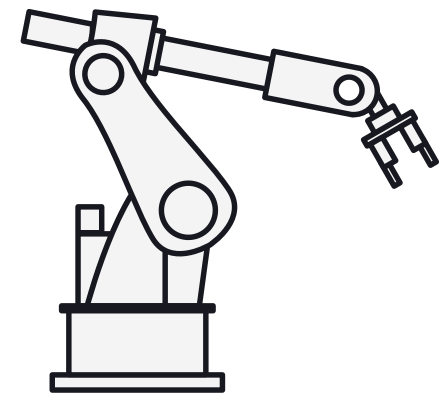
ECE 499: SMART MARINE CHARGER

An overview of our solution to the challenge of a guidance system for a smart marine charger.



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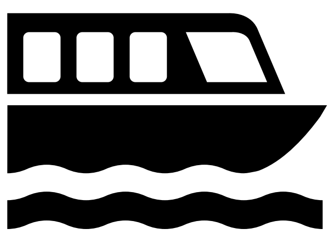
AFFILIATIONS

This project was completed in order to satisfy the requirements of the ECE499 project course at the University of Victoria.

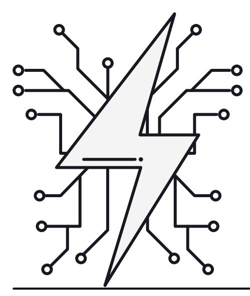
We would also like to thank our project sponsor Babak Manoucherhrinia Ph.D for his support and guidance.



01 INTRODUCTION

As the world moves into a more sustainable future with the electrification of transportation, one of the most important considerations that needs to be made is how can we improve and invent infrastructure to support charging of electric vehicles.

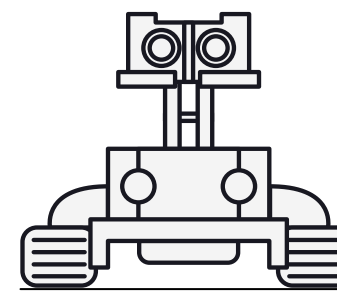
This challenge is compounded when taken in context to an electric ferry route which often requires fast and efficient connection and charging of vessels.



02 GOALS

The purpose of our study was to prototype and develop a camera vision guidance system that will facilitate the autonomous charging of an electric ferry via a robotic charging station.

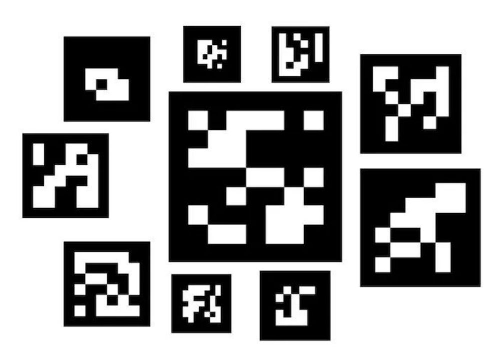
The system was designed to autonomously locate the charging receptacle of an electric ferry and provide guidance co-ordinates in real time to a robotic arm in order to facilitate connection.



03 METHODOLOGY

Our approach to this problem involved the use of a camera paired with unique identifying markers which can relay data regarding the position of the camera space vs the world space it is interacting with.

The markers selected were the ArUco markers which is an OpenCV solution that is supported in the Python Development Environment.



04 RESULTS

The following measurements were made using the system developed and are listed to denote the centimeter (cm) precision of the solution.

	Measured Distance	Actual Distance	Abs Error
p_{12}	$[1.97 \quad 0.04 \quad 0.01]^\top$	$[2 \quad 0 \quad 0]^\top$	0.06
p_{23}	$[0.01 \quad 1.96 \quad 0.24]^\top$	$[0 \quad 2 \quad 0]^\top$	0.25
p_{13}	$[1.97 \quad 2.01 \quad 0.25]^\top$	$[2 \quad 2 \quad 0]^\top$	0.25

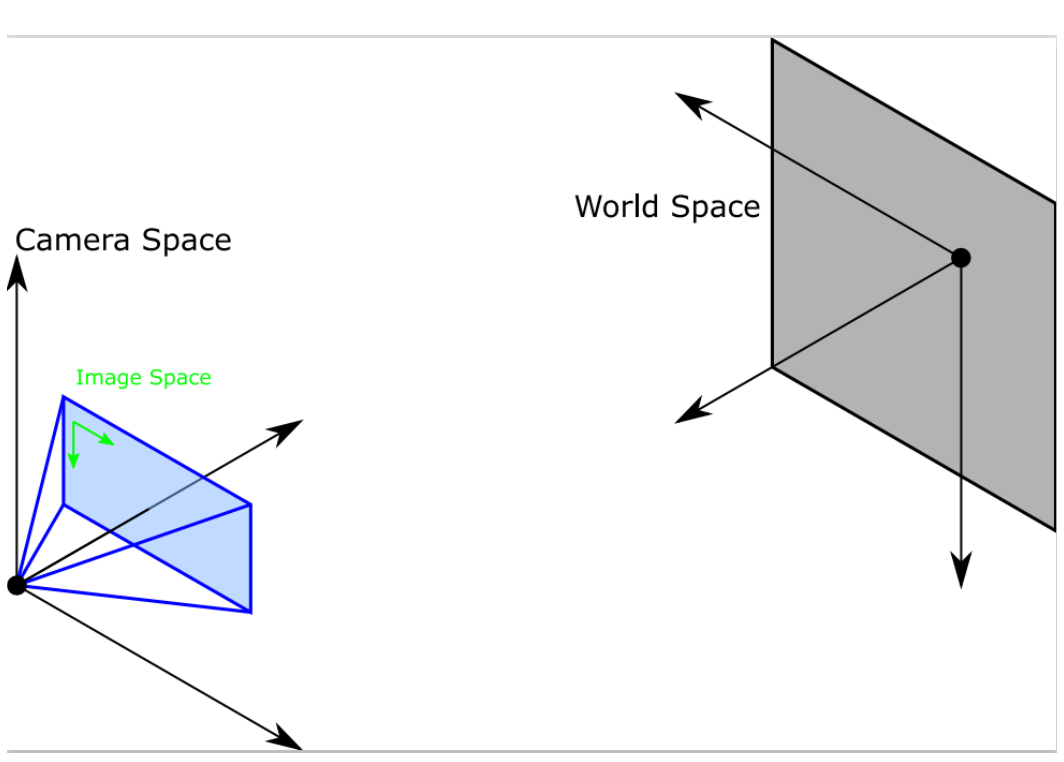
Table 1: XY Plane Results

	Measured Distance	Actual Distance	Abs Error
z_{12}	2.17	2.2	0.03

Table 2: Z Axis Results

05 ANALYSIS

The system works by capturing an image from a camera which is located on the robotic charging arm. The ArUco marker is located near the location on the ferry where electrical connection will be made.



Points are mapped between the camera and the marker by use of the following formula:

$$\hat{\boldsymbol{x}} = \boldsymbol{K}\boldsymbol{R}\left[\boldsymbol{I_3}| - \hat{\boldsymbol{X}}_{\boldsymbol{0}}\right]\hat{\boldsymbol{X}} = \boldsymbol{P}\hat{\boldsymbol{X}}$$

With

$$\hat{\boldsymbol{x}} = \begin{bmatrix} \boldsymbol{x} \\ 1 \end{bmatrix} \qquad \hat{\boldsymbol{X}} = \begin{bmatrix} \boldsymbol{X} \\ 1 \end{bmatrix}$$

$$\hat{\boldsymbol{X}}_{\boldsymbol{0}} = \begin{bmatrix} \boldsymbol{X_0} \\ 1 \end{bmatrix}$$

Where

- $\hat{\boldsymbol{x}} \in \mathcal{R}^2$ is a point in image space
- $\hat{\boldsymbol{X}} \in \mathcal{R}^3$ is the corresponding point in world space
- $\hat{\boldsymbol{X}}_{\boldsymbol{0}} \in \mathcal{R}^3$ is the position of the camera in world space
- $\boldsymbol{R}$ is a rotation matrix
- $\boldsymbol{K}$ is the intrinsic camera matrix
- $\boldsymbol{P} \in \mathcal{R}^{3\times 4}$ is the projection matrix

Example of our test setup

Since the position of the camera on the robotic arm and the position of the marker on the receptacle are static the relative position matrix can be generated and used to guide the autonomous arm to final connection.

06 CONCLUSION

We believe this project presents a very viable solution to the challenge of an autonomous marine charger guidance system. The final implemented solution can be improved through the use of more expensive and sophisticated camera equipment which will greatly enhance the quality of images taken as well as provide optical methods to reduce glare or other environmental conditions.

REFERENCES

[1] OpenCV Team. “Detection of ArUco Markers,” OpenCV Docs, [Online]. Available: https://docs.opencv.org/4.5.2/d5/dae/tutorial_aruco_detection.html (accessed on 07/26/2021).