System for mapping from world coordinates to galvo voltages

Stingray Marine Solution

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1 Introduction

The goal of this task is the ability to find the galvanometer voltages that will aim the laser at a certain point in 3D space. This task assumes that by early 2019 we will have achieved an accurate way of measuring the position of a point in 3D space using our stereo camera system. The task is divided into several sub-tasks that are described below. These sub-tasks' initial focus is to build, visualize and calibrate a 2D galvanometer setup and then expand this to 3 dimensions. The implementation of the solution should preferably be in either python or C++. It is ok to make adjustments to the models described below if neccessary (e.g if it gives a more accurate model of the real world). We will work in a shared google docs folder where we will upload necessary and useful material. This includes

- Data sheet of galvanometers
- Dissertation of Anne Jordt. Contains useful modelling of underwater light.

Some tasks may be done in cooperation with other employees of Stingray if appropriate. It is important that the different tasks are documented as the solution to this problem will be used in production if the results are satisfying.

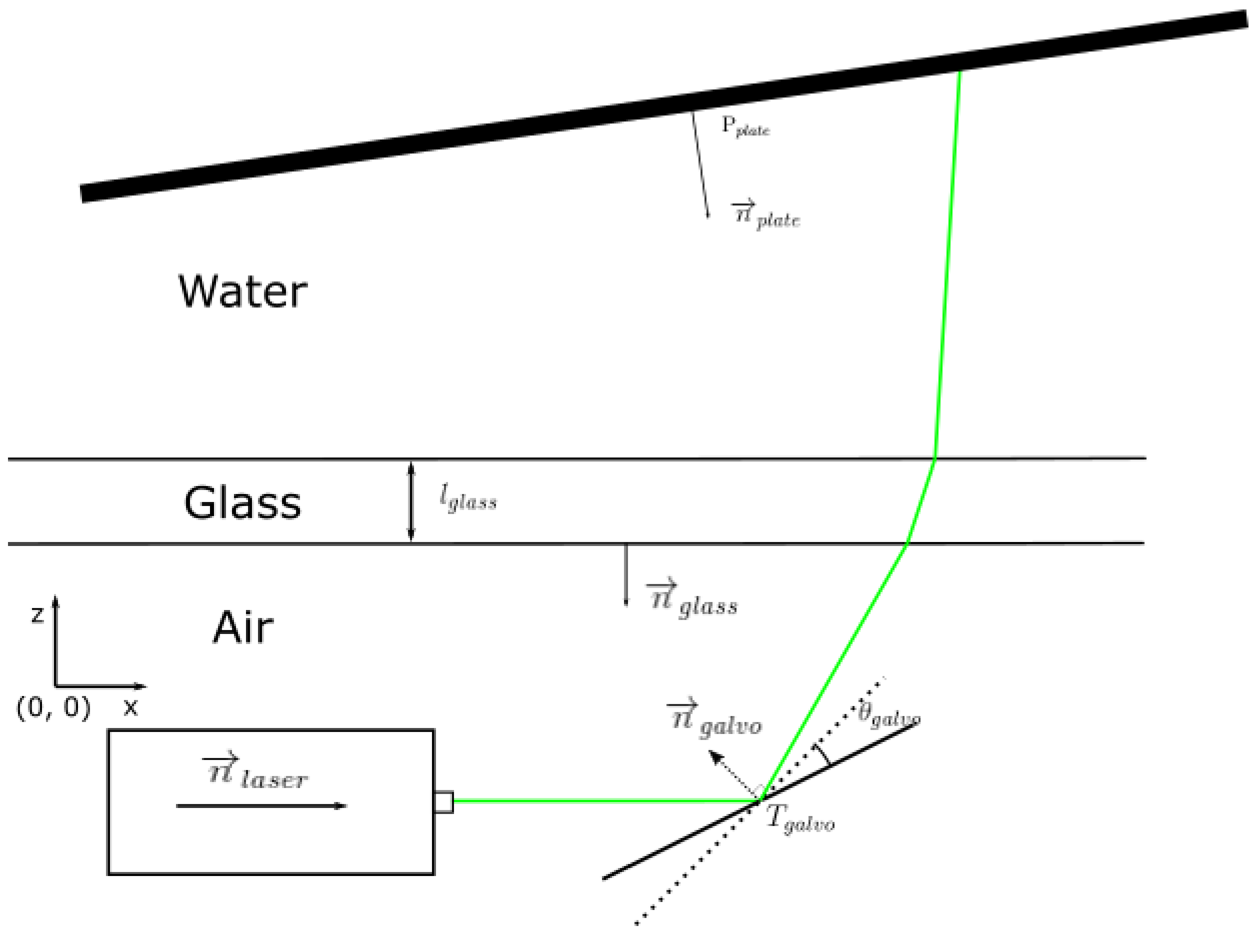

Figure 1: Laser system setup in 2D

2 Tasks

2.1 Create virtual system (2D)

The first task consists of creating a virtual system of the laser setup in 2D. This means that only one galvo (x) is used. The system should correspond to the model described in Picture 1 and Table 2.1. When the task is finished the program can project and visualize the laser throught the different interfaces.

Variable	Description
$\overrightarrow{n}_{galvo}$	Vector normal to default position of galvanometer
θ_{galvo}	Angle of galvanometer
T_{galvo}	Translation of galvo in world coordinate system
$\overrightarrow{l}$	Direction of laser
$\overrightarrow{n}_{glass}$	Vector normal to glass interface
l_{glass}	Thickness of glass
$\overrightarrow{n}_{plate}$	Direction normal to the "calibration plate"
P_{plate}	Point on plate

Table 1: Description of variables

2.2 Obtain voltage values from world coordinates (2D)

Given a world coordinate that we want to shoot. What is the corresponding voltage that will hit the point? This assumes that all the different parameters of the system are known. The suggestion is to use an "inverse kinematic" approach. The method could be either analytical or iterative.

2.3 Calibration of laser system (2D)

In reality, there are many unknown parameters in the system and we would like the ability to estimate/calibrate these. The task is to come up with a method to obtain these parameters. We are using CMA-ES for the calibration of the housing parameters for the cameras, which also could be investigated for the laser calibration. Suggested approach

1. Select random set of parameters
2. Forward a pattern on the virtual calibration plate
3. Extract voltage/world-coordinate pairs
4. Assume unknown parameters. Use voltage/world-coordinate pairs to estimate the parameters of the system

2.4 Create virtual system (3D)

Same task as in 2.1, but expand the model to include the vertical galvo as well (y). This might include adding new parameters to the model. The system

	Parameter
Unknown	$\overrightarrow{n}_{galvo}$
	T_{galvo}
	$\overrightarrow{l}$
	$\overrightarrow{n}_{glass}$
	l_{glass}
Known	$\overrightarrow{n}_{plate}$
	P_{plate}
	θ_{galvo}

Table 2: Description of variables

should take into consideration that the galvos are two separate mirrors and not treat the galvos as one mirror with two degrees of freedom (Picture 2). When projecting the laser with voltages sampled from a grid the laser should project a pin cushion pattern on the back plate due to the translation between the galvos (Picture 3).

2.5 Obtain voltage values from world coordinates (3D)

Same as in 2.2 but in 3D.

2.6 Calibration of laser system (3D)

Same as in 2.3 but in 3D. The additional parameters added when moving the model from 2D to 3D should be added. Some justificitaion of whether new parameters will be calibrated or assumed to be known should be done. This could be done by using the system in 2.4 to investigate what the impact of an error in different parameters is on the laser projection. .

2.7 Calibrate virtual system using real laser points

Use real laser points from a unit. The calibrated system should correspond to the CAD models of the system. Test on multiple nodes to see how much the different units diverges in their setup. Is it possible to use the same calibration for multiple units?

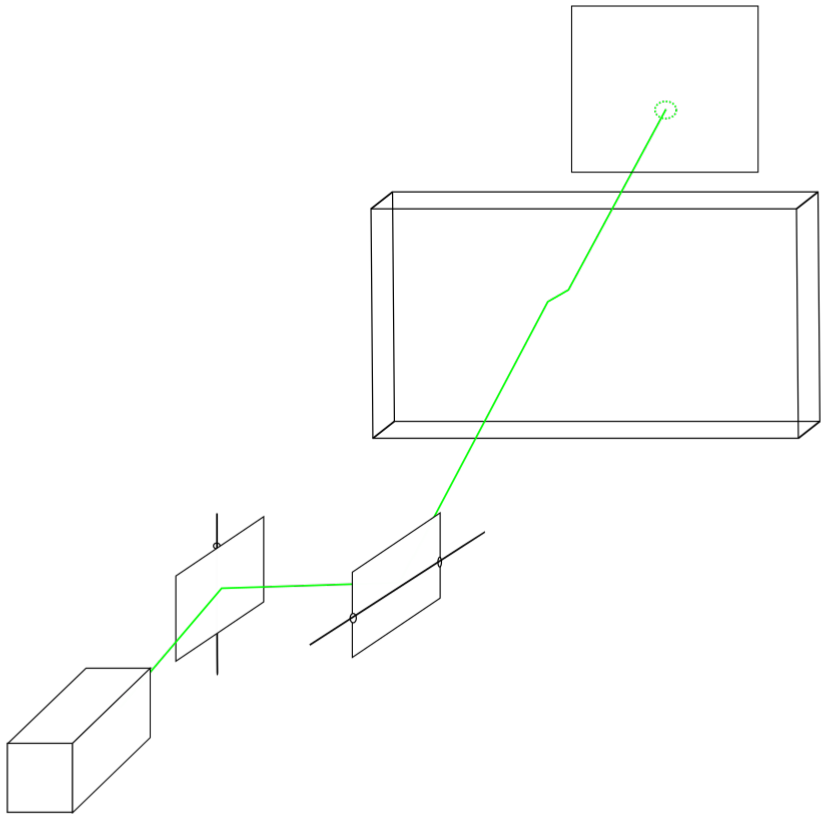

Figure 2: Laser system setup in 3D

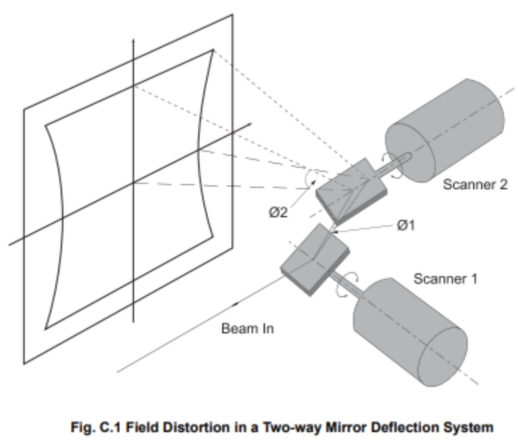

Figure 3: Pin cushion pattern as a result of the galvanometers being to separate mirrors.

2.8 Test precision on real system

Test the voltage values obtained on a real node to assess the precision. This requires an implementation integrated into *thirdeye*.

3 Project Plan

With each task described in 2, there is a corresponding deliverable. The deliverable will be a demo and presentation of the job done along with a small "report" describing the work and mathematical theroy used. The project is divided into 3 different phases: 2D, 3D and practical testing. The time estimates given in the list below assumes a 50% work load.

1. System in 2D (8 weeks)
   (a) Get to know task (1 week)
   (b) Create virtual system (2 weeks)
   (c) Obtain voltage values from world coordinates (2 weeks)
   (d) Calibration of laser system (3 weeks)
2. System in 3D (4 weeks)
   (a) Create virtual system (1 week)
   (b) Obtain voltage values from world coordinates (1 week)
   (c) Calibration of laser system (2 weeks)
3. Practical testing (5 weeks)
   (a) Calibrate system using real laser points (2 week)
   (b) Test precision on real system (3 weeks)