3630 Project 2: Multi-Modal Sensing

Released Sep 17, 2024
Due Sep 30, 2024

Overview

The setting for this project is that an e-puck robot is navigating a maze to find a traffic sign. You are provided code that will determine whether the traffic sign is in the camera feed of the robot. Your task will be to determine:

1. The depth (not the distance) and angle to the sign using the 2-cameras method
2. The distance and angle to the sign using camera + lidar method

There are two identical cameras attached to the robot, horizontally displaced from each other. First, you will determine the distance using the stereo camera feed. You will use the two images captured simultaneously from these two cameras to determine the distance and heading from the traffic sign using a triangulation method. The L7_Camera.ppt lecture notes (found in Canvas) should be helpful for accomplishing this portion of the assignment.

In the second part, you will leverage the lidar on the robot to determine the distance and heading, using both the point cloud of the lidar, and one image captured by the robot. The lidar data is composed of an array of 360 distance values around the robot, one for each degree for 0 to 359 deg.

Webots Simulator

We will be employing the Webots simulator in this project (and in some of the future projects in this course). You will need to install it using the following installation procedure (this includes documentation for Linux, Windows, and Mac).

You will be provided with a series of world files and a controller for the e-puck robot. The assignment will then require finding the distance/depth and heading of a traffic sign, relative to the robot, in each world file. The code structure and respective functions are described in the next section.

To test out your scripts in the Webots simulator, open a world file (named either as `proj2_world_vision_lidar_#.wbt` or as `Vision_only_world#.wbt`), and run the simulation. The first few (typically 3) iterations running the controller might have blank images, however it should then allow you to see the required distance/ depth and angle values print on the Webots console.

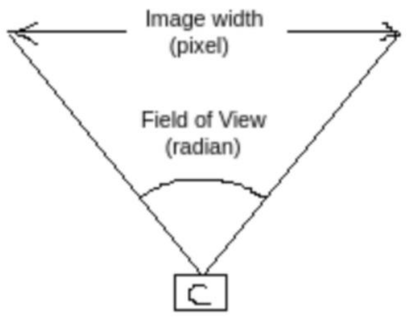
Requirements Installation

You can use the requirements.txt file to install all necessary packages by running `pip install -r requirements.txt`

Assignment

Preliminaries

The field of view is the range of the world (in this project, defined in radians) in the horizontal plane that is visible.



We provide the following formula that can be used to include the field of view in the calculation of focal length for both parts 1 and 2:

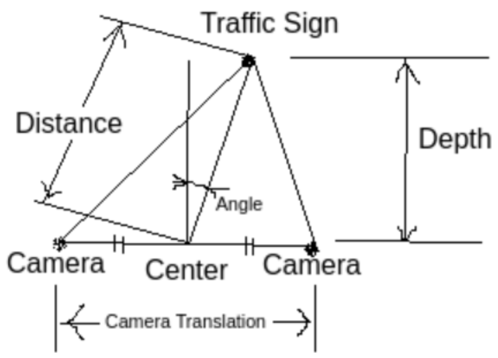
focal_length = image_width / (2 * math.tan(fov / 2))

Part 1: Determine depth and angle using stereo vision

To complete part 1, you will need to fill out the `vision_only_depth_calculation(image1, image2, fov, camera_translation)` function in

`proj2_vision_only_controller/vision_only_calculation.py`

The `vision_only_depth_calculation(image1, image2, fov, camera_translation)` function takes in two images, camera field of view, camera translation (distance between the 2 cameras) and returns the depth (perpendicular distance from the traffic sign to the line joining the cameras) and angle from the robot to the traffic sign in the images.



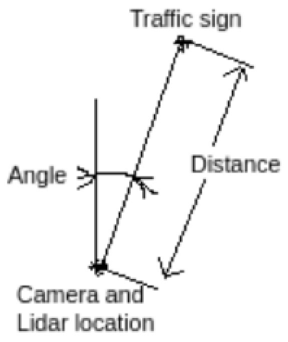
Hint: try using trigonometry to calculate the angle, using the parameters mentioned in the diagram above. Refer to the appendix for more information.

Part 2: Determine distance and angle using vision and lidar

To complete part 2, you will need to fill out the `vision_lidar_distance_calculation(image, lidar_range_array, fov)` function in

`proj2_vision_lidar_controller/vision_lidar_calculation.py`

The `vision_lidar_distance_calculation(image, lidar_range_array, fov)` function takes in an image and the point cloud returned from a lidar, and returns the distance and angle from the robot to the traffic sign in the images.



Functions Provided

To complete the above two parts, you are provided with the `contour.py` file, which contains a function `box_measure(image)` that calculates the pixel values of the centroid of the identified traffic sign in the image. This file (identical copies) can be found in both the `proj2_vision_lidar_controller` and the `proj2_vision_only_controller` folders.

Note: In some edge cases, such as when the simulator is initializing, the `box_measure(image)` function may not return the correct centroid. You should be able to complete the assignment despite that.

Submission Instructions

The files you will submit to Gradescope are `vision_lidar_calculation.py` and `vision_only_calculation.py`

To test your solution locally, you can employ the provided `local_tests.py` files.

You are allowed to employ the following two libraries. Note that you may not use any libraries outside this list.

- NumPy
- OpenCV

Rubric for Vision Component

Your solution for part 1 (stereo vision) will be evaluated in 5 world files. Each world will be worth 10 points for a total of 50 points possible.

Depth Evaluation

For each world, you will receive a number of points based upon how close your detected depth is from the true depth. The difference between your depth and the true depth will be evaluated as a percentage of the true depth.

For example, if the true depth is 10 cm and you say that the depth is 9 cm, then the difference is 1 cm. This is 10% of the true 10 cm, so the grade would be 8 out of 10 for that world file.

Percentage difference in distance	**Point Count**
<= 5% of true distance	5 points (full credit)
<= 10% of true distance	4
<= 15% of true distance	3
<= 20% of true distance	2
<= 25% of true distance	1
> 25% of true distance	0

Angle (Heading) Evaluation

For each world, you will receive a number of points based upon how close your detected angle is from the true angle. The difference between your angle and the true angle will be evaluated as difference in degrees.

Degrees difference in heading	**Point Count**
<= 5 degrees	5 points (full credit)
<= 10 degrees	3.75
<= 15 degrees	2.5
<= 20 degrees	1.25
> 20 degrees	0

Rubric for Vision + Lidar Component

Similarly, your solution for part 2 (vision + lidar) will be evaluated in 5 world files. Each world will be worth 10 points for a total of 50 points possible for part 2.

Distance Evaluation

For each world, you will receive a number of points based upon how close your detected distance is from the true distance. The difference between your distance and the true distance will be evaluated as a percentage of the true distance.

Percentage difference in distance	**Point Count**
<= 5% of true distance	2 points (full credit)
<= 10% of true distance 1.5	1.5
<= 15% of true distance 1	1
<= 20% of true distance 0.5	0.5
> 20% of true distance 0	0

Angle (Heading) Evaluation

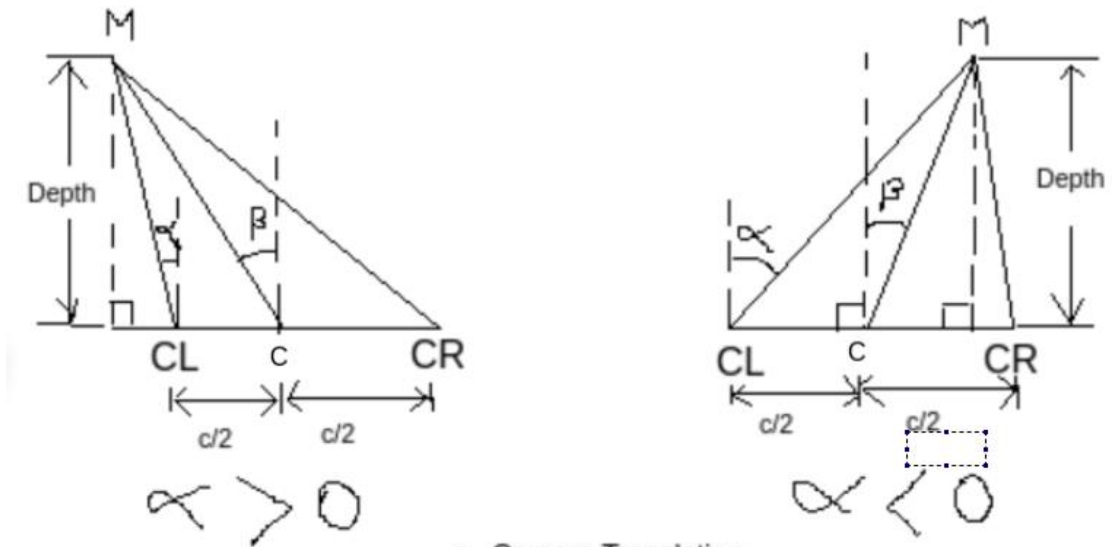
For each world, you will receive a number of points based upon how close your detected angle is from the true angle. The difference between your angle and the true angle will be evaluated as difference in degrees.

Degrees difference in heading	**Point Count**
<= 5 degrees	8 points (full credit)
<= 10 degrees	6
<= 15 degrees	4
<= 20 degrees	2
> 20 degrees	0

Appendix

Extra hint for finding the angles and distances. Given the figure bellow, the following procedure might help:

1. Compute alpha using the pixel difference of marker w.r.t camera center
2. Use trigonometry to find the length of the base of the right triangle containing alpha
3. Use the value from step 2 along with the `camera_translation` to compute the relevant edge of the right triangle containing beta
4. Use trigonometry again to find beta (might need depth again for this)



c - Camera Translation
CL - Camera Left
CR - Camera Right
C - Robot Centre
M - Traffic sign (marker)
α - Angle which M makes with respect to CL
β - Angle which M makes with respect to C
Find β

The diagrams are for reference as to how you should proceed. We suggest you also take into account other cases and provide a robust code which satisfies all conditions.