Vision Based Door Detection for the DARPA Robotics Challenge Finals Door Task

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Introduction

The door task for the DARPA Robotics Challenge requires the robot to open a door and walk through it. Sounds simple, but is it really? The robot needs to do all these things autonomously. It needs to detect the door, walk up to it, grab the handle, push the door open, hold it open while walking through it and then if all goes well, it can heave a sigh of relief. This poster will give an overview of the the controller that the Atlas has, its walking planner, its trajectory optimizer, the door task controller and the main concentration will be on the vision based door detection algorithm.

Walking and Motion planning

- Full body controller based on keeping COM over the support polygon.
- TrajOpt, an optimization based trajectory optimizer for motion planning.
- Foot step planning is done using linear interpolation.

Door task controller outline

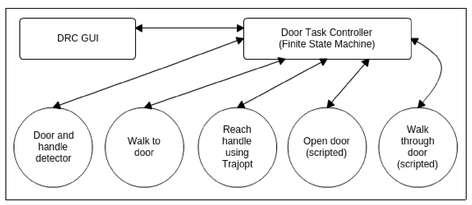

Figure 1: (a) Multisense head from Carnegie Robotics. (b) Motion planning using TrajOpt with a linear initial trajectory.

- Task controller implemented as a finite state machine.
- Controller runs on the field computer and interfaces with the DRC GUI.

Approach to door and handle detection

Doors usually have a generic shape and aspect ratio. Doors have parallel edges at the top and on the sides. Since the door image is seen by the camera that is mounted on a standing robot, we can make some strong assumptions regarding the door in the image. The door always stands vertical and hence will also be vertical in the image, i.e., the edges of the door will correspond to vertical and horizontal lines in the image with a little bit of relaxation due to the camera position and point of view.

A. Feature extraction in 2D

- Histogram equalization is performed initially to increase the contrast of the image.
- Bilateral Filtering is done to smoothen the image and reduce noise.
- Canny Edge detector is applied to segment out the edges.
- Probabilistic Hough Transform is done to segment out lines from the edge image.

Figure 2: (a) Handle detection using CCA (Connected Component Analysis). (b) Door detection in a complex scene.

- Get rid of lines that are not vertical and also lines that are really small (outlier lines).
- Separate out pairs of lines that have a minimum threshold pixel distance between them. These line pairs are probably doors.

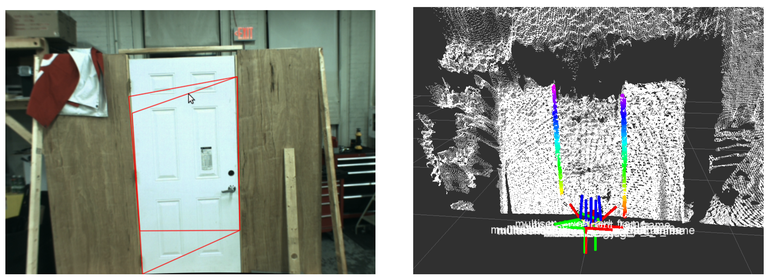

Figure 3: (a) Possible door pairs before pairing. (b) Detected door line pair in the stereo point cloud.

B. Segmenting door using stereo information

- Reproject the image in the 3D space.
- Find out the corresponding line equations in 3D from the 2D lines using RANSAC.
- Remove line pairs that have a horizontal distance between them less than or greater than the width of the door with a relaxation of 5 cm.
- Club the door line pairs that are the same, i.e., there might be discontinuities between the same line and using the line coefficients, it can be merged together. This reduces the redundancy in the probable line pairs.
- Get diagonal points in the 3D space validate their existence.

Repeat the steps given above over a sliding window of at least 10 frames to segment out significant door line pair(s).

C. Getting the door normal

The plane normal is found out by doing a cross product between the line joining the two door edges and one of the door edge. These are easily calculated from the line coefficients found out earlier using RANSAC.

D. Handle detection

Handles are usually different in colour than the door. Therefore, a valid assumption in this part of the problem is that the handle should be of a different colour than the door.

- Get the mean and standard deviation of the pixels in the image space inside the door region detected earlier.
- Use Connected Component Analysis (CCA) to grow the region which corresponds to the pixel value within the range $\mu - \sigma$ and $\mu + \sigma$.
- Based on the knowledge that the handle is on the left or the right hand side, select a region correspondingly to exclude the central part of the door.
- In that selected region, the region which is not white starting from the bottom is most probably the door handle.

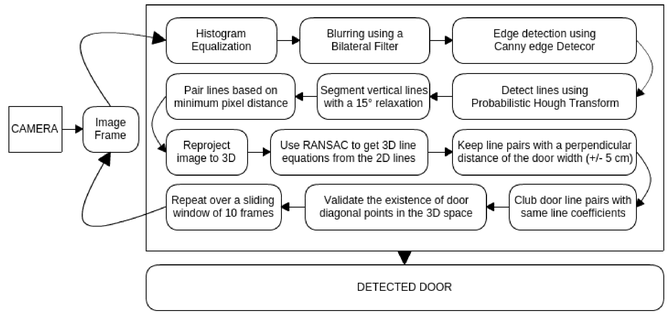

Figure 4: Door detection algorithm flow diagram.

Results

The algorithm was tested in scenarios with varying levels of scene complexity: low (just the door), medium (door in a simple environment with good ambient light), complex (door in a material intensive environment). The algorithm worked in all three cases with a min distance of 0.3 m and a max distance of 2 m from the door. The detection was not reliable outside this range.

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