Computer-Vision Based Indoor Path Detection and Navigation

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Intro:

Reliable automated navigation has forever been a significant area of research. Systems used to guide both manned and unmanned vehicles outdoors are commonly based on GPS positioning. This provides accurate location when used in conjunction with atmospheric measurement devices such as barometers and Inertial Measurement Units (IMUs) to gauge the vehicles physical orientation. However, for an indoor setting GPS is unreliable at best, as it relies on having constant reception of GPS satellite data. It is for this reason that an alternative navigation system based on computer vision will be devised for use indoors.
The scope of this project will include the recognition of doorways and corridors with the help of a forward facing D435 stereo camera. Rooms or tributary corridors will then be identified, and a decision will be made to determine which one the vehicle will enter. With this, it is hoped that the project will result in the ability to allow an unmanned vehicle to reliably navigate a system of corridors, and enter a specified room. Such a system would be useful in emergency situations to guide either emergency services or unmanned inspection vehicles through a building.

Background:

Doorway detection has previously been accomplished using a variety of methods. The most rudimentary of these is to apply a Canny or Gaussian filter to an image. Applying a Hough transform finds all horizontal and vertical lines. Door frames would then be detected by searching for defined patterns resembling the proportions of a door frame.
An issue with this method is its vulnerability to different lighting conditions, as well as the presence of various objects in the image. According to [1], the standard method of searching for two vertical lines of a certain length connected by a horizontal line at the top yields 69% detection accuracy.

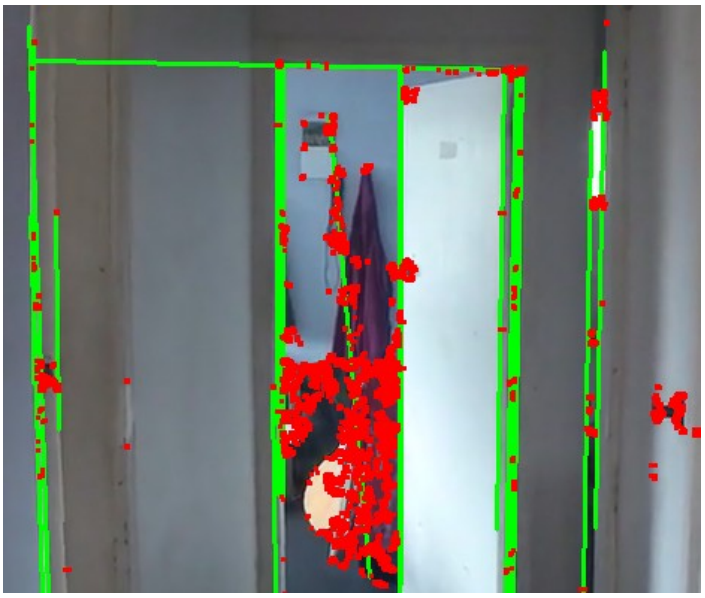

Illustration 1: Harris corner detector and Hough line transform applied to an image of a doorway

In an attempt to increase the accuracy of this method, a Harris Corner Detector was used. This process is proposed in [2]. Figure 1 clearly shows the unreliability of a Harris Corner Detector when

applied to a view down a model corridor. Dispite the correct detection of the door frame corners, many other corners have been detected in the image. This result was expected as the doorway has very little colour gradient with its background. The hough transform clearly shows some accuracy, and it is clear that the left and centre doorway, as well as the corridor off to the right, are defined by a pair of vertical lines. Changing light conditions would only decrease the accuracy of this, as parameters in both the Canny filter and Hough transform require specific parameter tuning to accurately detect lines in the image. According to [2], accuracy of this method is ~91% with a false positive rate of ~3%.

A more elegant solution is posed in [1], using the depth point cloud from an RGBD camera to detect weather a door is in the open or closed state. Sections of wall are scanned for 'holes' fitting the dimensions of a doorway. Accuracy of detection from this method is in the range of 66% at a viewing angle of 75° to 100% at an angle of 20°. However, using this method to detect doorways will be unreliable at best when doors are closed. This poses a serious problem in certain emergency situations where fire doors will be closed.
Both of these methods pose promise, as they require no training of neural networks. This will allow the algorithm to be applied to any indoor setting, regardless of the shape or colour of the interior doors.

Proposed Solution:

The proposed solution combines the two methods described above, and would involve an overlay of a group of vertical lines onto the depth image. As seen in figure 1, parallel vertical lines can indicate the presence of a corridor or doorway. The ability to detect sudden changes in depth will allow the program to distinguish between a possible path and other visual features in the image.
This method would also allow the program to estimate the distance to each door along a corridor, allowing it to recognise its position along a given path, making navigation possible.

Milestones and project goals:

1) The program must accurately detect corridors and doorways.
2) Distance from the target door/corridor must be accurately measured. This is important for indoor navigation.
3) A path will then be followed through a network of corridors. Initially, fiducial markers will be placed along the path to assist navigation.

The Following will be attempted if the former three milestones are completed within the time constraint:

1) System will be implemented on a single board computer for use on an unmanned vehicle.
2) Fiducial markers will be removed. System will use visual odometry to keep track of its position along a path.

References:

[1] Matthew Derry & Brenna Argall, Automated Doorway Detection for Assistive Shared-Control Wheelchairs, Northwestern University, Evanston, IL
[2] X. Yang and Y. Tian, "Robust door detection in unfamiliar environments by combining edge and corner features," 2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition - Workshops, San Francisco, CA, 2010, pp. 57-64