EE 565 – Mobile Robotics
Project Proposal

Title: Surface Detection and Localization

Group Members:
Huda Kamran – 15100111
Fatima Rahman – 15100241

Project Description

Surface detection is an important problem when it comes to autonomous control of mobile robots. Applications of surface detection include localization of the robot in a given 3D environment and detection of workspace on which a robotic manipulator is to operate. Detection of planar surfaces is important in identifying key features that can be used for localization, obstacle avoidance and motion planning as many mobile robots today are constructed to move on a flat surface and many dominant surfaces in an indoor environment are planar, for example, doors, windows, cupboards etc.

The project will aim at detecting a planar surface in a given environment and consequently the quadrotor will position itself parallel to a certain point on the planar surface.

Proposed Approach

A quadrotor will be used, and its front camera will be our visual sensor of the environment. Initially raw images at different angles will be taken to calibrate the camera and find its intrinsic and extrinsic parameters. Then a feature detection algorithm like SIFT will be used to identify key features, edges and corners in our environment. The results of this will then be processed to identify planar surfaces in the environment. The structure from motion algorithm will help in achieving this and also in finding the location of the quadrotor with respect to the surface. ROS will be used to communicate with the quadrotor and the opencv library will be used for functions needed for computer vision for e.g. the SIFT algorithm.

There are two main ways through which the robot can perceive a 3D structure:

1. Structure from Motion, where the robot moves around a body/object and takes pictures from various orientations, then uses the optical flow to reconstruct the object from the images. This requires the robot to move around a lot, since it requires the use of at least 5 images for computation.
2. Stereo Vision, where the robot uses two cameras much like the human visual system. Corresponding key features from both the camera images are found, which are then triangulated to reconstruct the object in 3D. Here, the robot does not need to move, since it is getting two images from slightly different poses - which is essential to 3D reconstruction - at the same time, and these are sufficient for stereo vision.

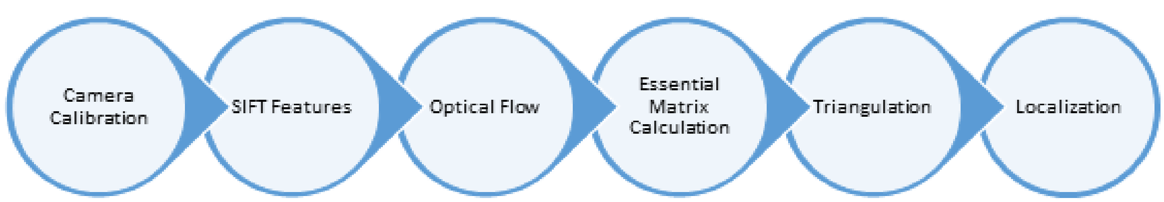
We will be using the structure from motion approach to identify the key features of objects and their 3D structure due to the availability of existing cameras on the quadrotor. This will, as stated above, require the robot to move about a lot as compared to stereo approach, but we will be able to get a more complete picture of the object (surface texture) in this way. Research has been done in which a visual system is able to derive depth information given individual stimulus features through a process of surface interpolation [2]. The process involves filling in the missing depth information between feature points and hence keeping track of surfaces over time and space. The 3D reconstruction is done using the structure from motion algorithm.

Our project requires two broad steps: Structure from Motion and Localization.

Steps involved:

1. Camera Calibration: Images at different angles will be taken as input and processed to calibrate the camera and find the distortion coefficients of the camera lens. This is very important since we will bring our image points into a rectified form from which we will be detecting surfaces.
2. Feature extraction: The SIFT algorithm will be run on the images to find features of interest. Edges often make for good feature points and are characterized by sharp changes in intensity in one direction. This change is measured by the first order derivative of the intensity function. However, the images first need to be filtered for noise as otherwise it is difficult to locate the gradient change due to edges alone. This is normally done by convolving with the double derivative of the Gaussian function and consequently removing the noise and successfully detecting edges at the zero crossings. Further steps involved in successful edge detection include thresholding, non-maximal suppression and the tracing out of high magnitude contours.
3. Optical flow calculation: In order to find correspondences between images, Lucas-Kanade optical flow algorithm will be used.
4. Essential Matrix Computation: Using 5 images of the same object from different viewpoints and epipolar constraints, the essential matrix will be calculated through either the 8 point or the RANSAC algorithm.
5. Triangulation of correspondences: After Essential Matrix is found, the corresponding points in all the images will be triangulated to get a 3D reconstruction of the object.
6. Localization: Once the quadrotor has obtained a 3D map of the planar surface of interest it will attempt to localize (position) itself at a point on that surface which it will do with the help of the visual data it receives from the camera and the odometry information it gets from its sensors. It will use the Kalman filter to correctly estimate its position.

Flow Chart



Deliverables

The project will aim to accomplish real time detection and linear mapping of planar surfaces in the robot's environment. The quadrotor will be able to detect planar objects placed around it, and if there is a flat surface such as a table or a blackboard and identify a target point on the surface. If time permits the quadrotor will be given the ability to find its position with respect to the planar surface and navigate its way to it.

References

[1] Juan Manual Saez and Francisco Escolano, "*A Global 3D Map-Building Approach Using Stereo Vision*", Departamento de Ciencia de la Computaci´on e Inteligencia Artificial, Universidad de Alicante, Ap.99, E-03080, Alicante, Spain.

[2] Structure-from-motion: Perceptual Evidence for Surface Interpolation

https://www.vis.caltech.edu/documents/226-treue_95_v35_p139.pdf

[3] Pattern Recognition and Structure From Motion for a UAV

http://www-personal.umich.edu/~pratikag/reports/ComputerVisionFinalReport.pdf

[4] http://hci.iwr.uni-heidelberg.de/publications/mip/techrep/baehnisch_09_fast.pdf

[5] http://vision.ai.illinois.edu/publications/surface_stereo_TPAMI_1989.pdf