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Simulation of an autonomous vehicle with a vision-based navigation system in unstructured terrains using OctoMap.

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***Abstract*—Design and implementation of autonomous vehicles is a very complex task. One important step on building autonomous navigation systems is to apply it first on simulations. We present here a vision-based autonomous navigation approach in unstructured terrains for a car-like vehicle. We modelled the vehicle and the scenario in a realistic physics simulation with the same constraints of a real car and uneven terrain with vegetation. We use stereo vision to build a navigation cost map grid based on a probabilistic occupancy space represented by an OctoMap. The localization is based on GPS and compass integrated with wheel odometry. A global planning is performed and continuously updated with the information added to the cost map while the vehicle moves. In our simulations we could autonomously navigate the vehicle through obstructed spaces avoiding collisions and generating feasible trajectories. This system will be validated in the near future using our autonomous vehicle testing platform - CaRINA.**

***Index Terms*—navigation, stereo vision, octomap, simulation**

I. Introduction

Building autonomous navigation systems requires the application of many techniques and algorithms, also, the use of diverse sensors requires the fusion of all the information [1]. Simulation plays an essential role on building such systems. The modelling of the system in a virtual environment is an important step to allow experiments to be done in a simulator. We implemented all the system independently of being simulated or not. The interfaces between the core system and the vehicle controls and sensors are the same for the simulated or real hardware. We present here our strategy to create a navigation map of the environment for autonomous navigation in unstructured terrains. We are relying on stereo vision as our main sensory data for the environment perception. To deal with the noisy data resulting from the stereo vision we are applying a probabilistic approach to construct this map based on OctoMap. OctoMap is a method presented in [2] for representing the occupancy of the space in a probabilistic model. The main goals of the OctoMap structure is to be updatable, flexible, compact and to be a full 3D model. The main idea of the OctoMap is to store a probability of occupancy in its leaf nodes. For an easier update policy the *logOdds* of the probability are computed and stored instead. The *logOdds* of the probability is defined by Eq. 1, where p is the probability.

$$L(p) = ln\frac{p}{1-p}, p \in (0,1) \tag{1}$$

II. System architecture

The main architecture of the system we are simulating is presented in Figure 1. We interact with the vehicle by the means of steering, break and throttle commands. Our system is based on the Robotic Operating System[1] (ROS) and the physics simulator Gazebo[2].

Our first attempt to detect obstacles is to consider that they are structures that contacts the ground. For this, we first apply a segmentation on the point cloud with a region growing algorithm based on smoothness constrains and local connectivity of the points [3]. Then, analyse each segmented cluster if it is near to the ground by looking at its bounding box. Cluster with fewer point than a threshold are discarded, clusters that are near to the ground are given high probability in the occupancy map, floating clusters are stored with less probability as it can be part of a bigger structure not completely detected at that moment (Figure 2).

A. Vision

The real sensor used is a Bumblebee 2 stereo camera with a baseline of 12 centimetres with a horizontal field of view of a 43 degrees at a resolution of 640x480 pixels. Our vision pipeline consists first on a disparity map computed from the stereo camera images. We apply the block matching local search based on the sum of absolute differences (SAD) algorithm implemented in the OpenCV[3] library. This kind of algorithm have a lower computational cost with a reasonable quality [4]. Based on the disparity map and the camera calibration parameters the 3D coordinates of each matched pixel is computed in a point cloud. For the point cloud manipulation and filtering we are relying on the implementations in the Point Cloud Library [5] (PCL).

[1]ROS - http://www.ros.org
[2]Gazebo - http://www.gazebosim.org
[3]OpenCV - http://opencv.org

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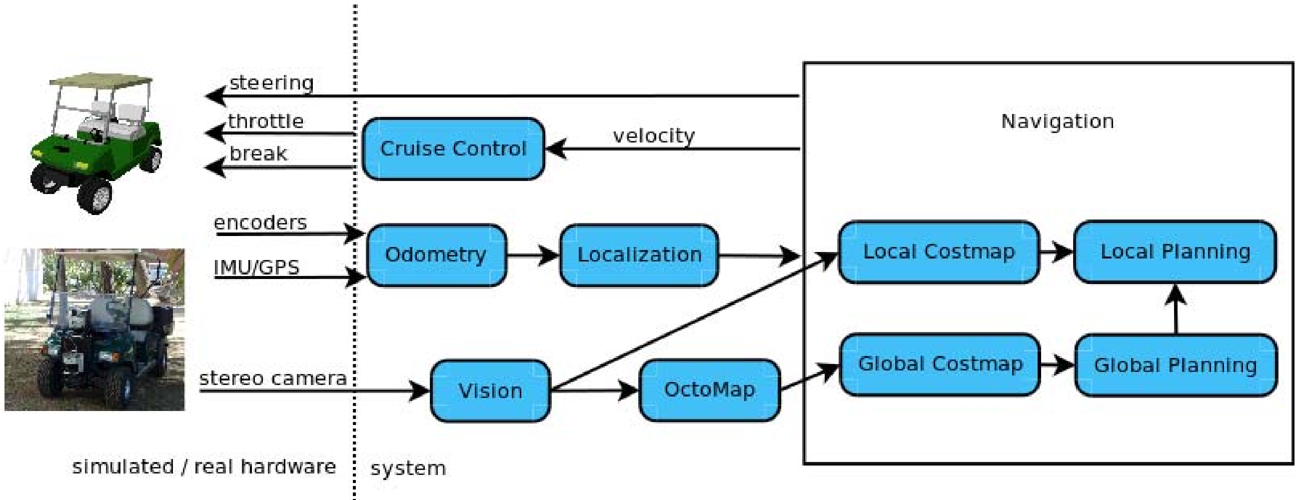

Fig. 1. System architecture

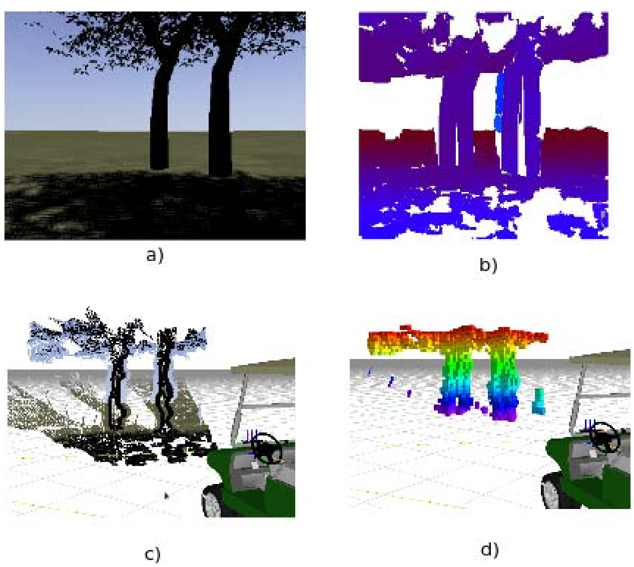

Fig. 2. Vision pipeline: a) image (only left), b) disparity map, c) point cloud, d) OctoMap occupancy

III. Navigation

A common aspect in autonomous navigation is the concern about the unknown and unmapped space. Is a consensus to consider the unexplored areas as forbidden to the robot navigate in, or at least, be avoided when planning a route. We assumes as an off-road vehicle in an open field that the space can be explored, this way the vehicle can travel freely on unknown areas.

A. Costmaps

For a ground vehicle, we can consider it navigates in a plane, so all obstacles are projected to a planar grid with associated costs. This leads to a bi-dimensional navigation cost map that is used by the trajectory planner to trace a collision free path. The process of building the global map is done asynchronously and the global planning are based on the more recent map not on the more recent data collected. By the other hand, the local planner acts in a reactive fashion and operates in real time with the sensory information.

IV. Summary

We presented here our vision-based navigation system based on a probabilistic occupancy space representation. Our navigation system do a path planning over a costmap based on this space representation. We are using a simulated environment for the experiments and we can conduct collision free navigation in an artificial unstructured scenario with vegetation (video available[4]).

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