Driving with Tentacles - Integral Structures for Sensing and Motion


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Abstract. In this paper we describe a LIDAR-based navigation approach applied at both the C-Elrob (European Land Robot Trial) 2007 and the DARPA Urban Challenge 2007. At the C-Elrob 2007 the approach was used without any prior knowledge about the terrain and without GPS. At the Urban Challenge the approach was combined with a GPS-based path follower. At the core of the method is a set of “tentacles” that represent precalculated trajectories defined in the ego-centered coordinate space of the vehicle. Similar to an insect’s antennae or feelers, they fan out with different curvatures discretizing the basic driving options of the vehicle. We detail how the approach can be used for exploration of unknown environments and how it can be extended to combined GPS path following and obstacle avoidance allowing safe road following in case of GPS offsets.

1 Introduction

In this paper, we put forth a very simple method for autonomous robot navigation in unknown environments. The method is not restricted to a particular robot or sensor, however we demonstrated it on the two vehicles in which the approach was integrated. Our method was applied at the Civilian European Land Robot Trial 2007 (C-Elrob 2007) on our VW-Touareg MuCAR-3 (Munich Cognitive Autonomous Robot, 3rd generation) and the DARPA Urban Challenge 2007 (UC07) on the VW-Passat of Team AnnieWay. Both vehicles had an almost identical hardware setup, in particular both being equipped with a Velodyne 64 beam 360 degrees LIDAR (see figure 1).

While quite complex approaches to mobile robot navigation exist (e.g. solving the SLAM problem (Dissanayake et al., 2001; Julier and Uhlmann, 2001), methods based on trajectory planning (Sariff, 2006)), our research was driven by the search for simplicity: What is the simplest approach that lets a robot safely drive in an unknown environment? Intentionally, we write...
Fig. 1. The two vehicles our approach was tested with. (a) The VW-Passat of Darpa Urban Challenge finalist Team AnnieWay (b) The VW-Touareg MuCAR-3 (Munich Cognitive Autonomous Robot, 3rd generation), a C-Elrob 2007 Champion. Both vehicles are equipped with a 360 degree Velodyne-LIDAR as primary sensor scanning its environment at 10 Hz using 64 laser beams.

Fig. 2. (a) Among other functions insects use antennae as tactile sense (b) Shakey [Nilsson, 1984] - one of the first robots - uses mechanical “cat-whiskers” to detect collisions (c) Braitenberg vehicles use some sort of antennae with simple, hard-wired reactive mechanisms to produce complex behaviors (d) In our approach we use speed depending sets of antennae that we call “tentacles”.

“drive” instead of “explore” because we do not demand to construct a map of the environment (in contrast to SLAM approaches [Dissanayake et al., 2001; Julier and Uhlmann, 2001]), but just demand safe driving within that environment. Our basic intention underlying this paper is to let our robot move within an unknown environment similarly to how a beetle would crawl around and uses its antennae to avoid obstacles. Indeed, our basic approach consists of using a set of virtual antennae that we call “tentacles” probing an ego-centered occupancy grid for drivability. Of course, the idea of using antennae is not new: In fact, one of the first robots, “Shakey” [Nilsson, 1984], used “cat-whiskers” (micro-switches actuated by a 6 inch long coil spring extended by piano wires to provide longer reach) to sense the presence of a solid object within the braking