Single Camera Stereo for Mobile Robot World Exploration

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Abstract

This paper introduces a single-camera-based stereo vision system used for creating local 3D occupancy models. The design of the system is described, the range data error analysis is presented and the sensor model which assigns the values of evidence to the registered data is built. The application of the proposed system for mobile robot world exploration is shown. Data obtained by running a single camera mobile robot are presented.

Keywords: Occupancy grids, visual sensor model, range data fusion, evidence theory.

1 Introduction

In world exploration, the occupancy model of the world is one of the most commonly used [3, 20, 7, 25]. In this model, the evidence that a point in space is occupied is calculated, based on the data registered by a range sensor.

Originally developed for building 2D maps [9], the occupancy-based approach has recently been extended to build 3D models of the world [15, 17], which provide much more information about the environment.

There are two problems however with building 3D occupancy world models. The first problem is the representation of the occupancy information. The conventional way of storing the occupancy data using grids requires a considerable amount of memory and is time consuming. It is also inefficient for map extraction. The second problem concerns range sensors. Sonar sensors are not expensive and their models are known [3, 16]. However, they do not yield accuracy sufficient for 3D modeling [15]. At the same time, laser range sensors and highly calibrated stereo systems, which also have well defined sensor models, are very expensive and cannot be used in many situations.

These were the problems we addressed in the Boticelli project. As a solution, first, we proposed a regression-based technique for fusing range data, which allowed us to build 3D occupancy models represented in a parametric way, and second, we designed a single camera visual sensor, which allowed us to register 3D range data with the aid of an off-the-shelf video-camera. Boticelli is the name of the robot we used for the proof-of-concept demonstrations. It explores an unknown environment by building local occupancy world models based on the visual data captured by a single camera. While the issues of range data fusion, occupancy model representation and vision-based navigation are covered in [4], [5] and [1], respectively, this paper is dedicated to the vision part of the project.

We show how a single camera visual sensor can be designed so as to provide range data needed for building 3D occupancy models of the required quality. This includes designing the stereo rig, presenting the error analysis of the stereo algorithm, building the visual sensor model and showing the advantages of using the proposed visual sensor for mobile robot world exploration.

The paper is organized as follows. The design of the stereo setup is presented in the next section. The sensor model which assigns the values of evidence to registered depth data is built in Section 3. Experimental results and discussions conclude the paper.

2 Visual sensor design

The design of a visual sensor depends on the objective of the project. In our project the sensor is used for building local occupancy models, where we want the models to be fast in calculation and compact in representation. There are many applications where such models can be used and in this paper we concentrate on their application for the mobile robot exploration task. Let us outline this task.