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Environment modelling for visual rover navigation

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Abstract

A visually guided planetary rover is a resourceful tool for planetary surface exploration missions. The integration of several tasks for rover navigation is a challenging problem, especially for future rover designs. The essential issue is to find a comprehensive model that is not only capable of exploiting the rover's components and sensory data, but also allows the rover to adapt to the surrounding enviroment and dynamically changing mission goals. We present a case study of environmental modeling for an on-board system design for planetary exploration on surfaces covered by rocks and sand. The system integrates independent components for tasks such as visual recognition, localisation, motion planning and mission control. In particular, we present an environment representation model that facilitates adaptable and modular system design. We outline the main challenges as crucial steps towards future versatile rover systems.

1. Introduction

A visual navigation system for a planetary rover consists of several key tasks, such as perception, localisation, motion planning and mission scheduler supervision. These tasks require high-level information that is difficult to obtain from the rover's low-level sensory data. Therefore, it is challenging to find a common environment representation that offers efficient interaction and cooperation of all subsystems of the rover.

As outlined in [3] and [1], it is required to model system interfaces for accessing and producing information from visual features and relating the rover's surroundings to the rover's coordinate system. In [1] a simple heuristic-based approach for combining data from subsystems is presented, and in [3] such tasks are applied to indoor environments.

Our goal is to develop a system capable of 1) describing a dynamic outdoor environment by interpreting visual input in the robot's context, and 2) to generate interfaces for combining data from different robot systems. As in [2], we wish to establish a recognition process but making use of 2D or 3D data produced by cameras and rangers. We propose the representation of interfaces as data products that all system components can acknowledge.

Finding a useful environment model is an essential step for integrating data among subsystems and its different data products (interfaces). Furthermore, due to controlled or unexpected changes in the mission objectives and system components, interfaces need to be defined and able to respond to changes in the architecture. This facilitates a simple and flexible design by providing accessible data without further conversion or processing. Our goal also includes to find a tradeoff between the number of required interfaces and the processing time they require.

2. Environment Representation

In order to perform adequate integration of multiple subsystems within a minimum information processing, we make use of components and interfaces for assigning task functionality. The interfaces can be seen as data transitions that are defined by data structures. These structures correspond to data products on different levels of information for the description of the rover's surroundings.

The proposed structure is divided into three main blocks: data pre-processing, data processing and map generation, as depicted in Figure 2. These blocks correlate all functionalities of different system components and allow modular system integration.

2.1. System Interfaces

The system integrates several key components for rover navigation, i. e. visual recognition, motion planner, visual SLAM, and mission planner. In relation to such tasks, the system interfaces represent the required transformations from sensed data to a map of the rover's surroundings. They are conversion points for interrelating not only components but also any process that makes use of principal data formats. As a starting point in data formatting, we use three main interfaces in each of the environment representation blocks:

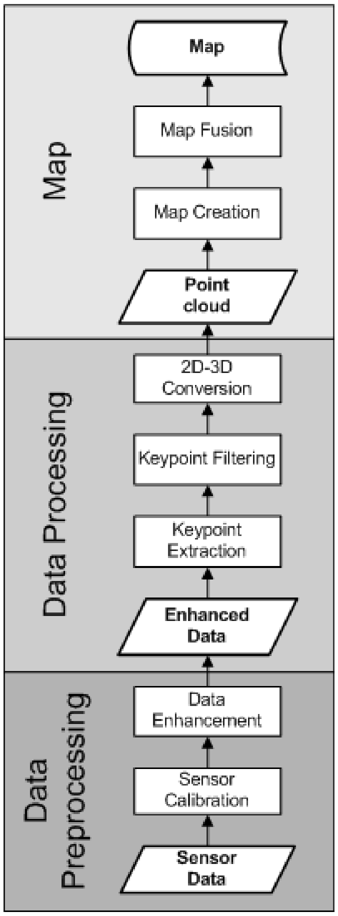

Figure 1: Stages of environment representation.

- *Sensor Data* is the sensor output in the form of images, laser sets or data point clouds. The properties of this interface describe the essential unit for processing in the form of pixels or coordinate points in relation to the robot frame. The operations performed are for calibrating and enhancing white and systematic noise.

- *Enhanced Data* represents raw but reduced noise data that can be used as 2D or 3D objects appearing during robot motion. They are usually structures for abstracting obstacles or landmarks with systematic and white noise reduction.

- *Point cloud*: This 3D data structure is a representation of coordinate points in relation to the rover and it is used for mapping according to robot's localisation state.

2.2. Map representation

This block, being the top layer of the environment model, represents common the grided and landmark-based maps that can be used by higher level tasks. These maps can be created in 2D or 3D and with a number of different structures, ranging from low-level data like image features to higher level objects such as rocks. A common map representation aims at these maps being widely adaptable and above all supports the use of multiple maps to obtain coherent high level world understanding.

3. Summary and Conclusions

We present an environment model for the design of an adaptable planetary rover system. It can flexibly integrate different software components through adaptation of sensor capabilities. The system interfaces are represented through data products that permit components to manipulate data with predefined operations. Also, the system modules have independent processing tasks, which can be maintained through the developed interfaces in the environment representation.

Our contribution lies in the design of an environment representation for visually guided rover navigation that is capable of integrating independent subsystems in a modular way. Using this environment model, the system architecture can be modified in response to changing mission conditions. This is an essential step towards future autonomous rover operations on remote planets.

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