Passive Localization of a Robot Using Multiple-View Geometry

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ABSTRACT

Finding the location of a robot, equipped with an imaging sensor, by taking photos from its surrounding environment is a multifaceted task consisting several obligatory phases. It starts from the calibration of a sensor, and ends in propagation of errors, to consequently express our uncertainty about the unknowns. This article uses a mathematical language to elaborate a model based on recent trends to show how the structure and motion can be estimated by image-processing methods on digital images taken from a regular non-metric camera. The direct and inverse Brown’s model for calibration, as well as the basic definition of an image pyramid is discussed first. The concepts of Epipolar geometry, collinearity and co-planarity, and registrations of models, are described next. Generating a reference map, the bundle-adjustment and localization are presented finally. In the last sections, some recent trends about parallel computing are reviewed, and recommendations for building a real-time system are discussed.

Keywords: Bundle-Adjustment, Computer Vision, Convex Optimization, Localization, Multiple View Geometry, Stereo Reconstruction, Structure and Motion Recovery

1. INTRODUCTION

This paper introduces the methods that make a robot or more generally any moveable object, which is equipped with an imaging sensor, able to process a set of captured digital images in order to find its way and get visual understanding about the geometry of its surrounding environment. For the most parts of this section the methods are described that are mainly used in multiple-view geometry computer vision and close-range photogrammetry. In order to understand the materials of this section, no specific pre-reading is required, although a background in basic mathematics and linear algebra is an asset.

Images are one of the earliest data that we sense from our nearby environment. During the time, we gradually learn how to deal with the complications lying in this wonderful source of information. Maybe one of the earliest steps in our visual learning process is the classification

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of our environment into recognizable instances of objects. At the same time maybe, we start to understand the concept of a geometric distance. Progressively, our brains find out how to measure a distance between two points. This amazing functionality enables us to locate our relative position and find our way through a complicated set of objects in our surrounding environment. Our brains finally equipped with various types of image-based functionalities that constantly increase our geometric understanding. We may safely call it our geodatabase. This complicated process is a result of the ability of our brains in encoding a complex set of image processing functionalities into a nerve system.

Nowadays, the image capturing devices are vastly accessible and popular; consequently it is reasonable if we expect to have the similar functionalities in a robotic system. Images are sensible for us, passive, and proved to be suitable for the location finding. It turns out that the type of image-based operations that we naturally use in our brain becomes considerably complicated when we try to algorithmically implement them. Many of these methods have been developed by engineers and scientists a century ago. Surprisingly, it is not more than two decades that some influential methods, such as direct relative orientation, have been discovered and employed in 3d-reconstruction algorithms. Some of the methods discussed in this paper are still open problems that make it exciting to understand and employ them.

There exist a good variety of text books, literature, and recent articles that talk about the concepts of this paper; however, the recent advancements are scattered through them. Therefore, we try to simplify and unify the diverse notions used in many different resources, and express them with a clear language in a concise and comprehensive way. Thus, this paper is designed to be more readable for the graduate students and researchers who want to understand the fundamental concepts of stereo vision.

The paper mainly concentrates on a small part of the aforementioned big puzzle, which is an introduction to the mathematical concepts of finding geometric information and location from a single image or a set of images by employing image processing techniques.

2. CAMERA

The most abstract element in a localization system is a regular camera, which is a light-measurement device. Two general types of regular camera exist in the market: the analogues and digitals. It is not so far that the analogues had a major rule in mapping; however, digital cameras are the main focus of this paper. A digital camera consists of a regular grid of sensors that measures the amount of light. A camera also contains an optical system that allows the light to be systematically measured by its sensors, and a linear or a set of linear arrays of sensors. In its most ideal form, the optical system consists of a single aperture that called the focal point. Each ray of light, after passing through this point, will put a signature on the front wall called image plane. Consequently, the image formed by this setting is a mirror of...
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