Chapter 72
Self-Calibration of Eye-to-Hand and Workspace for Mobile Service Robot

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ABSTRACT

The geometrical relationships among robot arm, camera, and workspace are important to carry out visual servo tasks. For industrial robots, the relationships are usually fixed and well calibrated by experienced operators. However, for service robots, particularly in mobile applications, the relationships might be changed. For example, when a mobile robot attempts to use the visual information from environmental cameras to perform grasping, it is necessary to know the relationships before taking actions. Moreover, the calibration should be done automatically. This chapter proposes a self-calibration method using a laser distance sensor mounted on the robot arm. The advantage of the method, as compared with pattern-based one, is that the workspace coordinate is also obtained at the same time using the projected laser spot. Further, it is not necessary for the robot arm to enter the view scope of the camera for calibration. This increases the safety when the workspace is unknown initially.

INTRODUCTION

For a mobile robot servicing in the general environment, camera is a common sensor due to its availability and cost-effectiveness. A sensor network system composed of multiple cameras can be utilized to efficiently guide a mobile robot to reach its goal and finish its task. These separated artificial eyes can form a large-scale surveillance system and can be coordinated by a central brain to access images at a time and integrate the information into useful data for robot action. A Distributed Vision System (DVS) can monitor humans, objects, and robots at different place,

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track a specific target, and locate it in the whole surveillance area. A mobile robot can take this advantage to locate itself relative to a large-scale environment and detect a target far away from it.

This chapter provides a scheme to calibrate the geometric relationships among robot arm, environmental camera, and workspace for mobile service robot. Specially, the situation considered is that the cameras may not have an overlapping view region. This calibration scheme can run without any human participation and is useful for an autonomous system. The calibration device does not have to go in the camera field of view, so it can work without interrupting the mobile robot and can collect calibration data quickly. The geometry constrains existing in the whole system is utilized to achieve the calibration goal. This calibration scheme has two major portions. Firstly, a method to calibrate the geometric relationships between the laser distance sensor and the end-effector of the robot arm based on Wei and Hirzinger's (1998) method is introduced for precision enhancement purpose. The second part is to calculate the eye-to-hand and the workspace relationships based on camera calibration techniques. As a result, all geometric relationships among devices can be obtained.

BACKGROUND

Distributed Vision System (DVS), a particular example of sensor network, consists of physical vision agents monitoring the working environment (Ishiguro, 1997). The vision agents connect with each other through computer network or are controlled by central computer. The concept of distributed vision system can be applied to construct a wide area surveillance system for human tracking (Atsushi *et al.*, 1998; 2002), a robot indoor navigation system (Ishiguro, 1997; Nakazawa, et al., 1998; Sogo, et al., 1999), or a non-specific target tracking system (Takashi & Norimichi, 2002).

Positioning in three-dimensional space is an important technical issue in many industrial and commercial applications. Specifically, noncontact measurement of the rough surface of a target is useful in many industrial occasions because it is convenient and non-destructive. Distance measurement device based on laser diode technology can provide precise measurements. This kind of measurement device is called laser distance sensor or laser range finder. Laser distance measuring method can be technically divided into three categories: interferometry, time-of-flight, and triangulation and each of them have advantages and limitations (Amann, et al., 2001). A robot arm equipped with a 2-D laser range finder can take dimensional information of the target while adapting its view in applications such as 3-D scanning (Soucy, et al., 1998; Lamb, et al., 1999). In some applications where target locations (points) in space relative to the robot arm are required, it is sufficient to use a 1-D distance sensor mounted on the end effector. Usually a 1-D laser distance sensor with a visible laser light is able to serve the measurement purpose. In such a sensing system, the factors causing the systematic errors include imperfect position and orientation arguments of the laser distance sensor. Since the accuracy of such measurement system is influenced by the precision of installation parameters, the calibration is essential and critical.

Camera calibration is to identify intrinsic parameters and extrinsic parameters of a camera. The intrinsic parameters indicate the optical characteristics and internal perspective geometric relationships, which project outside points to its image pixel coordinate. The extrinsic parameters denote the 3-D geometric transformation from the world coordinate system to the camera coordinate system, which includes a rotation and a translation as a result of the rigid body transformation in 3-D space. Camera calibration methods need reference objects which could be a 3-D object (Heikkila, 1997), a 2-D pattern (Zhang, 2000), or a 1-D bar (Zhang, 2004). Once the camera

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