Multimedia Contents

Part C

Sensing

Part C Sensing and Perception

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Part C covers material related to sensing and perception. The section covers all the aspects of sensing for basic measurement of physical parameters in the world to making sense of such data for the purpose of enabling a robot to perform its tasks. Right now robotics is seeing a revolution in use of sensors. Traditionally robots have been designed to have maximum stiffness and applications have been designed to be predictable in their operation. As robots emerge from the fences areas and we deploy robots for a wider range of applications from collaborative robotics to autonomously driving cars it is essential to have perception capabilities that allow estimation of the state of the robot but also the state the surrounding environment. Due to these new requirements the importance of sensing and perception has increased significantly over the last decade and will without doubt to continue to grow in the future.

The topics addressed in this section include all aspects from detection and processing physical contact with the world through force and tackle sensing over augmented environments for detection of position and motion in the world to image based methods for mapping, detection and control in structured and unstructured environments. In many settings a single sensory modality/sensor is inadequate to give robust estimate of the state of the environment. Consequently a chapter on multi-sensory fusion is also included in this part. Part C considers primarily the sensing and perception aspects of robotics with a limited view to many of the other aspects. Part A is providing the basic, Part B provides the kinematic structures that we need to design control methods for interaction, while Part D will cover the grasping and manipulation of objects. The remaining parts of the handbook covers application verticals where sensors and perception plays a key role.

With this brief overview of Part C, we provide a brief synopsis of each chapter.

Chapter 28 covers force and tactile sensing, which is essential for physical interaction with the world. Tactile sensing addresses the issue of detecting and handling contact with objects and structures in the world. Tactile sensing is essential both for safety and manipulation applications as the control of a robot changes due to contact which changes the kinematic configurations. Force sensing addresses estimation of force and torque as part of dynamic motion but also for interaction with physical objects such as inserting an object or turning a valve. The model chosen for force estimation also impacts the control of the robot.

Chapter 29 covers use of odometry, inertial and GPS for estimation of motion and position in the world. Odometry is the ego-estimation of your position/motion based on robot mounted sensors. With the introduction of sensors for estimation of accelerator and rotational velocity it is possible improve the estimation of position and motion. With the introduction of inexpensive inertial measurement units (IMU), driven by the game and phone industry, the use of IMU has increased significantly. For outdoor operation it is frequently possible to utilize Global Navigation Systems such as the global positioning systems (GPS). The integration of odometry, IMU and GPS information allow design of systems for precision agriculture, autonomous driving, etc. The chapter provides a description of the core techniques to make this possible.

One of the first sensors to be used for large scale estimation of distance to external objects was sonars. Chapter 30 covers the basic methods for sound based ranging and localization. Sonars are widely used for underwater mapping and localization, but is also used as an inexpensive modality for localization and ground vehicles and landing of Unmanned Aerial Vehicles. Typically a single sensor has limited precision but through used of phased array techniques and multiple sensors it is possible to achieve high-fidelity ranging. The chapter covers both the basic physics, sensing, and estimation methods.

Over the last two decades we have seen tremendous progress on laser based ranging as a complement to stereo/multi-ocular methods for distance estimation. Light detection and ranging (LIDAR) is today used as an effective modality for mapping, localization and tracking of external objects in the environment. In Chapter 31 the basic techniques for range estimation using light based ranging is described and fundamental methods for three-dimensional (3-D) modeling of the environment are described. Recently there has been a renaissance in range based sensing due to the introduction of RGB-D sensors, that utilize structured light and cameras to generate a dense range maps at very-low prices.

Chapter 32 covers the general topics of 3-D vision which covers estimation of distance from the parallax between two or more cameras and/or the motion of a camera over time. The parallax between two or more images allows estimation of the distance to external objects, which can be leveraged for localization and navigation, but also for grasping and interacting with objects in the environment. The chapter covers both the basic aspects of 3-D estimation and some of the common applications of 3-D vision for robot control.

Chapter 33 covers the topic of object recognition. Computer based object recognition has been studied for more than 50 years. Over the last decade we have seen tremendous progress on object recognition due to improved cameras and availability of much better computers and increased memory. We are seeing both image based recognition techniques and methods for recognition based on the 3-D structure of objects. More recently we have seen a renewed interesting use of neural nets for detection of objects due to new Bayesian methods and the problem of object categorization – recognizing categories of objects such as car, motorcycle, traffic sign, people, etc. has become an important problem. The chapter covers both view and 3-D based methods for recognition and discusses also categorization of objects.

Chapter 34 covers the problem of image servoing. When trying to interact with an object we can use image data to drive the end-effector to a goal location. Two common configurations are eye-in-hand and hand-to-eye. In addition the control can be performed directly in image coordinates or through recovery of two-and-a-half-dimensional (2.5-D) or 3-D pose for an object. To enable all of this an impact aspect is to derived the relation between changes in robot motion and changes in the image/pose, which is derivation of the Jacobian for the system. This chapter discusses both eye-in-hand and hand-to-eye visual servoing and image/pose based control of the process and provides examples of use of visual servoing in real scenarios.

Finally, the part is concluded by Chapter 35 which discusses multi-sensory data fusion. As mentioned earlier most applications require use of multiple sensors to generate robust/complete methods for control. Data fusion involves a number of different aspects from time synchronization to transformation into a common reference frame to integration of data over time/space to generate more robust/accurate estimate of the world state. Recently a number of new methods for Bayesian data fusion have emerged. In this chapter the fundamental of data fusion are reviewed and a number of the most common techniques for multi-sensory fusion are introduced.