Part C

Sensing a

Part C Sensing and Perception

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Part C of the Handbook is concerned with sensing and estimation. The world is not deterministic and, in addition, models of our robots are not perfect. Sensing is introduced to allow compensation for model approximations, and to estimate the layout of the environment to facilitate planning and execution of tasks.

Sensing is here considered the transformation of physical entities such as contact, force, distance, light intensity, etc. into an internal computer representation. Perception is the extraction of key properties from the sensory data and integration of sensory information over time. Perception is typically a data compression task in terms of extraction of the characteristics that allow recognition, tracking, and description of particular properties in the world, which are required to allow a robot to execute its tasks. This part of the Handbook covers the most typical sensor modalities used in robotics and the basic processes associated with these sensors.

Robotics is often paraphrased to be the intelligent coupling of perception and action. As such Part C complements Part B of the handbook and the following parts are all examples of such couplings in terms of sensing and mechanisms with associated intelligence.

This part is building on the foundations (Part A) and here in particular on Chap. 4, Sensing and Estimation. The material presented in this part is for obvious reasons tightly coupled to later chapters on systems and applications. Chapter 30 (Haptics) has a close coupling to the chapter on force and tactile sensing. Chapter 36 on world modeling is building on sensor models and the fusion methods presented in Chap. 25. The same applies for Chap. 37 on Simultaneous Localization and Mapping. Chapter 62 presents results from neuroscience and how it can be applied to robotics and has a strong coupling to many different sensory modalities and also integration of these into internal representations. Finally, Chap. 63 presents methods in human visual perception that are of relevance to robotics. These methods are in many ways the basis for techniques used in computer vision as discussed in Chaps. 23 and 24.

Part C contains chapters related to all the main sensory modalities from touch and proprioception to ranging and visual perception.

Chapter 19, Force and Tactile, discusses methods for detection of contact with objects in the external environment and also force as a reaction to acceleration and/or contact with external objects. Force sensing is essential to many high-precision assembly tasks, but increasingly also for interaction with nonrigid objects as, for example, experienced in medical applications. Contact and force sensing is thus essential for many grasping and manipulation tasks.

Chapter 20, Inertial Sensors, GPS, and Odometry, covers methods for estimation of ego motion based on direct estimation from acceleration forces, shaft/wheel encoders or through exploitation of external reference systems such as GPS. Robot systems experience drift and slippage due to poor contact, but also due to material variations due to temperature etc. A fundamental capability is thus use of proprioception to estimate ego motion and internal state as a basis for decision making and action generation.

Chapter 21; Sonar Sensing, covers ranging and object detection based on sound information. Sound propagates significantly slower than light and as such allows use of electronics that it easier/cheaper to manufacture. This in part explains why much early work on mapping and position estimation for mobile platforms was based on ultrasonic sonars. Sonar is still a dominant modality for underwater applications and it often offers an economically attractive solution for basic mapping.

Chapter 22, Range Sensors, covers use of distance estimation based on light. Recently the use of laser radar has seen a significant increase in popularity. Laser-based sensors are active sensors in the meaning that the system emits energy of some form into the environment and measures the returned information, which allow use of matched techniques which simplifies the data-association problem and enable use in more noisy settings. Ranging can also be performed based on multi-ocular systems such as a stereo pair of cameras. The different methods for active and passive ranging are presented in this chapter.

Chapter 23, 3-D Vision and Recognition, covers 3-D modeling and recognition of objects based on image data. There is no doubt that vision is one of the most flexible and compelling sensory modalities. It has a significant potential for future applications. The flexibility poses, on the other hand, also a challenge as the detection of objects in cluttered environments can be very difficult. The chapter present methods for visual modeling of objects and the main steps and methods for recognition of objects.

Chapter 24, Visual Servoing and Visual Tracking, presents the main methods for tracking and control based on image data. Tracking of objects is essential in many applications either for interception or avoidance. Visual servoing addresses the problem of control to arrive at a goal location often associated with grasping of an object. The main techniques for tracking are presented and the three major methods for visual servoing are introduced.

Chapter 25, Sensor Fusion, addresses the problem of integration of information across space and time. Sensor data are contaminated by noise in various forms and often there is a need to integrate data from multiple sensors or across time to provide robust and accurate estimates. This chapter presents the main techniques for sensory fusion and provides mathematical frameworks that are utilized in several of the following chapters.

Due to changes in materials and electronics, the area of sensors is changing rapidly. Within the last decade major changes in terms of laser ranging and visual sensors have been fielded. In addition computer resources have changed dramatically to allow advanced processing of data to generate advanced perception systems. The availability of cheap, robust, and accurate sensing is also impacting other fields of robotics. Earlier robots were built to have a maximum of stiffness to avoid sensing. Today flexible robots are relying on sensors in the internal control loop to achieve hyperaccuracy at a reduced cost. There is no doubt that this is a trend that will continue as flexible robots can be made safer, cheaper and more efficient. The integration of sensing and actuation, especially with new nanotechnology, is going to change robotics significantly over the next decade.