Sensor Devices and Systems for Robotics

机器人传感器装置及系统〔英〕

Edited by
Alícia Casals

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This book contains the proceedings of a NATO Advanced Research Workshop held within the activities of the NATO Special Programme on Sensory Systems for Robotic Control, running from 1983 to 1988 under the auspices of the NATO Science Committee.

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PREFACE

As robots improve in efficiency and intelligence, there is a growing need to develop more efficient, accurate and powerful sensors in accordance with the tasks to be robotized. This has led to a great increase in the study and development of different kinds of sensor devices and perception systems over the last ten years. Applications that differ from the industrial ones are often more demanding in sensorics since the environment is not usually so well structured. Spatial and agricultural applications are examples of situations where the environment is unknown or variable. Therefore, the work to be done by a robot cannot be strictly programmed and there must be an interactive communication with the environment. It cannot be denied that evolution and development in robotics are closely related to the advances made in sensorics.

The first vision and force sensors utilizing discrete components resulted in a very low resolution and poor accuracy. However, progress in VLSI, imaging devices and other technologies have led to the development of more efficient sensor and perception systems which are able to supply the necessary data to robots.

This book is a collection of papers presented at the NATO Advanced Research Workshop (ARW) "Sensor Devices and Systems for Robotics" held in October 1987 at the Costa Brava, Catalonia, Spain. About 40 researchers from the academic community and from industry from all over the world were invited and 22 of these presented papers. Many of the participants are well-known researchers in the field of Robotics and Sensorics.

The workshop was divided into sessions dealing with the different kinds of sensors and related systems for data interpretation with special emphasis on their application to Robotics. The sessions were in the form of lectures and panel discussions. In addition to the discussion panels the debates that arose from the lectures contributed greatly to the success of the workshop.

Robotics and Sensorics are subjects of considerable interest today and the participants recognized the need to promote contacts among researchers in order to encourage further development and progress. In this connection, the question of whether to include the teaching of Robotics in Electrical and Electronic studies or in Mechanical Engineering studies was discussed. However, the field is so wide that it would not be feasible to restrict Robotics to one or other of these fields. Nevertheless, agreement was reached on the need to set up new centers.

This book includes lectures concerning the sensors, their use in perception systems and their applications. It is divided into parts dealing with the different kinds of parameters to be measured in accordance with each application. Different aspects of force and torque sensors, which are of special interest in assembly tasks, are treated: making models of the interaction between the robot and its [illegible] so as not to damage the manipulated objects and obtaining information [illegible] bot for calibration. A number of punctual force sensors may be used to build a tactile surface. Tactile sensors are analyzed in two ways: using sensitive materials (carbon and piezoelectric film) and evaluating their own geometry and influence on the sensor performance.

Although acoustic sensors have a poorer resolution than vision sensors, acoustic sensors can measure distances more easily than vision systems. Acoustic sensors are used in robotics to provide feedback for robot motion control. Acoustic signals are used in range finder systems to control a robot task. Acoustic sensors can also be used to obtain a 3D map of the robot environment.

Optical sensors and vision systems are treated in different papers. The first group of papers concerns the analysis of the optical sensors and imaging devices. The second group deals with the use of these devices to build vision systems, a combined laser/camera vision system for calibration. The last two papers are devoted to parameter estimation in digital signal processing and object shape estimation from partial information. The last section on sensors ends with communications on other kinds of sensors such as dynamic weighing, position deviation and multisensorial fusion.

Finally, some applications arising form the use of force or vision sensors are described.

This book is, in short, an overview of the current state of robot sensors and their application.

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The grant received from the CIRIT (Research Agency of the Catalan Government) is gratefully appreciated.

The editor would also like to thank all the lecturers and participants whose active participation throughout helped to make the workshop fruitful and enjoyable.

Barcelona, December 1988

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I. FORCE AND TORQUE SENSORS

JOINT FORCE SENSING FOR UNIFIED MOTOR LEARNING

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ABSTRACT

Motor learning consists of using in-built sensors to learn more about one's own motion behavior. In this paper, we present an approach for motor learning based on a perturbed parameter scheme. A technique is developed for determining the link inertias based on joint reaction data, obtained through force sensors. Due to inexactness of the model, the parameters thus estimated are likely to differ from their true values. This perturbed parameter set can be thought of as a "learned" model of the executed motion. Running the dynamics procedure with these altered parameters results in a more accurate prediction of the control torques needed for the desired motion.

1. Introduction

In the manipulator task execution domain, motions are usually executed with all degrees of freedom under direct control and without regard to the high-level representation for the motion. The trajectory is reduced to a joint motion history and this is implemented through a suitable control scheme. It is well recognized that there are several interrelated effects which make the computations inadequate. The dynamics is highly coupled and non-linear. Also the model usually ignores significant effects like joint compliance, loading effects and coulomb friction. Finally, there are uncertainties in the model parameters such as inertias and geometrical terms. These inaccuracies, as well the computation-intensive nature of the algorithms have caused many robot controller designs to forego any realistic consideration of the dynamics.

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An alternative to this approach is *motor learning*, which can be understood as a scheme for refining the motion control by executing many motions, and efficiently storing the execution data for future recall. With such a scheme, the desired motion is compared to known motions which have been "learned" through prior training, so that all control computations do not have to be performed during every execution.

In this paper we develop a motor learning scheme which is based on joint force sensing. The first part looks at motor learning schemes in man, and compares these with some of the attempts for motor learning in robots. The second part develops a method for obtaining link inertia estimates from joint torques, and the final part shows how this method may be applied to obtain motor learning.

2. Motor Learning in Man

Motor learning is an integral part of the human motor system, one of the most versatile manipulation systems known. Motor learning in man consists of two phases:

a) Skill acquisition or motion refinement through repeated trials.
b) An efficient storage and recall mechanism for the learned motions.

Acquired skill in motor control is sometimes explained by the theory of the *motor program*, whereas organization of learned knowledge at the task level is explained in terms of the *schema*. The schema generates flexible motor programs which are capable of adapting to different parameters within the same task framework. Another theory, first proposed by Adams, is the *open-loop* theory, and is analogous to the computed-torque control for robot manipulators.

2.1. Motor Program

The motor program theory postulates that most skilled motions are executed from memory without feedback [Lashley 1951]. There are two phases - in the *learning* phase (mostly during infancy), various motions are attempted and slowly improved. Sensory feedback is widely used at this stage. The *perceptual trace* corresponding to successful executions are gradually