Field and Part F

Part F Field and Service Robotics

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Part F , Field and Service Robotics, covers the most recent advances concerned with the growing area of robot applications, ranging from industrial robotics, through a diverse array of air, land, sea, and space applications to educational robotics. The future vision for robotics is for the pervasive application of robots. The robots of the future will perform all the dangerous, dirty, and dreary (DDD) tasks. Joe Engelberger, the pioneer of the robotics industry, wrote in his 1989 book *Robotics in Service* that the inspiration to write the book came as a reaction to a forecast study of robot applications, which predicted that in 1995 applications of robotics outside factories (the traditional domain of industrial robots) would account for less than 1% of total sales. Engelberger believed that this forecast was wrong, and he instead predicted that the non-industrial class of robot applications would become the largest class of robot applications. Engelberger's prediction has yet to come to pass. However, he did correctly foresee the growth in nontraditional applications of robots. Previous parts of this Handbook show the great strides that robotics technology has made in the past 50 years. The technology has reached a level of maturity such that robots are now marching from the factories into field and service applications.

The topics in Part F cover the essentials of what is required to create robots that can work in all environments. Part F describes fit-for-purpose robots and includes hardware design, control (of locomotion, manipulation, and interaction), perception, and user interfaces. The economic/social drivers for the particular applications are also discussed. Part F builds on all of the previous parts of the Handbook. Robot Foundations (Part A) and Robot Structures (Part B) are essential for providing the basic mechanisms and control structures for any robot that is targeted for applications work. Sensing and Perception (Part C) and Manipulation and Interfaces (Part D) are critical capabilities for robots that need to interact with changing environments and perform manipulation tasks under human supervision. To fully utilize the potential of a working robot requires mobility and the ability to cooperate with other robotics, the basic technologies described in Mobile and Distributed Robotics (Part E) are essential.

Chapter 42 , Industrial Robotics, gives a history and description of typical industrial robot applications. Most robots today can trace their origin to early industrial robot designs. All the important foundations for robot control were initially developed with industrial applications in mind. The chapter describes how robots with different mechanisms are designed to fit different applications.

Chapter 43 , Underwater Robotics, deals with challenges of technology to support marine applications. A historical background showing the expanding role of robotics in oceanic engineering applications is given. The chapter deals with modeling underwater dynamic effects, sensors and actuators for marine robots, mission control systems, guidance and control algorithms. Underwater localization and manipulation are discussed. Fault detection and fault tolerance aspects, together with the coordination control of multiple underwater vehicles are also covered. The chapter reports on successful deployments of marine robotics.

Chapter 44 , Aerial Robotics, describes the technology, challenges, and applications of airborne robotics. The wide range of potential uses for robots that can fly, from military to civilian applications, is described. The challenges for aerial robots span many fields, including state regulations, man–machine interface design issues, path planning, navigation, safety/reliability, collision prevention, take-off/landing techniques, and dealing with other aerial vehicles. Basic aerial robot flight concepts including propulsion systems, control systems, and flight vehicle types including lighter-than-air systems are covered. The chapter ends with a description of integrated automated aerial robotics systems.

Chapter 45 , Space Robots and Systems, deals with robotics technology for space applications. It covers two classes of robotics: orbital and surface. Any unmanned spacecraft is a robotic spacecraft. However, space robots are more capable devices that can facilitate manipulation, assembly, assisting astronauts, or extending exploration to remote planets as surrogates for human explorers. This chapter covers the key issues in space robots and systems: manipulation, mobility, sensing and perception, teleoperation and autonomy, and dealing with extreme environments. A historical overview and a review of technical advances for space robots is provided. A description of the mathematics for the control of robotic devices in microgravity environments is also given.

Chapter 46 , Robotics in Agriculture and Forestry, describes how robotics has made a impact in the agricultural and forestry industries. Automatic vehicle guidance of farming machinery are being widely used. Automatic sensing, handling, and processing of produce are commonplace, and there has been a substantial automation of processes and procedures for livestock handling. In forestry, legged harvesters and automation of trimming are maturing technologies. Computer vision is being

applied to allow tractors to follow a row of crops, collecting macadamia nuts, and for sorting and grading of produce. A number of farm automation projects, such as automated milking of cows or sorting sheep from goats using a swinging gate to separate different species using computer vision are a commercial success. The chapter emphasizes the agricultural field as a fruitful source for robotics applications, some sufficiently demanding to require the development of new theoretical techniques and methods.

Chapter 47, Robotics in Construction, describes the construction automation concepts that have been developed and presents examples of construction robots that are in use and/or in various stages of development. The chapter gives an overview of the construction industry and discusses the concept of automation versus robotics. Sensing systems that enable the use of robots and automation in construction are reviewed. The chapter also discusses economic aspects of implementing robotics in construction. Unsolved technical challenges including interoperability, connection systems, tolerances, power, and communications are discussed.

Chapter 48, Robotics in Hazardous Applications, discusses robot technologies for dealing with difficult and dangerous environments. The technology solutions that are adopted depend on the nature and magnitude of the hazards. When the magnitudes of hazards reach the point that human exposure represents a direct threat to life or has long-term health consequences, e.g., nuclear radiation, some form of remote operation must be used. This chapter describes robotics technologies for dealing with eradicating landmines, and hazardous materials handling, e.g., explosives disposal, and handling of dangerous biological and nuclear material. Enabling technologies to support demining and hazardous material handling are discussed, including mobile platforms, manipulator design, teleoperation and control, and the supply of energy and communication signals through reliable and robust tethers. The chapter ends with a discussion of the advances that are required to progress the field. Progress is needed in mechatronics design, sensing, machine intelligence, and fully understanding the application and its associated economic factors.

Chapter 49, Mining Robotics, discusses the application of robotics to the mining industry. Mining remains physically demanding and hazardous work. The scope for the application of robotics is great since mining requires the handling of enormous quantities of material in a cost-effective and safe manner. High operational costs, the need for greater productivity, and improved health and safety outcomes are powerful drivers for robotics. Existing approaches to improving productivity and safety through training, work practices, and larger and improved machine design are providing diminishing returns. The industry is at a tipping point where robotics and automation will provide the next step change in productivity and safety. This chapter reviews the history of robotic mining; it describes the enabling robot technologies associated with metalliferous mining and coal mining (open-cut and underground).

Chapter 50, Search and Rescue Robotics, describes the state of the art of an emerging applications field. Rescue robots serve as extensions of responders to a disaster, providing real-time video and other sensory data about the situation. The technology is still emerging and is still to be adopted by the international emergency response community. Rescue robots are beginning to be used by fire departments and for bomb disposal. This chapter describes the basic characteristics of disasters and the impact on robotic design, describes the robots actually used in disasters to date, promising robot designs, and concepts and methods of evaluation in benchmarks for rescue robotics. The chapter discusses the fundamental challenges facing rescue robotics, including the key challenge of evolution from a concept to the adoption as a solution technology.

Chapter 51, Intelligent Vehicles, describes the emerging robotics application field of intelligent vehicles: motor vehicles that have autonomous functions and capabilities. The chapter describes why the development of intelligent vehicles is important and gives a brief history of the field and the potential benefits of the technology. It describes the enabling technologies for intelligent vehicles to sense vehicle, environment, and driver state, work with digital maps and satellite navigation, and communicating with intelligent transportation infrastructure. The chapter describes the challenges and solutions associated with road scene understanding. Advanced driver assistance systems which use robotics technologies to create new safety and convenience systems for motor vehicles, such as collision avoidance, lane keeping, parking assistance, as well as driver monitoring to mitigate against driver fatigue, inattention, and impairment are described.

Chapter 52, Medical Robots and Systems, describes the development of medical robotics. In the last 20 years starting with brain surgery, orthopaedics, endoscopic surgery, and microsurgery, the field has expanded to include commercially marketed, clinically deployed systems and an active research community. This chapter provides a historical review of the field and discusses the major thrusts using examples from current and past

research. Medical robots are described within the context of larger computer-integrated systems including presurgical planning, intraoperative execution, and postoperative assessment and follow-up. The basic concepts of computer-integrated surgery including the critical factors affecting the deployment and acceptance of medical robots are described. An overview of medical robot systems is provided, including remote telesurgery and robotic surgical simulators.

Chapter 53, Rehabilitation and Health Care Robotics, describes robotic systems that assist persons who have a disability or provide rehabilitation therapy for persons. The chapter provides a historical review of the field. Physical therapy and training robots as well as robotic aids for people with disabilities are described. Advances in smart prostheses and orthoses for rehabilitation robotics are also described. An overview of work in diagnosis and monitoring for rehabilitation is provided. The chapter provides a solid understanding of the future challenges for rehabilitation and heath care robotics.

Chapter 54, Domestic Robots, describes the technology that everyone would one day like in their home, that will vacuum the house, clean the kitchen, load the dishwasher, or polish the shoes. In spite of hundreds of millions of potential users surprisingly not many domestic robots exist. This chapter examines what it means not only to develop but also to commercialize domestic robots using cleaning robots as a representative example. The chapter reviews domestic floor cleaning robots, robotic pool cleaners, window cleaning robots, and robotic lawn mowing. The chapter also examines smart appliances such as ironing robotics, intelligent refrigerators, and digital wardrobes. A description of research projects on smart environments and smart homes is presented. The chapter concludes on the importance of the economic case for the development of service robots.

Chapter 55, Robots for Education, describes robotics technologies for the education market, both as motivational tools for research programs and as concrete, real-world deployments that demonstrate the state of the art in robotic technologies. This chapter provides a technology overview of education robots. The chapter also provides a survey of robot-themed tournaments and an overview of robotic installations in informal learning spaces. Robotic technology is being used in hands-on, active-learning museums; this requires a new level of technology robustness and standardization. The chapter discusses physical robot platforms that have successfully supported active learning. An important tool in the study and execution of educational robotic systems is the formally evaluation of the efficacy of a robot system in an educational context. The chapter summarizes the manner in which conventional analytical tools may be used to evaluate educational programs that use robotic technologies as learning tools.