# INTELLIGENT ROBOTIC SYSTEMS

## DESIGN, PLANNING, AND CONTROL

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# Preface

Robotic systems are effective tools for the automation necessary for industrial modernization, improved international competitiveness, and economic integration. Increases in productivity and flexibility and the continuous assurance of high quality are closely related to the level of intelligence and autonomy required of robots and robotic systems.

At the present time, industry is already planning the application of intelligent systems to various production processes. However, these systems are semi-autonomous and need some human supervision. New intelligent, flexible, and robust autonomous systems are key components of the factory of the future, as well as in the service industries, medicine, biology, and mechanical engineering.

A robotic system that recognizes the environment and executes the tasks it is commanded to perform can achieve more dexterous tasks in more complicated environments. Integration of sensory data and the building up of an internal model of the environment, action planning based on this model and learning-based control of action are topics of current interest in this context. System integration is one of the most difficult tasks whereby sensors, vision systems, controllers, machine elements, and software for planning, supervision, and learning are tied together to give a functional entity. Moreover, robot intelligence needs to interact with a dynamic world. Cognition, perception, action, and learning are all essential components of such systems, and their integration into real systems of different levels of complexity should help to clarify the nature of robotic intelligence.

In a complex robotic agent system, knowledge about the surrounding environment determines the structure and methodologies used to control and coordinate the system, which leads to an increase in the intelligence of the individual system components.

Full or partial knowledge of an agent's environment, as in industry, leads to an intelligent robotic workcell. Because of the rather high level of this knowledge, all the planning activities can be performed off-line, and only task execution needs to be done on-line.

A different approach is needed when little or no information about the environment is available. In this situation, a robotic multiagent system that shows no clear grouping of components is better suited to develop plans and to react to changes in a dynamic environment. All the calculations have to be done on-line. This requires more processing power and faster algorithms than the organized structure, where only the operations in the execution phase have to be computed in real time.

This book only treats the intelligent robotic cell and its components; the fully autonomous robotic multiagent system is not covered here. However, the on-line components, methods, and algorithms of the intelligent robotic cell can be used in multiagent systems as well.

The book deals with the basic research issues associated with each subsystem of an intelligent robotic cell and discusses how tools and methods from different discrete system theory, artificial intelligence, fuzzy set theory, and neural network analysis can address these issues. Each unit of design and synthesis for workcell control needs different mathematical and system engineering tools such as graph searching, optimization, neural computing, fuzzy decision making, simulation of discrete dynamic systems, and event-based system methods.

The material in the book is divided into two parts. The first part gives detailed formal descriptions and solutions of problems in technological process planning and robot motion planning. The methods presented here can be used in the off-line phase of design and synthesis of the intelligent robotic system. The chapters present the methods and algorithms which are used to obtain the executable plan of robot motions and manipulations and device operations based only on the general description of the technological task.

The second part treats real-time events based on multilevel coordination and control of robotic cells using neural network computing. The components of such control systems use discrete-event, neural-network, and fuzzy logic-based coordinators and controllers. Different on-line planning, coordination, and control methods are described depending on the knowledge about the surrounding environment of robotic agent. These methods call on different degrees of autonomy of the robotic agent. Possible solutions to obtain the required intelligent behavior of robotic system are presented.

In writing this book, a formal approach has been adopted. The usage of mathematics is limited to the level required to maintain the clarity of the presentation. The book should contribute to the better understanding, advancement, and development of new applications of intelligent robotic systems.

# Acknowledgments

This book would not have been possible without the help of numerous friends, colleagues, and students. On the professional side, I am most grateful to my colleagues at the University of Linz for the level of support they showed through all these years. In particular, I would like to thank Prof. Franz Pichler, Prof. Gerhard Chroust, and Prof. Bruno Buchberger for providing me with an academic home in Austria.

Much of the work included here was taught in lectures at the University of Linz and at the Technical University of Wroclaw, and several improvements can be attributed through feedback from my students there. Other parts of the theory were developed in cooperation with my Ph.D. students and colleagues, in particular with Dr. Ireneusz Sierocki, Dr. Stephan Dreiseitl, Dr. Gerhard Jahn, **Dr. Paweł Rogaliński,** Dr. Robert **Muszyński,** Dr. Ignacy **Dulęba,** and Dr. Tomasz Kubik, who should also be mentioned for providing valuable input on several topics.

Finally let me thank my family for their continuous support during weekends and late nights when this text was written.

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