Since the first part of the twentieth century, cybernetics and systems research have been developed as scientific disciplines. Investigations, launched in the area of cybernetics, previously dealt with control and information processing. In a more narrow sense, they consisted in the consideration of analogies of the control and the information processing between life beings and systems of different nature, e.g. technical, economic, social as well as of activities requiring traditionally understood intelligence. Nowadays, a notion ‘cybernetics’ is used more and more rarely, but the corresponding research is continued and developed, e.g. in the framework of artificial intelligence, intelligent computing, control theory. The cybernetics as an interdisciplinary scientific and research discipline is strongly connected with systems studies dealing, among others, with methodological and applied problems of analysis and decision making (synthesis) for systems of different nature. From many known systems theories, only mathematical systems and their applications are addressed in this book. Other aspects of systems-based research are not considered.

Systems research in the area distinguished provides scientists from different disciplines with useful tools for solving analysis and decision making problems. On the other hand, the development of computer science technology enables researchers and practitioners to computerize and to automate more and more effectively such man’s activities as reasoning, understanding, learning, perception. It leads to the advancement of intelligent systems which now are intensively developed and investigated as a vital scientific discipline. It seems that nowadays knowledge – understood, roughly speaking, as facts, principles and the ability of reasoning on their basis – is an indispensable element of any intelligent system.

Taking into account mentioned methodological tools developed in systems research, it is interesting and useful to apply them also for intelligent systems. In particular, these tools concern modeling and identification of systems, analysis and simulation of systems as well as decision making for systems of different nature, e.g. control, diagnosis, pattern recognition, clustering.

The following well recognized general topics are represented in chapters collected and presented in this volume: complex systems, control theory and engineering, cybernetics and economy, fuzzy systems, information and communication systems, systems modeling, control, management and decision making. Particular specific investigations presented in any chapter refer to one or more system-based tools. On the other hand, knowledge, information or data are used in different aspects as well as existing artificial intelligence-based facets are highlighted in the problems considered.

A considerable part of the book is based on original presentations delivered during the 14th International Congress of Cybernetics and Systems of World Organisation of Systems and Cybernetics (WOSC) which was held in Wroclaw, Poland in September 2008. These chapters encompass updated and substantially extended results of previously conducted studies as well as of fruitful discussions during the Congress.
Other chapters, brought by known researchers, joined this group and make it possible to have as the result a valuable collection of works pertaining not only to important methodological issues on intelligent systems but also to applications in medical, economic, and technical systems. From all submissions, nineteen most adequate chapters have been selected and included into this book. The chapters have been divided into three sections, namely: Modeling, Analysis and Decision Making.

The **first section** comprises six chapters in which systems are considered where not only knowledge but also information and measurement data are processed. The aspect of creating their models is highlighted. General tools and methods are used, in particular: estimation and identification. To cope with uncertainties, which are considered, stochastic and fuzzy sets based approaches are proposed.

The **first chapter** by B. J. Oommen and L. Rueda aims to consider modeling of time-varying systems using knowledge-based and intelligent approaches. Authors concentrate on using new estimation methods which are based on the principles of stochastic learning and are referred to as the Stochastic Learning Weak Estimators (SLWE). The chapter reports conclusive results that demonstrate the superiority of the SLWE methods in two applications: pattern recognition (PR) and data compression. The application in PR involves artificial data and real-life news reports from the Canadian Broadcasting Corporation (CBC). For data compression, the underlying distribution of the files being compressed is modeled as being non-stationary. The advantage of the SLWE in both these cases is demonstrated.

P. Kucera presents in the **second chapter** an applicable reliability model of the TMR (Triple Modular Redundancy) system, based on analogue measurement channels, which has been still missing unlike the model of the standard TMR system based on digital channels. The description of analogue measurement channel’s structure is followed by the presentation of the reliability model of the wiring system. The standard TMR model is presented and its reliability model is also given. An analogue TMR measurement channel system is introduced and its reliability model based on Markov processes is presented. Then the reliability model of the communication channel is described. The analytical calculation of model’s reliability and the presentation of a simple numerical example complete the chapter.

The **third chapter** by K. Brzostowski, J. Drapała and J. Świątek focuses on selected parametric problems of a complex systems identification. Problems of the identification with limited measurement possibilities as well as global and multi-stage identification are explained in detail. The usefulness of the two-stage identification is shown for a specific biomedical system dealing with the rehabilitation of patients with muscle impairment relies. To manage this problem, an adaptive decision making system based on the two-stage identification is applied with an additional knowledge given by a physician. The fuzzy and neuro-fuzzy approaches are employed for knowledge representation. The pattern recognition algorithm as well as the learning procedure supplement the decision making system. The results of simulation experiments using real-world data complete the chapter.

In the **fourth chapter** by M. Mouhoub and J. Liu, a new framework for handling uncertain symbolic and numeric temporal information is presented. To manage the uncertainty, two models are employed based on probabilistic extensions of Temporal Constraint Satisfaction Problem (TCSP) framework and Interval Algebra (IA) approach. In a probabilistic CSP, each constraint is given a probability of its existence. In the consequence, there is more than one CSP to solve unlike the traditional CSP. A branch and bound algorithm along with a constraint propagation are proposed to determine the solution (model) of the highest probability. An experimental study conducted on randomly generated temporal problems demonstrates the efficiency in time of the algorithm. The considerations are supplemented by several examples illustrating main topics.
Foundations of computer vision, image processing and machine vision, the important topics of knowledge-based intelligent systems are addressed by D. Jakóbczak in the fifth chapter. The classical problem in these areas is that of determining an object via characteristic features. The important feature of the object is its contour. The accurate reconstruction of contour points leads to the possibility to compare the unknown object with models of specified objects. The chapter deals with a new method of contour reconstruction via the curves interpolation. First, the contour points of the object to be recognized are computed. Then, one compares models of known objects, given by the sets of contour points, with coordinates of interpolated points of an unknown object. The contour points reconstruction and the curve interpolation is possible using a new method of Hurwitz-Radon Matrices.

M. Pokorný and P. Fojtík consider in the sixth chapter fuzzy modeling of non-linear dynamic systems applicable for the fault diagnosis. Takagi-Sugeno fuzzy model is used with the decomposition of the non-linear dynamic system into the number of linear sub-models, so that it is possible to overcome difficulties in conventional methods for dealing with nonlinearity. A linear residual generator formed by Kalman filters which are designed for each linear subsystem is then proposed to create diagnostic signals (residuals). Since the task is formulated on a statistical basis, the diagnosis uses a generalized likelihood ratio test. Two real-world examples are presented to demonstrate the applicability of the approach proposed.

General, both analytical and simulation, tools for analysis of economic, production, control or computer systems are discussed in the second section. The systems of different nature are described using knowledge discovered from data, given by experts or created on the basis of scientific rules. Various cases of AI-based approaches are employed for the analysis of knowledge-based systems, e.g.: learning, clustering, linguistic summaries, agent-based modeling, heuristic optimization.

Baczko, Kacprzyk and Zadrożny report in the seventh chapter a successful attempt to apply the AI-based knowledge discovery from data for the innovativeness evaluation of enterprises, being a crucial aspect for the development of a national economy. Proper functioning of a national innovation system requires a lot of information to be gathered and then analysed. In this chapter the pioneering system for the evaluation based on integrated indicators constructed for individual enterprises in Poland is described. An evaluation methodology has been developed, incorporating both quantitative and qualitative characteristics of the enterprises. The linguistic summaries of data are shown to be a promising data analysis tool. These summaries make it possible to grasp the essence of the collected data and communicate it in an intuitive, natural language like form.

The problem of knowledge exchange in the inter-enterprise cooperation process design is presented in the eighth chapter by A. Moczala. The development of an innovative character of an enterprise requires facilitating of initialization, creation, and extension of cooperative links among enterprises. The collaborative design process gathers enterprises which have to achieve a common objective with respect to a new product, i.e. the innovation by knowledge sharing. The development of methods and algorithms of knowledge exchange in such a cooperation enables the elaboration of computer aided systems for the production cooperation which is outlined. The analysis of the cooperation process among enterprises is also shown.

A case study comprising an analysis of power dispatch in a power distribution system is investigated by E. R. Sanseverino, G. Zizzo and G. F. Scimemi in the ninth chapter. The problem is formulated for small connected distribution sub-systems called 'microgrids'. To evaluate costs, power losses and voltage deviations in the system, the corresponding multi-objective optimization problem is stated with knowledge about the complex system in the form of mathematical models. The authors use two
heuristics to solve the problem, i.e.: their own version of non-dominated Genetic Algorithm, originally determined earlier, and Ant Colony Optimization algorithm being the novel proposition. The case study and its analysis are preceded by a general introduction to multi-objective optimization and to the corresponding selected solution tools.

The analysis of binding neuron output firing statistics is considered by A. Vidybida and K. Kravchuk in the tenth chapter. Such a neuron uses as one of its inputs the feedback and delayed output impulse which allows to mimic the operating manner of a biological neuron. The neuron is driven externally by the Poisson stream. The influence of the feedback, which conveys every output impulse to the input with time delay, on the statistics of neuron’s output spikes is considered. The distributions found for the case of instantaneous feedback include jumps and derivative discontinuities and differ essentially from those obtained for BN without feedback. The statistics of a neuron with delayed feedback has remarkable peculiarities as compared to the case without delay. It is concluded that delayed feedback presence can radically alter the neuronal output firing statistics.

G. Narvydas, V. Raudonis and R. Simutis provide us in the eleventh chapter with the practical application of a knowledge-based intelligent control system for a mobile robot. The main idea of the chapter is to show that, while creating intelligent control systems for autonomous mobile robots, it is the most important to transfer as much as possible human knowledge and human expert-operator skills into the intelligent control system. The successful transfer ensures good results. One of the most advanced techniques in robotics is an autonomous mobile robot on-line learning from the experts’ demonstrations, which is briefly described in this chapter. The results of experiments are also presented in which a mobile robot Khepera II is used.

An intelligent e-learning system tailored to different students’ needs is described by D. Zakrzewska in the twelfth chapter. The individual requirements of learners may depend on their characteristic traits such as dominant learning styles. Finding groups of students with similar preferences can help when systems are being adjusted for individual requirements. The performance of personalized educational systems is dependant upon the number and the quality of student clusters obtained. The application of clustering techniques for grouping students according to their learning style preferences is considered. Such groups are evaluated by disparate validation criteria and the usage of different validation techniques is discussed. Experiments were conducted for different sets of real-world and artificially generated data of students’ learning styles.

The role of efficiency for firms’ competitiveness in the context of an agent-based modeling and a knowledge redundancy is discussed by L. Biggiero in the thirteenth chapter. Through an agent-based model of industry competitiveness based on suppliers’ quality, the chapter tests four groups of hypotheses. It innovates current literature in two ways: firstly, it considers redundancy in terms of organizational knowledge. Secondly, it compares the effects of two forms of perturbations: environmental shock and opportunism. The results show that these two forms impact differently on industry profitability, and that knowledge redundancy can compensate the effects of environmental shocks but not of opportunism. Moreover, it demonstrates that, as agents exchange more information, knowledge efficiency declines.

Methodological and practical aspects of control problems, being constantly inherent issues of cybernetics, are mainly addressed in the third section. Their modern and up-to-date versions, namely, multivariable fuzzy control, adaptive control, and adaptive control combined with learning are discussed, the first two in comprehensive surveys. Real-world applications of knowledge-based intelligent systems for diagnosis and for control in one biomedical and in two technical systems, respectively are presented.
P. Albertos, A. Sala and M. Ramírez describe in the fourteenth chapter the state of the art of fuzzy-logic control with application to multi-input/multi-output systems. The basic steps in designing of such control systems are given. Two approaches of the fuzzy control are presented. The idea of the first, heuristic approach consists in compiling a set of rules provided by human experts in order to control a complex plant. The application of the second, function-approximation approach to modeling and control is then introduced together with the description of some universal approximation ideas and the popular Takagi-Sugeno approach to modeling of non-linear systems, including fuzzy polynomial ones. The summarization of main advantages and drawbacks of both approaches complete the chapter.

The fifteenth chapter by K. J. Burnham, I. Zajic and J. G. Linden starts also with the review of crucial developments in self-tuning control (STC). The notion of two coupled sub-algorithms forming the basis of STC together with enhancements to produce adaptive on-line procedures are discussed. The techniques covered include optimal minimum variance, sub-optimal pole-placement and long range model-based predictive control. Based on the experiences of the authors in the industrial application of STC, extensions of the standard linear model-based approaches to encompass a class of bilinear model-based schemes, are proposed. Some on-going developments and future research directions in STC for bilinear systems are highlighted. These include the requirements for combined algorithms for control and fault diagnosis and the need for models of differing complexities.

The idea of adaptive control is considered also by T. Banek and E. Kozłowski in the sixteenth chapter. It is used for the determination of an optimal control algorithm for the case where the knowledge representation of the uncertain system’s parameters is given in the form of probability distributions. A general approach to self-learning based on ideas of adaptive control is presented to cope with the uncertainty. The trade-off between learning of systems’ parameters values and optimization of the objective function is investigated. The conditions of optimality for the general stochastic adaptive control problem along with the resulting algorithm are presented. By using analytical results and numerical simulations, it is shown how control actions depend on a priori knowledge about a system.

A fault diagnosis and its application to diagnostic decision-making systems are dealt with by A. Chohra, N. Kanaoui, V. Amarger and K. Madani in the seventeenth chapter. A reader is provided with a short overview of some methodological aspects of hybrid intelligent diagnosis systems for a large variety of biomedical and technical applications. Firstly, main diagnosis tasks for such applications are presented. Then, the description of fault diagnosis systems is followed by the presentation of the design procedure of hybrid intelligent diagnosis systems. Then, the suggested approach is developed for a computer aided diagnosis in the biomedical system. Auditory Brainstem Response test is investigated, and the corresponding prototype design and experimental results are presented.

The practical oriented considerations are again comprised in the eighteenth chapter by Z. Zwierzewicz, which are concerned with a problem of adaptive ship control in the case of limited knowledge of the ship’s model. Two tasks of ship control are considered: the ship course-keeping and the path-following. Two different approaches to the control synthesis problem are proposed. The first one is based on adaptive feedback linearization technique, while the second one refers to the backstepping method where the tuning of unknown parameters is also taken into account. It has been demonstrated that the thereby determined controllers enable on-line learning of unknown model characteristics, having at the same time the performance comparable to the one obtained for the case of fully known model parameters.

In the last, nineteenth chapter by S. Zaporojan, C. Plotnic, I. Calmicov and V. Larin a real-world application-based decision-making problem is addressed. Preliminary results of an applied research project concerning the development of an intelligent plant for microwire casting are given. To maintain
the important characteristics of the casting process, the knowledge-based decision-making system is proposed which consists of a sub-system of data acquisition from the process and a fuzzy-logic controller based on the knowledge representation given by a human operator and a mathematical model of a molten drop’s shape. A hardware implementation of the decision-making system considered, in particular of the control system, is also proposed.

Each chapter of this book is self contained. We are convinced that the book as a whole and any of its part can be useful for researchers and students in the field of knowledge-based systems and intelligent systems of different nature, in particular in the area of computer, information and control systems.

Jerzy Jozefczyk
Wrocław University of Technology, Poland

Donat Orski
Wrocław University of Technology, Poland

December 2009