Preface

Mathematics and the physical sciences made great strides for three centuries by ***constructing simplified models of complex phenomena****, deriving, properties from the models, and verifying those properties experimentally. This worked because the complexities ignored in the models were not the essential properties of the phenomena.* ***It does not work when the complexities are the essence.***

Frideric Brooks [68]

This book was mainly written on the basis of the author's conclusions, drawn over four decades of acquiring of practical experience. During that time, the author had an occasion to participate in and/or monitor the implementation of about real-life 200 projects.

One of the most important conclusions from the gained practical experience is that one can distinguish some processes playing a relatively crucial role when it comes to the successful implementation of complex projects. In this context, *processes aimed at discovering, processing, using, developing, communicating, and interactively improving comprehension of "important concepts" for practical uses* (especially those relevant to **effective and efficient problem-solving** as part of a given project) are of utmost importance. These "important concepts" are modeled and represented in the book by *complex granules* (*c-granules*, in short) that are used, approximated, and processed by networks of agents. These granules play a primary role in processes aimed at generating, processing, and archiving c-granules by networks of c-granules belonging to a single agent or to a team or a network of agents. Any agent is perceiving other agents or their networks using c–granules.

In other words, the processes aimed at processing "important concepts" are represented and investigated in the book by means of computations performed on c-granules, modeled using concepts and tools based on Interactive Granular Computing (IGrC). In this approach, "important concepts" are approximated and represented by c-granules as well.

It should be noted that "agents" pertain both to human beings and all physical devices that process data (including "intelligent" robots). Networks of these agents may cooperate with one another to solve various types of problems (e.g., related to satisfying the needs of individual agents and/or a network of agents). Networks of agents may also compete with other networks of agents to satisfy certain needs of agents. It should be emphasized that in recent decades, we witness a dynamic development of research conducted by numerous scientific centers and companies, which is devoted to networks and their use in supporting the processes of solving problems that occur in complex systems, especially in the field of Complex Systems Engineering (CSE). This is evidenced, e.g., by extensive scientific literature related to the complex network and CSE topics (e.g., [14, 20, 23, 58, 78, 79, 84, 85, 89, 95, 97, 102–104, 148, 149, 170, 179, 208, 212, 271, 272, 303, 314, 315, 332, 334, 335, 345, 354, 357, 380, 432, 439, 478, 485, 503]).

At this point, we should distinguish some characteristic features of the approach presented in this book, which are related to complex networks of agents and/or complex networks of c-granules. These features include:

1. *Physical nature of networks, c-granules, and computations performed by c-granules considered in IGrC.* This physical nature means that networks, c-granules, and computations are grounded in the physical reality.
2. *Assumption of a limited access of agents and c-granules to knowledge about the world, which can be accessed only through interactions between c-granules and the environment.*
3. *Openness and complexity of the world, leading to occurrence of unpredictable disturbances.* This generates a need to construct numerous models of local aspects with regard to the reality in which an agent is interested. These models have mechanisms for a continuous verification how well they match the phenomena that occur in the surroundings (through continuous interactions) and adaptation of these models according to observed changes.
4. *Assumption that analyzing, modeling, and solving problems related to complex systems cannot be successful without taking into consideration interactions between agents (networks of agents) and the surroundings.* Through interactions, agents may become more and more familiarized with the environment and conceptual tools for solving problems (these tools are represented as networks of c-granules).
5. *Perception of objects can be either by direct means or by indirect means.* Perception by direct means is realized by directly measuring the states of objects, represented, e.g., as the values of attribute or a satisfiability degree of a formula which defines the property of objects. Perception by indirect means is realized by creating an adequate configuration of physical objects and using it for launching in it new interaction processes to be able to identify the states of these objects by measuring the states of relevant measurable objects influenced by these interactions.
6. *Relations with issues concerning the self-organization of complex systems* [302, 420, 555].

7. *Relations with Valiant's ecorithms* [521, 522]. Here, learning of interaction rules by c-granules plays a key role. Learning these rules of interaction helps acquire knowledge, which was not possessed a priori by an agent (agents), and at the same time, plays a significant role in the process of controlling computations performed on c-granules.

The above list does not include all characteristic features of the approach to complex networks of agents and/or c-granules presented in the book. However, they show the key role of interactions in this approach.

It is worth emphasizing that apart from complex networks, there are many more currently developing domains, which are significantly related to various aspects of interactive granular computations in complex systems. In particular, this remark applies to complex systems involving human beings (e.g., social networks) and/or networks of data processing devices. These intensively developing domains include, among others:

a. machine learning, data mining, and pattern recognition (in particular big data analytics);
b. intelligent agents and intelligent multi-agent systems;
c. nonconventional models of computing (in particular computing models based on interaction, ecorithms);
d. cognitive science;
e. decision making under uncertainty, decision support systems;
f. human–computer interaction;
g. self-organizing systems;
h. adaptive control and complex adaptive systems;
i. complex systems engineering;
j. internet and the semantic web, cyber-physical systems, internet of things, wisdom Web of things, and ultra-large-scale systems;
k. complex biomedical systems and signals;
l. social networks;
m. linguistic and cognitive systems;
n. risk analysis, management, and minimization.

More examples of these domains and adequate references to literature may be found in Chap. 3, for example.

In the book, we foreground relations between the above-mentioned domains (particularly from the perspective of IGrC). At the same time, we emphasize that all these domains could be enriched through a more in-depth development of the foundations of IGrC. At the same time, the results achieved within these domains may enrich the knowledge about IGrC.

The above observations are also related to the importance of interactive granular computations performed during the implementation of complex projects. In this context, we have aimed at developing IgrC for controlling interactive granular computations, which model project's implementation processes, so that they contribute to maximizing the chance for a successful completion of a project, while minimizing the emerging risks. With this regard, the **IGrC control of CSE projects should be performed by means of properly selected and enforced (among project participants) project implementation principles**. In particular, the author used both appropriately selected and adapted principles that are commonly known (e.g., [100, 107, 279, 545]) and some other principles that were specifically developed and implemented by him.

The families of principles for the implementation of complex projects (with special regard to the specificity of the projects presented in Part IV of the book), gathered by the author, can be used by sponsors, managers, and complex project engineers. If skillfully applied, these principles may help to increase the efficiency of the project's implementation, decrease the number of project risks, and reduce some negative consequences of various project's activities (including redundant costs), which stem from a *gap between theory and practice* (cf. Part III Chap. 11).

Moreover, the author's conclusions, drawn from years of practical experience, were used in the scientific research, aimed at a deeper understanding of mechanisms related to the functioning and development of complex systems, with special regard to Complex Adaptive Systems (CAS) and to networks of agents and/or CAS.

From the point of view of the book's content, projects specific to CSE seem particularly important. **The projects themselves can be treated as complex adaptive (meta-)systems, aimed at the construction of adaptive complex systems with required properties.**

In his scientific research (e.g., devoted to computational models for CAS), the author focused on various types of CAS, particularly:

1. CAS related to software design and implementation, in which large project teams and teams of stakeholders cooperate in terms of planning and development.
2. CAS, implemented using the Internet of Things [211] and the Wisdom Web of Things (W2T) [445].
3. Complex biological systems that use natural computing [420]. Within these systems, societies of living organisms (e.g., bacteria, insects, birds, fish, mammals) learn various behaviors by acting in societies [420] in order to solve problems of the biological survival (e.g., colonies of bacteria [42]).
4. General models of CAS [543], including current mathematical models of learning systems [119, 400, 521, 527], neural network technology [8, 36, 50, 126, 137, 340], as well as *ecorithms* and computational models in ecological *niches* [210, 521].
5. CAS related to computational models of social life [338].

These systems include "intelligent" agents (e.g., human beings, animals, and/or "intelligent" robots), that are engaged in various interactions. In general, agents have their needs and they try to fulfill them on their own, in cooperation and/or by competition.

The author's reflections presented in the book concentrate around the problems related to:

A. The identification and analysis of the causes that lead to the widely discussed in the literature gap between theory and practice (cf. [19, 279, 530, 531]) during the implementation of CSE projects, especially those, that result in the creation of new software systems and technologies based on Artificial Intelligence (AI). These reflections are based on the conclusions drawn from the implementation of projects, presented in Part IV of the book (Case Studies), as well as on numerous publications and expert reports devoted to this subject (cf. Part III of the book).
   Numerous scientists and engineers agree with the thesis postulated by Linda Northrop, which is expressed in the first motto of this book. It states that despite a great progress in the research on techniques related to the implementation of very large CSE projects, we may still witness a fast growing gap between our research and reality.
B. The development of techniques for modeling mechanisms of "intelligent" interactions between agents, e.g., human beings and/or robots and computations realized by these interactions in complex systems (particularly, CAS systems). By "intelligent interactions," we mean, e.g., influencing the surroundings to stimulate behaviors, aimed at fulfilling the agent's prioritized needs. We assume that these needs include:

   1. the need related to the *perception* (understood as the process by which it is possible to comprehend the perceived situations) and interpretation of interactions, occurring in a system and its environment (especially those, needed to plan and implement the survival and development of an agent, that is as "comfortable" as possible);
   2. the need related to the agent's control over interactions to ensure her/his fulfillment of needs;
   3. the need related to the agent's understanding of perceived interactions to increase the efficiency of her/his activities, e.g., for boosting cooperation or competition among agents;
   4. the needs related to the processes of learning concepts which represent the priority needs of an agent and improving techniques used to fulfill these needs.

C. The development, on the basis of appropriate computational models (cf. B), of a set of advanced technical tools for:

   1. a deeper understanding of the causes that lead to the gap between theory and practice (mentioned in point A),
   2. the reduction of negative consequences of this gap (mentioned in point A),
   3. the maximization of increase in the quality (including the efficiency) of computations, modeled by means of the techniques, mentioned in point B.

When it comes to scientific achievements, the following significant elements should be mentioned:

I. Descriptions of selected projects designed and implemented under the author's supervision (POLTAX, AlgoTradix, Merix, Excavio). In these descriptions, a special emphasis is put on *principles* for development of CSE projects, which were, to a large extent, obeyed during the implementation of the projects presented in the book, in particular, in Parts III and IV, and also in Appendices. These principles were mainly used to control the processes of design and implementation of the projects in order to maximize the chances of achieving the expected results.

II. The analysis of conclusions from designing, modeling, and implementing complex projects, carried out and/or monitored by the author, provide some advices in searching for solutions of the problems, mentioned in points A, B, and C. This was achieved mainly by establishing the foundations for constructing computational models, which provided the basis for the creation of supporting tools for solving A, B, and C problems in complex systems, and for the synthesis (including the design and implementation) and analysis of complex systems. The most significant results include:

   II.a. The formulation of appropriate computational models for analyzing problems and techniques of reasoning about computations, realized using these models, as well as techniques for the representation of knowledge that support the process of reasoning. This encompasses:

      II.a.1. Proposals of IGrC models as the basis for supporting the synthesis (including the design and implementation) and analysis of complex projects and/or systems (especially in terms of the research devoted to problems, mentioned in A, B, and C above).

      II.a.2. Proposals of techniques for the acquisition and representation of knowledge (e.g., by means of interaction principles that support the planning and implementation of the agent's priority needs). It applies to the acquisition and representation of both general knowledge and domain knowledge, which supports the efficient use of information possessed by an agent and/or a society of agents in particular projects or systems.

   II.b. The development of techniques for controlling computations performed by agents (or their societies) in complex systems. The aim of this control is to fulfill the adaptively changing needs of an agent (or a society of agents). These techniques include the basics of computational control in IGrC, with special regard to particular uses, mentioned in A, B, and C above. These basics rely on the author's approach to computational efficiency management in IGrC (including risk and co-risk), performed by agents (or societies of agents) that carry out computations.

Re I.
The book describes selected original achievements, related to the design and implementation of such complex projects as POLTAX, AlgoTradix, Merix, and Excavio.

The POLTAX system (cf. Chap. 16) has been used and developed in Poland for about a quarter of a century. The system ensures an effective replenishment of the Polish budget resources through tax administration (which encompasses, in particular, the central register of taxpayers, accountancy, and tax (PIT, CIT, VAT) settlement).

It should be emphasized that the tax system reform, which took place at the beginning of the 90s in Poland, played a crucial role in the modernization of the Polish economy, based on the so-called Balcerowicz Plan.[4] Owing to the implementation of POLTAX, it was possible to reform the Polish tax system, so that it meets the requirements of the Polish-UE integration, and tailor it to the country's market economy. Consequently, the new tax system (based on POLTAX) paved the way for a significant economic growth of Poland, as it is illustrated in Fig. 16.3 (based on the data from the World Bank[5]). For about a quarter of the century, POLTAX has been effectively supporting the collection of taxes for the Polish budget. According to the Central Statistical Office of Poland,[6] in 2015, around 75% of taxable revenues collected for the Polish budget by the Ministry of Finance were supported by POLTAX from PIT, CIT, and VAT taxes. The growth rate of the net taxes on products[7] collection in Poland is illustrated by Fig. 16.2, prepared on the basis of the data from the World Bank.[8]

POLTAX and other projects implemented under the direction of the author of this book (BGŻ, BGK, PKN ORLEN, PERN/OLPP, RUCH, etc.) are mainly based on the Polish work culture. However, the conclusions presented in the book are also based on the author's experiences from projects implemented in countries with significantly different work cultures and traditions, and with different historical, political, and technological background.

The projects implemented or monitored by the author include:

(a) key projects implemented for the purposes of public administration during the first three decades of systemic changes in Poland, starting from 1989;
(b) research and educational projects implemented by academic centers, as well as R&D and private companies (in Poland, the USA, and Japan);
(c) projects related to industrial applications implemented in Poland, the USA, and Japan.

[4]https://en.wikipedia.org/wiki/Balcerowicz_Plan.

[5]http://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2015&locations=PL-UA-SE&start=1990&view=chart.

[6]http://www.finanse.mf.gov.pl/documents/766655/5018330/wplywy_12_2015.pdf.

[7]http://en.eustat.eus/documentos/opt_0/tema_44/elem_3365/definicion.html.

[8]http://data.worldbank.org/indicator/NY.TAX.NIND.CD?end=2015&locations=PL-UA-SE&start=1991.

To illustrate the diversity of the author's practical experiences in the implementation of scientific projects devoted to the development of AI-based technologies (differing in specificity from the POLTAX project), let us list two examples that will be analyzed in detail further in the book:

1. Developing the concept and architecture of an interactive system called Excavio—an "intelligent" search engine for extracting information from a network of document servers. The technologies proposed by the author and developed under his direction as part of the project, described in (cf. Chap. 19), led to the submission of two patent applications in the US Patent and Trademark Office, together with Zbigniew Michalewicz. These scientific and industrial patents were related to the development of artificial intelligence, particularly, the techniques of intelligent dialog document search in the Internet. According to Google Scholar, the patents[9,10] have got around 260 citations and they were referred to by the leading R&D and industrial centers, run by such giants as: IBM, Google, Microsoft, Yahoo!, Hewlett-Packard, Oracle, Saor Kabushiki Kaisha, Matsushita Electric Industrial, MusicMatch, NEC, Endeca Technologies, Fuji, Xerox, Canon, Boeing, Hansen Medical, Sony, Accenture, and Red Hut.
2. Developing the concept and architecture of an algorithmic trade system, implemented on international financial markets (Forex). The concept and architecture were implemented, developed, and introduced by the AdgaM Group (2006–2011) as part of the AlgoTradix project, presented in (cf. Chap. 17). The softbots (i.e., software robots) constructed in this project were tested for one and a half years (2009/IX–2011/III) on numerous international financial platforms (the USA, EU and Japan) and on real money on the OANDA platform (NY, the USA). On the OANDA platform, the robots automatically performed about 24,000 positions, of which 80% were won. The AlgoTradix project was mainly based on technologies of interactive granular computations, described in the book, which were performed by the societies of softbots as part of the Wisdom Technology (WisTech) research development program [246, 247, 445]. The project provided a substantial empirical material for the scientific research on the development of techniques for modeling computations in IGrC, performed by multi-agent systems described in this book.

Re II.

The conclusions presented in the book are the result of long-term and intensive experimental works and scientific research, conducted by the author. The key conclusions are described in more detail in Chaps. 13–36 of the book.

[9]https://scholar.google.pl/citations?view_op=view_citationhl=pluser=zVpMZBkAAAAJcitation_for_view=zVpMZBkAAAAJ:u5HHmVD_uO8C.

[10]https://scholar.google.pl/citations?view_op=view_citationhl=pluser=zVpMZBkAAAAJcitation_for_view=zVpMZBkAAAAJ:9yKSN-GCB0IC.

The formulation of a fundamental cause (precause) of the gap between theory and practice is one of these conclusions (cf. Chap. 13). Some very important conclusions are briefly presented in II.a and II.b.

Re II.a.

In the book, *interactive granular computations* (*computations in* IGrC, for short) were proposed as the basis of computational models and IGrC techniques based on *adaptive judgment*, as techniques for reasoning about the properties of these computations.

Computations in IGrC are performed by *complex granules* (*c-granules*, in short) thanks to which it is possible to register, analyze, and synthesize the properties of interactions among physical objects perceived by agents. In particular, c-granules may be used to support techniques for reasoning about properties of interactive computations.

We assume that the states of certain physical objects, occurring within a specific domain of activity of a given c-granule, are directly recognizable and/or measurable. However, the states of other objects are perceived (approximated, recognized) indirectly by measurable states, through interactions of physical objects from a particular domain of c-granule's activity. Each measurable state of a c-granule (at a given moment of the agent's time) corresponds to a concept. This concept is understood as a set of situations (configurations of physical objects), perceived within this very c-granule, and, thanks to interactions, leads to a specific state. In the approach proposed in this book, the concept of a measurable state means the possibility of representing such a state by, e.g., the value of a corresponding attribute or by the *satisfiability degree* of corresponding concepts/formulas, which represent these concepts. Following the aggregation of c-granules, more complex c-granules, corresponding to structural objects, their properties, or relations over measurable states (e.g., *preference relations*), can be constructed.

Thanks to c-granules, it is possible to register both the results of sensory measurements and their hierarchical aggregation, which is performed to discover new c-granules. The hierarchical c-granules discovered in this manner may ensure a deeper understanding of a perceived situation (cf. [27, 117]). The statement above about the aggregation of c-granules (representing hierarchical aggregations of the results of sensory measures) refers to the main, according to Valiant,[11] AI challenge, which is the characterization of "computational building blocks" [522] for perception.

Adaptive judgment plays a crucial role in the assessment of what is currently important, and what is less important for an agent (from the point of view of hierarchy of her/his needs). Therefore, it constitutes the basis for the evaluation and improvement of interaction plans that are being implemented. In a sense, judgment [181, 183, 263, 276, 349, 524] may be treated as an elaboration of the concept of rational reasoning (especially about the properties of computations in IGrC) due to the

[11] http://www.seas.harvard.edu/directory/valiant.

necessity of taking into account not only mechanisms of logical reasoning, but also constraints and other mechanisms that influence decisions, which are being made. These mechanisms pertain, e.g., to perception, emotions, instinct, habits, intuition, fast thinking [263], and experience. Thus, adaptive judgment is not only limited to deduction, induction, abduction, and/or other techniques of logics. A deeper understanding of the concept of adaptive judgment should be also supported by psychology (in searching for c–granules representing patterns of behavior) and phenomenology (e.g., in making decisions based on experience) [151, 328].

The key role in the approach proposed in this book is played by the techniques of adaptive and interactive discovery of c-granules (through interactions with the environment) and their further use.

It turns out that in order to perform computations on c-granules, *ecorithms*, as understood by Valiant [521], should be used instead of classical algorithms.

Apart from the analogy to Valiant's ecorithms, the IGrC-based algorithms proposed in the book display a number of other features, which correspond to the motivations of scientific research in other domains (e.g., learning systems, CAS, soft-computing, multi-agent systems, natural computations). IGrC models are also related to the very foundations of AI, in particular, to the understanding of the essence of machine learning.

When applying the approach proposed in this book, **the design and implementation of a complex project may be seen as the process of discovering, learning, processing (including communicating), and developing concepts (represented as c-granules), which are necessary to complete a given project**.

The issues related to point II.a are discussed in detail in Chaps. 22–36. Moreover, in Chap. 32, the Framework Postulates for WisTech (FPW postulates) are presented. These postulates constitute frameworks (constrains), within which computations in IGrC should be performed. Due to their complexity, these postulates are often formulated using complex vague concepts from a natural language and thus, must be approximated by agents, who use other languages (e.g., formalized languages). The problems related to this phenomenon refer to the motto of this book, which includes statements by Lotfi Zadeh and Judea Pearl.

Another difficulty is that these approximations are learnt in an environment, in which the acquisition of knowledge is possible mainly through the agent's perception of certain properties of physical objects. Therefore, these difficulties directly affect the issues related to perception, in particular, the process of learning the principles of operation, based on the agent's perception of interactions between physical objects. A great size and complexity of ontologies of concepts for expressing the FPW postulates constitute other problems.

Re II.b.

Problems related to point II.b involve adaptive learning of **principles that govern an evolutionarily changing game, defined as a set of pairs (a concept, defining the conditions required for launching a given action, and an action and/or interaction plan that is being launched when the concept is satisfied to an adequate degree)**. This process of learning is carried out by agents (and/or their societies). In these principles, a significant role is played by learning the approximations of complex and, most often, vague concepts, which, when satisfied to an adequate degree, signalize the need to take some actions (or interaction plans), e.g., actions that protect against a growing risk or actions that support the enforcement of positive results, potentially stemming from a growing co-risk (cf. FPW-13 in Chap. 32).

Moreover, when making a decision about launching or stopping a given action (or interaction plan) in a current situation, we deal with a need to settle conflicts between arguments "for" and "against" the satisfiability of complex, vague concepts, which also decide about the launching of particular actions or interaction plans. In general, the process of reasoning, which leads to a decision about choosing a given action and/or interaction plan that is to be launched (or stopped), is based on adaptive judgment, which takes into account such elements as the assessment of risk involved in a current situation, knowledge about possible consequences of a given action/interaction plan that is to be implemented, or disturbances caused by interactions with the surroundings. In practice, we may find numerous recommendations as for the conditions and actions of launching controls against various types of risks among the existing standards relating to risk management. However, **updating this type of knowledge and sharing it with complex systems (including societies of artificial agents) is still a great challenge**.

When using contemporary standards, it is worth remembering that the classical approach to risk management is—generally—based on stationary foundations of the ontology of concepts which define risk management. On the other hand, according to the approach presented in this book, the semantics of concepts which define risk management (including the concept of "risk" itself) evolves with time. The dynamics of changes to these concepts depend both on the techniques of interactions between agents and the environment and on unknown external factors.

The reflections above show that the concept of ontology, understood as a conceptual apparatus of agents (or a society of agents) used for perceiving, planning, acting, learning, and communicating, plays a key role in IGrC. Moreover, the concepts used by agents constitute the primary building blocks of interaction principles, which provide the basis for controlling computations to satisfy the adaptively changing needs of agents (or societies of agents).

It is worthwhile mentioning that the ontologies present in IGrC computational models, which comply with the FPW postulates described in Chap. 32, are very complex. Moreover, the processes of creating and selecting an essential ontology for acquiring, representing, sharing, and updating domain knowledge, characteristic of a specific IGrC application, are also very complex. These ontologies are based on numerous vague concepts and relations between them.

Moreover, it is important to take into account some serious problems which are encountered while trying to acquire and develop ontologies (especially those, which involve vague, complex concepts) by artificial agents. These problems concern, among others, the need to understand numerous complex, vague concepts by artificial agents. For this purpose, some efforts may be made to help agents in the process of learning the approximations of such ontologies (cf. [27]). However, current results of the research in this field require a further elaboration. Another problem is related with a need to provide artificial agents with an access to techniques of reasoning on concepts from those ontologies, which mimic the reasoning in a natural language at least in an approximate sense. The reader must have noticed that these problems directly refer to the challenges formulated in a form of the motto of this book, which is the statement by Lotfi Zadeh and Judea Pearl. The aforementioned problems appear especially when efforts to share the experience related to managing complex projects with multi-agent systems are being made.

Currently, we are nowhere near developing fully effective techniques for transforming and filtering human experiences related to managing projects into knowledge accessible to specific complex systems consisting of artificial agents, who could take over some of these functions from human beings and share them with "intelligent" robots, ensuring, at the same time, that they are properly used.

On the other hand, due to the fact that there are no perspectives for developing effective techniques of automatic learning and discovery of complex knowledge, let alone its effective use in a way that is analogous to that of human beings, it seems inevitable for complex systems to use knowledge that is accessible to them. The aforementioned lack of perspectives is related to the complexity of the search space, within which concepts necessary to express either interaction principles for controlling interactive computations in IGrC or (semi-) optimal principles for the implementation of CSE projects are being discovered. These concepts may be particularly related to experiences in managing projects.

We have outlined some of the aspects that are important for modeling and control computations of complex systems. This outline shows the complexity of FPW, described in more detail in Chap. 32, which involve all aspects mentioned above. These postulates should constitute key constraints for controlling interactive computations in complex systems by agents.

The results of the research presented in this book may also be analyzed from the point of view of their potential contribution to advancements in dynamically developing scientific disciplines, such as CSE [356, 424], granular computational models [394], interactive computational models [169], models of natural computing [210, 420], models of learning systems [521], and models of computations performed by CAS [543] or multi-agent systems [121, 311, 488].

The main ideas presented in the book have their roots in the research on rough sets, initiated by Zdzisław Pawlak [381, 383, 385, 463]. At this point, we are particularly referring to Pawlak's approach to concepts such as concept approximations, information systems, decision tables (as they are understood in a rough set theory), and reasoning about vague concepts.

The research fields presented above are described in more detail in the introduction to the book (cf. Part I). It includes such chapters as in-depth research motivations (Chap. 1), research objectives and approaches to selected directions of searching for solutions (Chap. 2), and challenges of WisTech related to CAS Modeling (Chap. 3). It also contains a general description of scientific research results (Chap. 5) and a guide to the book's content (Chap. 4). Moreover, in the Part I of the book the references to the relevant publications are presented.

In this book there are many quotations. The crucial fragments (from the point of the book) of the quotations are bolded by the author of the book.

The approach to IGrC computations proposed and presented in the book as a scientific achievement of the author is a continuation and expansion of the research, conducted together with prof. Andrzej Skowron and described in several publications (e.g., [244, 245, 245–249, 252, 361, 444–448, 459, 460]).

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