Interactive Computations: Toward Risk Management in Interactive Intelligent Systems

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Abstract. Understanding the nature of interactions is regarded as one of the biggest challenges in projects related to complex adaptive systems. We discuss foundations for interactive computations in Interactive Intelligent Systems (IIS), developed in the Wistech program and used for behavior modeling of complex systems. We emphasize the key role of risk management in problem solving by IIS. The considerations are supported by real-life projects concerning, e.g., medical diagnosis and therapy support, control of an unmanned helicopter, algorithmic trading or fire commander decision support.

Keywords: rough sets, granular computing, interactive computations, interactive intelligent systems, risk management.

Traditional statistics is strong in devising ways of describing data and inferring distributional parameters from sample. Causal inference requires two additional ingredients: a science-friendly language for articulating causal knowledge, and a mathematical machinery for processing

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that knowledge, combining it with data and drawing new causal conclusions about a phenomenon .

– *Judea Pearl* [15]

1 Introduction

Information granules (infogranules, for short) are widely discussed in the literature (see, *e.g.*, [16]). In particular, let us mention here the rough granular computing approach based on the rough set approach and its combination with other approaches to soft computing. However, the issues related to interactions of infogranules with the physical world and to perception of interactions in the physical world represented by infogranules are not well elaborated yet. On the other hand the understanding of interactions is the critical issue of complex systems [4] in which computations are progressing by interactions among information granules and physical objects.

We extend the existing approach to granular computing by introducing *complex granules* (c-*granules*, for short) [8] making it possible to model interactive computations performed by agents in Interactive Intelligent Systems (IIS) used for behavior modeling of complex systems.

Any agent operates in a local world of c-granules. The agent control is aiming to control computations performed on c-granules from this local world for achieving the target goals.

Computations in IIS are based on c-granules. The risk management in IIS is of the great importance for the success of behaviors of individuals, groups and societies of agents. The risk management tasks are considered as control tasks aiming at achieving the satisfactory performance of (societies of) agents. The novelty of the proposed approach is the use of complex vague concepts as the guards of control actions. These vague concepts are represented, *e.g.*, using domain ontologies. The rough set approach in combination with other soft computing approaches is used for approximation of the vague concepts relative to attributes (features) available to the risk management systems.

This paper is organized as follows. In Section 2 an introduction to Interactive Rough Granular Computing (IRGC) is presented. Issues related to reasoning based on adaptive judgement are included in Section 3. The approach to risk management based on IRGC is discussed in Section 4.

This paper covers some issues presented in the plenary talk at the 5th International Conference on Pattern Recognition and Machine Intelligence (PReMi 2013), December 10-14, 3013, Kolkata, India.

2 Interactive Rough Granular Computing (IRGC)

The essence of the proposed approach is the use of IIS implemented using IRGC [7,20,21,19,8,18]. The approach is based on foundations for modeling of IRGC relevant for IIS in which computations are progressing through interactions [4].

In IRGC interactive computations are performed on objects called *complex granules* (*c-granules*, for short) linking information granules [16] (or infogranules, for short) with physical objects called hunks [5,8].

Infogranules are widely discussed in the literature. They can be treated as specifications of compound objects (such as complex hierarchically defined attributes) together with scenarios of their implementations. Such granules are obtained as the result of information granulation [27]:

> *Information granulation can be viewed as a human way of achieving data compression and it plays a key role in implementation of the strategy of divide-and-conquer in human problem-solving.*

Infogranules belong to the concepts playing the main role in developing foundations for AI, data mining and text mining [16]. They grew up as some generalizations from fuzzy sets [25,26,27], rough set theory and interval analysis [16]. The rough set approach is crucial because of necessity to deal with approximations of inforgranules by the others, *e.g.*, in inducing classifiers for complex vague concepts. The IRGC is based on the rough set approach in combination with other approaches to soft computing (such as fuzzy sets). However, the issues related to interactions of infogranules with the physical world and their relation to perception of interactions in the physical world are not well elaborated yet [4,24]. On the other hand the understanding of interactions is the critical issue of complex systems [10]:

> [...] *interaction is a critical issue in the understanding of complex systems of any sorts: as such, it has emerged in several well-established scientific areas other than computer science, like biology, physics, social and organizational sciences.*

We propose to model complex systems by IIS created by societies of agents. Computations in the discussed IIS are based on c-granules [8] (see Figure 1). Any c-granule consists of three components, namely soft_suit, link_suit and hard_suit. These components are making it possible to deal with such abstract objects from soft_suit as infogranules as well as with physical objects from hard_suit. The link_suit of a given c-granule is used as a kind of c-granule interface for handling interaction between soft_suit and and hard_suit.

Calculi of c-granules are defined by elementary c-granules (determined, *e.g.*, by indiscernibility of similarity classes) and c-granules making it to possible to generate new c-granules from already defined ones (see Figure 1 where the presented c-granule produces new output c-granules from the given input c-granules). The hierarchy of c-granules is illustrated in Figure 2. Moreover, c-granules create the basis for the agent (communication) language construction and the language evolution.

Any agent operates in a local world of c-granules. The agent control is aiming to control computations performed on c-granules from this local world for achieving the target goals. Actions (sensors or plans) from link_suits of c-granules are used by the agent control in exploration and/or exploitation of the environment

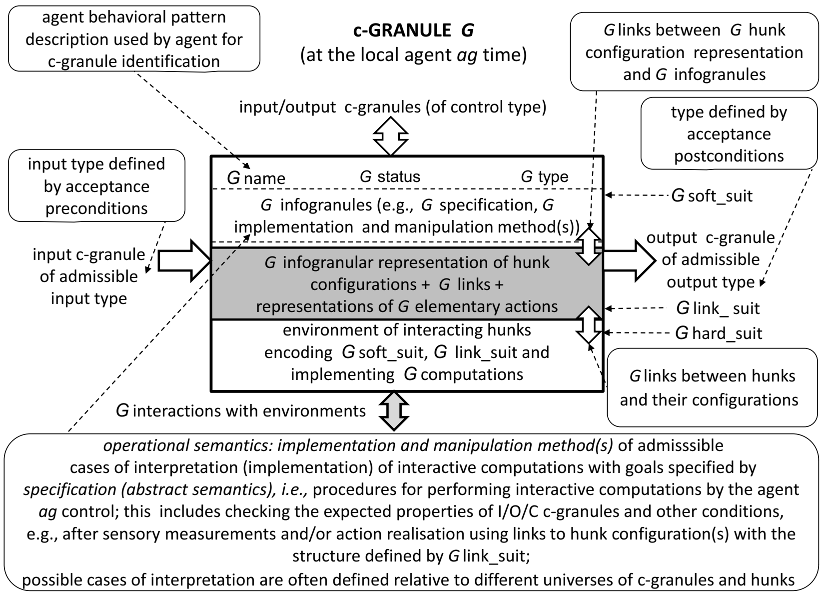

Fig. 1. General structure of c-granule

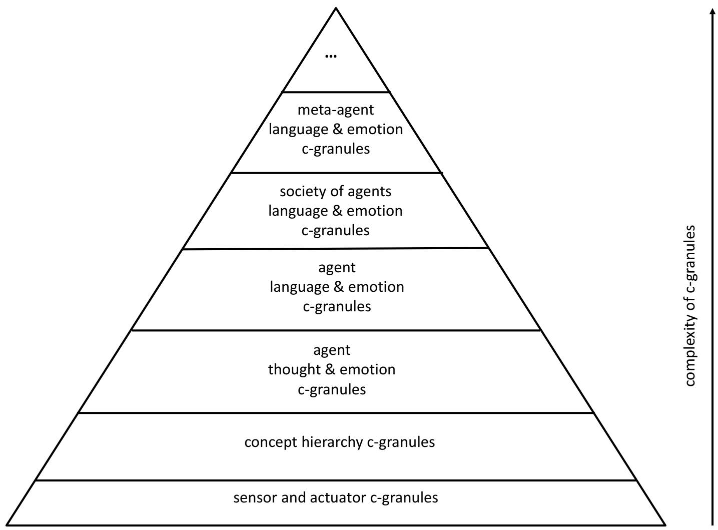

Fig. 2. Hierarchy of c-granules

on the way to achieve their targets. C-granules are also used for representation of perception by agents of interactions in the physical world. Due to the bounds of the agent perception abilities usually only a partial information about the interactions from physical world may be available for agents. Hence, in particular the results of performed actions by agents can not be predicted with certainty. For more details on IRGC based on c-granules the reader is referred to [8].

One of the key issues of the approach to c-granules presented in [8] is some kind of integration of investigation of physical and mental phenomena. The integration follows from suggestions presented by many scientists. For illustration let us consider following two quotations strongly related to the research on IRGC based on c-granules:

> *As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality.*
>
> – *Albert Einstein* ([3])

> *Constructing the physical part of the theory and unifying it with the mathematical part should be considered as one of the main goals of statistical learning theory.*
>
> – *Vladimir Vapnik* ([24], p. 721)

A special role in IRGC play information (decision) systems from the rough set approach [11,12,13,23]. They are used to record processes of interacting configurations of hunks. In order to represent interactive computations (used, *e.g.*, in searching for new features) information systems of a new type, namely interactive information systems, are needed [20,21,8].

3 Adaptive Judgement

The reasoning making it possible to derive relevant information granules for solutions of the target tasks is called *adaptive judgment*. *Intuitive judgment* and *rational judgment* are distinguished as different kinds of [9]. Among the tasks for adaptive judgment are the following ones supporting reasoning toward: searching for relevant approximation spaces, discovery of new features, selection of relevant features (attributes), rule induction, discovery of inclusion measures, strategies for conflict resolution, adaptation of measures based on the minimum description length principle, reasoning about changes, selection of parameters of (action and sensory) attributes, adaptation of quality measures over computations relative to agents, adaptation of object structures, discovery of relevant context, strategies for knowledge representation and interaction with knowledge bases, ontology acquisition and approximation, learning in dialogue of inclusion measures between information granules from different languages (*e.g.*, the formal language of the system and the user natural language), strategies for adaptation of existing models, strategies for development and evolution of communication language among agents in distributed environments, strategies for risk management in distributed computational systems.

Adaptive judgement in IIS is a mixture of reasoning based on deduction, abduction, induction, case based or analogy based reasoning, experience, observed changes in the environment, meta-heuristics from natural computing (see Figure 3). We would like to stress that still much more work should be done

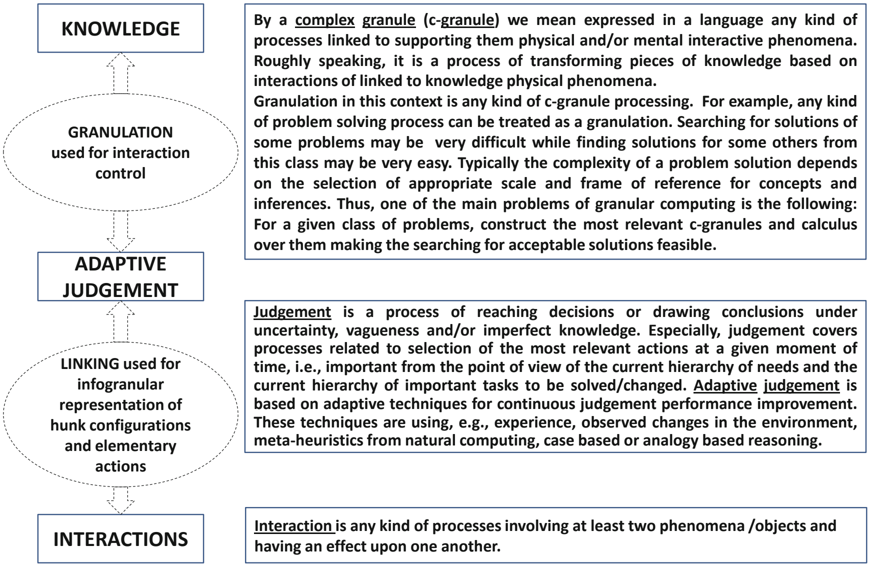

Fig. 3. Interactions, adaptive judgement and granulation

to develop approximate reasoning methods about complex vague concepts for making progress in development of IIS, in particular for the risk management in IIS. This idea was very well expressed by Leslie Valiant[1]:

> *A fundamental question for artificial intelligence is to characterize the computational building blocks that are necessary for cognition. A specific challenge is to build on the success of machine learning so as to cover broader issues in intelligence. [...] This requires, in particular a reconciliation between two contradictory characteristics – the apparent logical nature of reasoning and the statistical nature of learning.*

It is worthwhile to mention two more views. The first one by Lotfi A. Zadeh, the founder of fuzzy sets and the computing with words paradigm (see [26] and also `http://www.cs.berkeley.edu/~zadeh/presentations.html`):

> *Manipulation of perceptions plays a key role in human recognition, decision and execution processes. As a methodology, computing with words*

[1] see, *e.g.*, `http://en.wikipedia.org/wiki/Vagueness`, `http://people.seas.harvard.edu/~valiant/researchinterests.htm`

provides a foundation for a computational theory of perceptions - a theory which may have an important bearing on how humans make - and machines might make - perception-based rational decisions in an environment of imprecision, uncertainty and partial truth. [...] computing with words, or CW for short, is a methodology in which the objects of computation are words and propositions drawn from a natural language.

and the view by Judea Pearl included as the motto of this paper.

The question arises about the logic relevant for the above discussed tasks. First let us observe that the satisfiability relations in the IRGC framework can be treated as tools for constructing new information granules. If fact, for a given satisfiability relation, the semantics of formulas relative to this relation is defined. In this way the candidates for new relevant information granules are obtained. We would like to emphasize a very important feature. The relevant satisfiability relation for the considered problems is not given but it should be induced (discovered) on the basis of a partial information encoded in information (decision) systems. For real-life problems, it is often necessary to discover a hierarchy of satisfiability relations before we obtain the relevant target level. Information granules constructed at different levels of this hierarchy finally lead to relevant ones for approximation of complex vague concepts related to complex information granules expressed in natural language (see Figure 4).

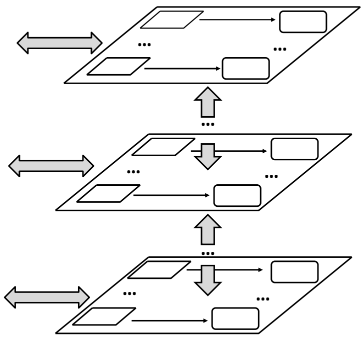

Fig. 4. Interactive hierarchical structures (gray arrows show interactions between hierarchical levels and the environment, arrows at hierarchical levels point from information (decision) systems representing partial specifications of satisfiability relations to induced from them theories consisting of rule sets)

4 Risk Management in IIS

Since the very beginning, all human activities were done at risk of failure. Recent years have shown the low quality of risk management in areas such as finance, economics, and many others. In this context, improvement in the risk management has a particular importance for the further development of complex systems. The importance of risk management illustrates the following example from financial sector. Many of financial risk management experts consider Basel II rules[2] as a causal factor in the credit bubble prior to the 2007-8 collapse. Namely, in Basel II one of the principal factors of financial risk management was

> *outsourced to companies that were not subject to supervision, credit rating agencies.*

Of course, now we do have a new "improved" version of Basel II, called Basel III. However, according to an OECD [3] *the medium-term impact of Basel III implementation on GDP growth is negative and estimated in the range of* -0.05% *to* -0.15% *per year* (see also [22]).

On the basis of experience in many areas, we have now many valuable studies on different approaches to risk management. Currently, the dominant terminology is determined by the standards of ISO 31K [1]. However, the logic of inferences in risk management is dominated by the statistical paradigms, especially by Bayesian data analysis initiated about 300 years ago by Bayes, and regression data analysis initiated by about 200 years ago by Legendre and Gauss. On this basis, resulted many detailed methodologies specific for different fields. A classic example is the risk management methodology in the banking sector, based on the recommendations of Basel II standards for risk management mathematical models [17]. The current dominant statistical approach is not satisfactory because it does not give effective tools for inferences about the vague concepts and relations between them (see the included before sentences by L. Valiant).

A particularly important example of the risk management vague concept relation is the relation of a cause - effect relationships between various events. It should be noted that the concept of risk in ISO 31K is defined as *the effect of uncertainty on objectives*. Thus, by definition, the vagueness is also an essential part of the risk concept. To paraphrase the motto of this study by Judea Pearl, we can say that traditional statistical approach to risk management inference *is strong in devising ways of describing data and inferring distributional parameters from sample*. However, in practice risk management inference requires two additional ingredients (see the motto of this article):

– *a science-friendly language for articulating risk management knowledge*, and
– *a mathematical machinery for processing that knowledge, combining it with data and drawing new risk management conclusions about a phenomenon.*

Adding both mentioned above components is an extremely difficult task and binds to the core of AI research very accurately specified by the Turing test. With regard to our applications, properly adapted version of the test boils down to the fact that on the basis of a "conversation" with a hidden risk management expert and a hidden machine one will not be able to distinguish who is the man and who is the machine.

[2] see `http://en.wikipedia.org/wiki/Basel_Committee_on_Banking_Supervision`
[3] see `http://en.wikipedia.org/wiki/Basel_III`

We propose to extend the statistical paradigm by adding the two discussed components for designing of the high quality risk management systems supported by IIS.

For the risk management in IIS one of the most important task is to develop strategies for inducing approximations of vague complex concepts making it possible to check their satisfiability (to a degree). A typical example of such vague concept is the statement of the form: “now we do have very risky situation”. The development of strategies for inducing approximations of such vague complex are based on the activation of actions performed by agents.

These vague complex concepts are represented by the agent hierarchy of needs. In risk management one should consider a variety of complex vague concepts and relations between them as well as reasoning schemes related, *e.g.*, to the bow-tie diagram (see Figure 5).

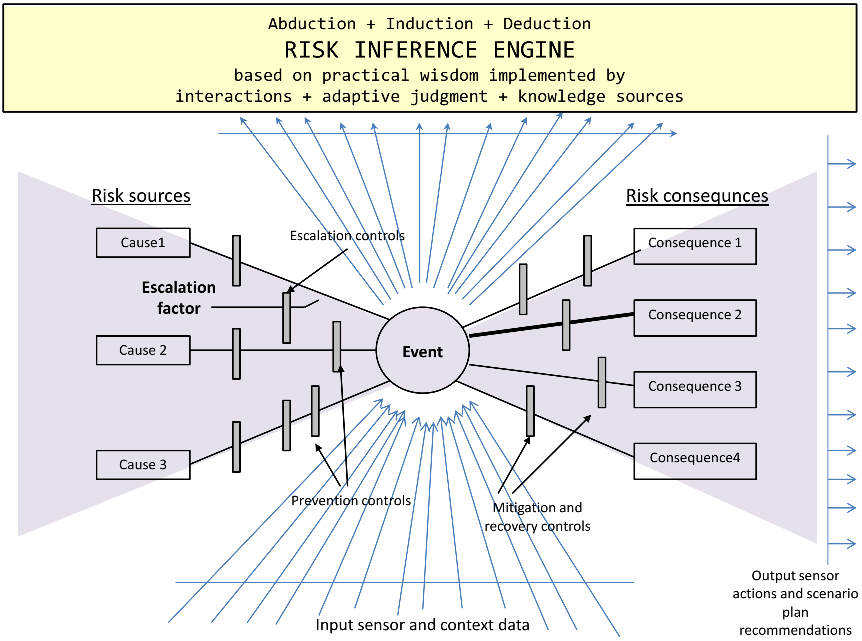

Fig. 5. Bow-tie diagram

Let us explain the bow-tie diagram using the chess game. Of course, the chess game is a very simple example. In practice the game could be much more complex. The bow-tie diagram has 3 basic parts:

1. concepts from risk sources,
2. current situation description represented by a hierarchy of concepts defined by the input sensors and context data,
3. concepts from risk consequences.

To make the next move in chess game the player should understand the current situation. To do this, he or she should use the domain knowledge representation (especially, related to the domain of risk management) and apply the relevant inference rules to the current situation description (see parts 1 and 2) enriched by knowledge about the history of moves. Based on the knowledge about possible sources of risk (expressed in part 1) and features of moves history, one should identify the prioritized list of hypotheses about the opposite player strategy. If the opposite player strategy is identified then it is much easier to win. This kind of inference leading to a list of the most likely to be true hypotheses for the opposite player strategy, is called abduction. This *is a form of logical inference that goes from observation to a hypothesis that accounts for the reliable data (observation) and seeks to explain relevant evidence* (by Wikipedia `http://en.wikipedia.org/wiki/Abductive_reasoning`). In the following step, the best possible next move should be proposed on the basis of the list of hypotheses for the opposite player strategy. For the chess game, one can generate the tree of all possible n-moves and propose the best next move using some well known algorithms (such as $minimax$, $alpha-beta$, $A-star$ [14]). In real life applications, such trees theoretically could be generated using the part of risk ontology related to consequences (part 3). If these trees are becoming huge then using relevant abduction inference one can try to identify constraints helping to make searching for the best next move in such trees feasible.

One can consider the mentioned above tasks of approximation of vague complex concepts initiating actions as the complex game discovery task (see Figure 6) from data and domain knowledge. The agents use the discovered games

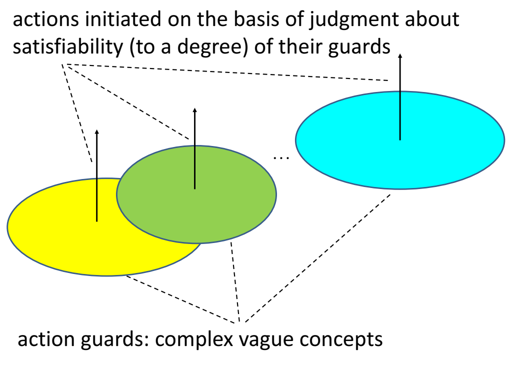

Fig. 6. Games based on complex vague concepts

for achieving their targets in the environment. The discovery process often is based on hierarchical learning supported by domain knowledge [8,2]. It is also worthwhile mentioning that such games are evolving in time (drifting in time) together with data and knowledge about the approximated concepts and the relevant strategies for adaptation of games used by agents are required. These adaptive strategies are used to control the behavior of agents toward achieving by them targets. Note that also these strategies should be learned from available uncertain data and domain knowledge.

The discussed concepts such as interactive computation and adaptive judgment are among the basic ingredient elements in the Wisdom Technology (WisTech) [6,8]. Let us mention here the WisTech meta-equation:

$$\begin{aligned} \text{WISDOM} \ = \ & \\ & \text{INTERACTIONS} \ + \\ & \text{ADAPTIVE JUDGEMENT} \ + \\ & \text{KNOWLEDGE} \ . \end{aligned} \tag{1}$$

An extension of the rough set approach on interactive computations realized by IIS is one of the current challenges.

5 Conclusions

The approach for modeling interactive computations based on c-granules was presented and its importance for the risk managements was outlined.

The presented approach seems also to be of some importance for developing computing models in different areas such as natural computing (*e.g.*, computing models for meta-heuristics or computations models for complex processes in molecular biology), computing in distributed environments under uncertainty realized by multi-agent systems (*e.g.*, in social computing), modeling of computations for feature extraction (constructive induction) for approximation of complex vague concepts, hierarchical learning, discovery of planning strategies or strategies for coalition formation by IIS as well as for approximate reasoning about interactive computations based on such computing models.

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