Preface

This volume is devoted to the 65th birthday of Dr. Boris Kovalerchuk. Dr. Kovalerchuk's results cover many research areas. Many of these areas are reflected in this volume.

In this preface, I would like to emphasize his contributions to research areas which are the closest to my own research: data processing under uncertainty, especially *fuzzy* data processing, when uncertainty comes from the imprecision of expert opinions.

Fuzzy research area: successes and challenges. Fuzzy techniques have many successful practical applications, especially in intelligent control, where expert knowledge – originally formulated in terms of imprecise ("fuzzy") words from natural language – is successfully translated into a computer-understandable form and then used in automated decision making.

However, there are still many applications problems (and even whole application areas) where, at present, we are not that successful in formalizing and using imprecise expert knowledge. To be able to use this knowledge, we must overcome several important challenges. In all these challenges, Dr. Kovalerchuk plays an important role as a research leader.

First challenge: need to select appropriate techniques. The first challenge is that, in contrast to (more traditional) probabilistic methods – which are based on solid foundations – many fuzzy techniques are, by nature, heuristic.

There are usually many ways to translate imprecise expert knowledge into precise terms, and the success of an application often depends on selecting the most adequate translation. To be able to select such a translation, we need to have a general description of all possible translations and ways to deal with them. This activity is known as *foundations* of fuzzy techniques.

This is a very complex area of research, an area that requires deep knowledge of mathematics, computer science, foundations and philosophy of science, and – since the ultimate goal is applications – a good understanding of many application areas.

Boris has all these skills, and he has used them successfully in his numerous seminal papers on fuzzy foundations. His paper appeared as chapters in the Springer book series "Studies in Fuzziness and Soft Computing" (see, e.g., [2, 10]; one of the first was his 1994 chapter [2] devoted to the difficult problem of optimization of an uncertain (fuzzy) objective function under uncertain (fuzzy) constraints.

Second challenge: need to combine fuzzy and probabilistic techniques. The second major challenge is related to the fact that, in addition to *subjective* expert knowledge, we also have measurement-based *objective* information about the corresponding system, information usually formulated in probabilistic terms. To solve the corresponding practical problems, we need to adequately combine fuzzy and probabilistic uncertainty. Here, we face two problems:

- a *foundational* problem – which is the best way to combine these two types of uncertainty? – and
- a *communication* problem, caused by the fact that the two communities are not very familiar with each other's research and, as a result, have misunderstandings about the other research areas, misunderstandings that prevent successful collaboration.

Boris is one of the main research leaders in solving both these problems.

He has published several seminal papers on selecting the best way of combining these two types of knowledge; see, e.g., [12, 23]; I would like to specifically mention his 2012 Springer chapter [10].

He has also done a great job of describing probability ideas to fuzzy community and fuzzy ideas to probability researchers, in particular, by showing that – contrary to the widely spread misunderstanding – fuzzy-related techniques do not violate the main idea of probability, and moreover, many such fuzzy techniques can be meaningfully reformulated (and explained) in probabilistic terms.

In particular, he has shown that many real-life applications of fuzzy techniques can actually be reformulated in probabilistic terms – and that the combination of such reformulated terms and traditional probabilistic techniques can enhance the probabilistic approach. He has also shown that a seeming inconsistency between fuzzy methods (based on t-norms) and probabilistic approach can be resolved within a new formalism that Boris called Exact Complete Context Spaces (ECCS). His series of publications starting with his 1994 paper [3], in which he showed that exact complete context spaces link fuzzy logic and probability theory in a new rigorous way. Specifically, he has shown how the use of ECCS can explain numerous successes of fuzzy control in application; this was the main topic of his 1996 paper [5] that was welcomed by Lotfi Zadeh. This work had been expanded in his other publications published in the proceedings of the IEEE World Congresses on Computational Intelligence WCCI'2008–2012, International Conferences on Information Processing and Management of Uncertainty in Knowledge-Based Systems IPMU'2012–2014, World Congress of International Fuzzy Systems Association IFSA/NAFIPS'2013, and in several seminal Springer book chapters published in 2012 and 2013; see also [4, 6, 16].

Third challenge: dynamic character of human reasoning. The third challenge is that, in contrast to the objective knowledge, which, once established, remains stable, subjective knowledge changes with time, it is dynamic: an expert may learn new things and/or realize that some of his/her previous opinions were imprecise or even incorrect. To make applications of expert knowledge more adequate, we need to take into account the dynamic nature of human reasoning. This is very difficult task.

In solving this task, Boris was one of the pioneers. With Leonid Perlovsky and Gregory Wheeler, he established a formal mechanism for modeling such dynamic character, a mechanism that they called Dynamic Logic of Phenomena. This is an approach to solve real-world tasks via a dynamic process of synchronous adapting the task and the solution criteria when both are uncertain. Boris started this research under the grant from the US National Research Council (NRC) when

he was working at the US Air Force Research laboratory in 2007–2008. His main results are overviewed in his seminal 2012 paper published in a prestigious Journal of Applied Non-Classical Logics [19].

Fourth challenge: dealing with (somewhat) inconsistent expert knowledge. The fourth challenge is that, due to imprecision of expert reasoning, some of the expert statements are, strictly speaking, contradictory to one another. It is desirable to be able to deal with such seemingly inconsistent knowledge. The logic of such inconsistent knowledge bases is known as *paraconsistent logic*. This a very active and a very difficult area of research, so difficult that at present, it has are very few applications to real life situations, and most of these applications only deal with "crisp" (non-fuzzy) expert statements.

In his pioneer 2006–2010 joint research with Germano Resconi, Boris developed a theory of *irrational* (= inconsistent) *agents*, a theory that combined fuzzy logic, probability theory, and paraconsistent logic into a general techniques for handling both rational and irrational agents [20, 21, 29–36].

Fifth challenge: translating computer results into human-understandable form. The fifth major challenge is related to the fact that, in contrast to fuzzy control where often a decision needs to be made urgently and thus, has to be automated, in many other application areas – e.g., in many cases of medical diagnostics – there is no such hurry. So, it is desirable to first show the resulting computer-generated decision proposal to an expert, to make sure that the automated system properly took all the experts' knowledge into account. To be able to do that, we face a problem which is reverse to the above-mentioned translation problem underlying fuzzy techniques – a problem of how to better translate numerical results of the computer data processing into expert-understandable form. There are two ways we humans get the information:

- in terms of words, and
- in terms of pictures.

Thus, we need to translate the computer results both into words and into pictures. On both tasks, Boris did a pioneer work.

The question of translating computer results into words is handled in Boris's publications on *interpretability* of fuzzy operations. Not only he analyzed this problem theoretically, he also proposed and conducted empirical studies that established the scope of applicability of different "and"-operations (= t-norms) of fuzzy logic. This work was published in Fuzzy Sets and Systems – the main journal of our community – in Elsevier's Journal of General Systems [25], in proceedings of IEEE WCCI'2010–2012 [9], and in many other places (see, e.g., [14]).

In terms of visualization, Boris is a recognized expert in analytical and visual data mining, and in visual analytics. He has published two related books: *Data Mining in Finance* [28] and *Visual and Spatial Analysis* [22]. Most recently (2014) Boris published a series of four conference papers (jointly with his colleague Vladimir Grishin) on lossless visualization of multi-D data in 2-D; see, e.g., [1, 15].

This is an interesting new development, with a potential for a breakthrough in the critical area of big data research. Boris introduced new concepts of collocated paired coordinates and general line coordinates that dramatically expand the scope of lossless multi-D data visualizations [1, 13, 15].

Need for applications. Finally, once all these challenges are resolved, it is important to actively pursue new applications of the corresponding techniques. Boris has many application papers, ranging:

- from applications to medicine, including breast cancer diagnostics [26, 27];
- to finance [28]
- to geospatial analysis – in a series of SPIE publications during the last 10 years; see, e.g., [11, 18, 24], and in [17];
- to efficient applications of his new visualization techniques to World Hunger data analysis and the Challenger disaster.

Dr. Kovalerchuk is a world-renowned researcher. All this research activity has made Boris Kovalerchuk a world-renowned expert in systems and uncertainty modeling.

For example, in 2012, he was invited to present a 3-hour tutorial on Fuzzy Logic, Probability, and Measurement for Computing with Words at the IEEE World Congress on Computational Intelligence WCCI'2012.

Service to the research community. In addition to doing research, Boris is also very active in the fuzzy research community. He regularly posts short tutorials and opinions on the relation between possibility and probability to the Berkeley Initiative Soft Computing (BISC) mailing list, often at the explicit invitation of Dr. Zadeh himself.

He also makes an important contribution to conferences. He chaired two Computational Intelligence Conferences [7, 8]. This year, he serves as a technical co-chair of the North American Fuzzy Information Processing Society (NAFIPS) Conference to be held in Redmond, Washington (August 2015). At the IEEE Symposium on Computational Intelligence for Security and Defense Applications, CISDA (New York State, May 2015), he organized and mediated a panel of leading experts from multiple organizations including DARPA on Current Challenges of Computational Intelligence in Defense and Security.

Conclusion. Dr. Boris Kovalerchuk is an excellent well-recognized world-level researcher in the area of fuzzy techniques and uncertainty modeling in general, he is one of the leaders in this research area. We wish him happy birthday and many many more interesting research results!

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