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Procedia Computer Science 120 (2017) 908–915

Procedia Computer Science

www.elsevier.com/locate/procedia

9th International Conference on Theory and Application of Soft Computing, Computing with Words and Perception, ICSCCW 2017, 24-25 August 2017, Budapest, Hungary

Development of fuzzy logics: from universal logic tools to natural pragmatics and non-standard scales

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Abstract

The need in new approach to developing applied fuzzy logics to bridge the gap between fuzzy logics in narrow and broad sense is suggested. It is based on combining concepts and tools of universal logic with the ideas of natural pragmatics, context-sensitive truth values and non-standard bipolar scales. The concept of meta-pragmatics for many-valued and fuzzy logics is introduced, its importance is shown on examples of bipolarities and neutralities. A methodology of computer-assisted fuzzy logic synthesizing on the basis of extended logical matrices is sketched.

Peer-review under responsibility of the scientific committee of the 9th International Conference on Theory and application of Soft Computing, Computing with Words and Perception.

Keywords: *Fuzzy logics; universal logic; logical matrix; natural pragmatics; bipolarity; oppositional scale; neutralities.*

1. Introduction

Nowadays *fuzzy logic* is considered in two senses: broad and narrow. The Father of Fuzzy Logic Lotfi Zadeh is the founder of a *broad view* on fuzzy logic as the system of formal methods and tools for natural language processing. This integrated system was appeared in 1960-1970's and included such concepts and models as *fuzzy set theory* (Zadeh, 1965) and *linguistic variable* (Zadeh, 1975), *fuzzy relations* and *approximate reasoning*, *fuzzy rules* and *fuzzy constraints*, *possibility theory* and *PRUF language*, *test-score semantics* and *information granulation* (Zadeh, 1997), etc. At the beginning of 2000's *generalized uncertainty theory* (Zadeh, 2005), extended fuzzy logic

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Peer-review under responsibility of the scientific committee of the 9th International Conference on Theory and application of Soft Computing, Computing with Words and Perception.
10.1016/j.procs.2017.11.325

(Zadeh, 2009) on the basis of fuzzy geometry and fuzzy transformation**,** the *restriction-centered theory* of *truth* and *meaning* (Zadeh, 2013) were proposed. Specifically, Zadeh's fuzzy logical model is given by many-valued logic with a graded and granular (linguistic) truth. In spite of its novelty, Zadeh's fuzzy logic continues, in some sense, the old tradition of *logical psychologism*: «from psychology to logics» (in particular, from perceptions to logic of perceptions and, furthermore, to computing with perceptions and even figures) and extends it by adding the slogan «from linguistics to logics and computing with words». Such an engineering approach to fuzzy logic has found a lot of valuable applications (see, for example, such areas as fuzzy control, fuzzy decision-making, fuzzy clustering); it is still very popular among practitioners.

However, for a long time, pure logicians and mathematicians (rare exceptions were Klaua, Goguen (see Goguen, 1969), Pavelka) had been ignoring fuzzy logic, considering it as some engineering tool rather than a serious logical theory. The situation changed by the end of 1990's when an extensive study of non-classical many-valued logical systems called Mathematical Fuzzy Logic (MFL) was started. It was stimulated by the pioneering book «Metamathematics of Fuzzy Logic» by Petr Hajec (Hajec, 1998) which was published in 1998 (the next year we will speak about 20 years of MFL). This seminal monograph together with fundamental books by Gottwald (2001), Cignoli et al.(2000), Klement et al.(2000), Novak et al.(1999), important papers by Esteva et al.(2001), Cintula and Noguera (2010) have revealed tight connections between multi-valued logics, fuzzy logics and the mainstream of modern logics – abstract algebraic logics (AAL). Today we observe a real explosion of publications in MFL.

Fuzzy Logic in a *narrow sense* (or MFL) is infinitely-valued logic developed in the spirit of classical logic (syntax, semantics, axiomatization, truth-preserving deduction, completeness, etc.; both propositional and predicate logic). It is a branch of many-valued logic based on the paradigm of inference under vagueness. Nevertheless, the definition of operations in fuzzy logic is much more general than in multi-valued logics. According to Hajek, the basic systems of fuzzy logics are triangular norm (t-norm) based, i.e. they use the real unit interval [0,1], (left) continuous t-norms as standard conjunctions and their residua as standard implications.

Last years, fuzzy logical systems are often constructed in the framework of AAL, which aims at understanding the various ways in which a logical system can be equipped with an algebraic semantics and developing methods and results to deal with broad classes of those systems. The state-of-the-art of MFL is perfectly shown in the Handbook of Mathematical Fuzzy Logic (2011), where fuzzy logics are constructed as weakly implicational (protoalgebraic) logics. It is obvious that current development of MFL is determined by classical logicist tradition (first calculus and second reasoning).

According to Novak (Novak et al., 1999), the MFL has to be naturally incorporated into the broad fuzzy logic. It is not the case for today. In our opinion, we observe the growing divergence between Zadeh's concept of fuzzy logic and the realm of MFL. Here the contradictions between mathematical and engineering approaches are crucial. There exists a gap between logicist tradition of MFL and psychologist tradition of Zadeh's logic, for example, between a very abstract representation of MFL and the need in useful comprehensive applied fuzzy logics, the highly axiomatized character of MFL and non-axiomatic nature of human cognition, and so on. For the sake of further development, we have to solve the problem of bridging the gap between *purely mathematical* and *engineering approaches* to fuzzy logics.

First of all, engineers have to study and use basic constructions of MFL and logicians – be interested at their applications. Here the problem «how to teach MFL for future engineers?» is of special concern (let us remember the brilliant manual of fuzzy set theory by Arnold Kaufmann «Introduction à la théorie des sous-ensembles flous à l'usage des ingénieurs» (Kaufmann, 1975).

The problems of *synthesizing multi-valued and fuzzy logical semantics* and *pragmatics* for practical use by applying the approaches of *Universal Logic***,** *Logical Pragmatics, Non-Standard Scales* and *Neutralities* are faced in this paper. Solving these problems supposes the presentation of *universal logic tools*, and discussion on *formalized approaches* to developing *pragmatics*, as well as the consideration of *useful visualizations* of logical scales, logical spaces and logical operations underlying natural pragmatics. Below we will move from fuzzy logical matrices enabling a unified representation of different many-valued and fuzzy logics to the study of its basic components – truth scales.

The main text of the paper is divided into 4 sections. Primarily, in Section 2 we select generic concepts and tools of *Universal Logic* to construct various fuzzy logics. In subsection 2.1 basic principles, concepts, techniques and tools of *universal logic* are presented. Possible ways of extending conventional logical matrices are discussed in sub-