Decision and Stability Analysis in Fuzzy Economics

R. A. Aliev
Department of Computer-Aided Control Systems,
Azerbaijan State Oil Academy,
20 Azadlig Ave., AZ1010 Baku, Azerbaijan
E-mail: raliev@asoa.edu.az

I. Abstract

Tracing the development of economics since 19^{th} century up to present days makes it evident that at its core there is a sequence of rather precise and mathematically sophisticated axiomatic theories. At the same time, there is always a noticeable and persistent gap between the economic reality and economic predictions derived from these theories.

The main reason for why economic theories have not been successful so far in modelling economic reality is the fact that these theories are formulated in terms of hard sciences characterized by their nature of preciseness.

Real economical and socio-economical world problems are too complex to be translated into classical mathematical and bivalent logic languages, solved and interpreted in the language of the real world. The traditional modelling methodology (economics deals with models of economic reality) is perhaps not relevant or at least not powerful enough to satisfy the requirements of human reasoning and decision making activities. A new much more effective modelling language and theory are needed to capture the economic reality.

The sheer complexity of causation in the economic arena mandates a fuzzy approach. In this study we consider economic system as human centric and imperfect information based realistic multi-agent system with fuzzy-logic-based representation of the economic agents' behavior and with imprecise constraints. We will mainly consider two important problems of fuzzy economics: fuzzy decision principle and fuzzy stability of imperfect economic system.

The first approach in classical theory of choice was formulated axiomatically in the expected utility theory and subjective expected utility theory. These theories are the predominant economic theories for decision making under uncertainty. The widely used principle of maximization of expected utility has serious shortcomings. Experimental evidence has repeatedly shown that people violate the axioms of von Neumann-Morgenstern-Savage preferences in systematic ways. It resulted in initiation of numerous non-expected theories to take into account for this discrepancy, from weighted utility to rank-dependent utility. Utility function and non-additive measures used in non-expected utility models to model human preferences are mainly considered as real-valued functions despite of the fact that in reality, human preferences are imprecise and therefore are described in natural language (NL). From the other hand, what is not available is a methodology for dealing with second-order uncertainty, that is, uncertainty about uncertainty, or uncertainty square. In real-world problems, probabilities, gains, losses, dependencies, relations are described in natural language and, therefore, should be considered as linguistic variables. One of the principal objectives of the study is aimed at the development of computationally effective methods of decision-making under uncertainty square.

We present a characterization theorem on existence of fuzzy utility function representing weak order relation defined over the set of fuzzy alternatives. We also develop computationally effective methods of decision-making under uncertainty square when environment of fuzzy events, fuzzy states, fuzzy relations, fuzzy constraints are characterized by imprecise probabilities.

Suggested decision making methods are based on computing with words and use propagation and counterpropagation of generalized constraints. In turn, these problems reduce to variational problems, for solving of which we use novel neuro-fuzzy-evolutionary approach. The proposed theory of decision analysis with imprecise probabilities includes non-expected fuzzy-number-valued utility function represented by a fuzzy integral with a fuzzy-number-valued fuzzy measure generated by imprecise probabilities.

Stability is one of the fundamental concepts of complex economical dynamical systems. In classical terms, the notion of stability inherently associates with any dynamical system and

determines whether a system under consideration reaches equilibrium after being exposed to disturbances. Predominantly, this concept comes with a binary (Boolean) quantification (viz. we either encounter systems that are stable or not stable). While in some cases this definition is well justifiable, with the growing complexity and diversity of economical systems one could seriously question the Boolean nature of the definition and its underlying semantics. This becomes predominantly visible in human-oriented quantification of stability of economical system in which we commonly encounter statements quantifying stability through some linguistic terms such as e.g., *absolutely* unstable, *highly* unstable, ... and *absolutely* stable. To formulate human-oriented definitions we use of a so-called Precisiated Natural Language (PNL), which comes as a subset of natural language (NL) and one of whose functions is redefining existing concepts. Being prompted by the discrepancy of the definition of stability and the Boolean character of the concept itself, in this study, we introduce and develop a Generalized Theory of Stability (GTS) for analysis of complex economical dynamical systems described by fuzzy differential equations (FDE). Different human-centric definitions of stability of dynamical economical systems are introduced. The introduced definitions offer an important ability to quantify the concept of stability using some continuous quantification (that is through the use of degrees of stability). In this manner we radically depart from the previous binary character of the definition. We establish some criteria concerning generalized stability for a wide class of continuous dynamical systems.

We also apply the obtained results to decision making on oil extraction at a potentially oil-bearing region, decision making on development of electronic company, group decision making in planning of the oil-refinery plants, the stability analysis of national economy and nonlinear manufacture dynamics.

II. Short Bio.

Rafik A. Aliev received the Ph.D. and Doctorate degrees from the Institute of Control Problems, Moscow, Russia, in 1967 and 1975, respectively. He is a Professor and the Head of the Department of Computer-Aided Control Systems, Azerbaijan State Oil Academy, Baku, Azerbaijan, and a Visiting Professor with the University of Siegen, Siegen, Germany and with Near East University, Nicosia, North Cyprus. He is also an invited speaker in Georgia State University, Atlanta, GA.

His research interests cover modern control theory, soft computing and multiagent distributed artificial intelligence, and computing with words. His current research is focused on generalized theory of stability, recurrent fuzzy neural networks, fuzzy type-2 systems, evolutionary computation, decision analysis with uncertainty square, and fuzzy economics.

Dr. Aliev is a regular Chairman of the International Conferences on Applications of Fuzzy Systems and Soft Computing and International Conferences on Soft Computing and Computing with Words. He is an Editor of the Journal of Advanced Computational Intelligence and Intelligent Informatics (Japan), a member of Editorial Boards of International Journal of Web-based Communities (The Netherlands), Iranian Journal of Fuzzy Systems (Iran), International Journal of Advances in Fuzzy Mathematics (Italy), and International Journal "Intelligent Automation and Soft Computing." He was awarded USSR State Prize in field of Science (1983) and USA Fulbright Award (1997).