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Human centricity and information granularity in the agenda of theories and applications of soft computing

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ABSTRACT

Soft computing is an interdisciplinary area that focuses on the design of intelligent systems to process uncertain, imprecise and incomplete information. It mainly builds on fuzzy sets theory, fuzzy logic, neural computing, optimization, evolutionary algorithms, and approximate reasoning et al. Information granularity is in general regarded as a crucial design asset, which helps establish a better rapport of the resulting granular model with the system under modeling. Human centricity is an inherent property of people's view on a system, a process, a machine or a model. Information granularity can be used to reflect people's level of uncertainty and this makes its pivotal role in soft computing. Indeed, the concept of information granularity facilitates the development of theory and application of soft computing immensely. A number of papers pertaining to some recent advances in theoretical development and practical application of information granularity in soft computing are highlighted in this special issue. The main objective of this study is to collect as many as possible researches on human centricity and information granularity in the agenda of theories and applications of soft computing, review the main idea of these literatures, compare the advantages and disadvantages of their methods and try to find the relationships and relevance of these theories and applications.

1. Introduction

The aim of this special issue is to showcase a small fraction of recent advances of information granularity in assist of development of soft computing. Information granularity can be viewed as an essential asset [3,4,30,31,37], which offers a tangible level of flexibility to a system (process). Soft computing paradigms [1,2], in general, aim to produce computing systems/machines that exhibit some useful properties, e.g. making inference with vague and/or ambiguous information, learning from noisy and/or incomplete data, adapting to changing environments, and reasoning with uncertainties. These properties are important for the systems/machines to be useful in assisting humans in our daily activities. It is by no mean exhaustive as this is a fast-moving area in which new techniques and applications related emerge almost every day. Since the first studies on information granulation proposed by Zadeh [36] in 1970s, there have been lots of researchers concentrating on its development. Some books are written to introduce and explain fundamental concepts on human-centric information processing [31,32,37–39]. In this paper, we analyze the literature from two aspects: theories and application of soft computing. The theories development mainly includes a principle of justifiable granularity, allocation of information granularity, granular models, granular neural networks, granular fuzzy models, granular prototypes, measures of granularity of partitions and so on. Many of these theories are applied in different fields, such as medicine, system modeling, system identification, decision making, fuzzy modeling, pattern recognition, formal concept analysis, Web application and food engineering. A summary of each paper is as follows.

2. Theory development

Within the field of soft computing, some researchers concentrate on the fundamental theories of information granularity. As we know, soft computing builds on fuzzy sets theory, fuzzy logic, neural computing, optimization, evolutionary algorithms, approximate reasoning et al. and is focused on the design of intelligent systems to process uncertain, imprecise and incomplete information. The granularity of information is an inherent manifestation of

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the diversity of results provided by sources of knowledge (information). This property provides an important aspect to deal with uncertain, imprecise and incomplete information. Thus the study of fundamental theory of information granularity becomes of great importance. Some representative papers are analyzed and a summary of each paper is as follows.

A principle of justifiable granularity is introduced in the first paper [5] which delivers a badly needed fundamental background by delivering a way of forming legitimate information granules. The term "justifiable" pertains to the construction of the information granule, which is formed in such a way that it is (a) highly legitimate (justified) in light of the experimental evidence, and (b) specific enough meaning it comes with a well-articulated semantics (meaning). The principle of justifiable granularity is concerned with formation of a meaningful representation of a collection of numeric values (real numbers). The design process associates with a well-defined optimization problem with the two requirements of experimental justification and specificity. A single information granule Ω is formed based on available experimental evidence, if Ω is a set (interval), then Ω (the interval $[a, b]$) is formed by specifying its lower and upper bounds, denoted here by "a" and "b", respectively; and med(D) means the median value. A series of experiments is provided as well as a number of constructs carried for various formalisms of information granules (intervals, fuzzy sets, rough sets, and shadowed sets) are discussed as well.

Another fundamental of the disciplines in granular computing is addressed in the second paper [6] by introducing an idea of granular models – generalizations of numeric models that are formed as a result of an optimal allocation (distribution) of information granularity. Here information granularity is regarded as a crucial design asset, which helps establish a better rapport of the resulting granular model with the system under modeling. Five basic information granularity distribution protocols are discussed which are (a) uniform allocation of information granularity, (b) uniform allocation of information granularity with asymmetric position of intervals around the numeric parameter, (c) non-uniform allocation of information granularity with symmetrically distributed intervals of information granules, (d) non-uniform allocation of information granularity with asymmetrically distributed intervals of information granules and (e) a random allocation of granularity. The design of granular fuzzy neural networks fully utilizes the optimization of allocation of information granularity. A number of illustrative examples are provided.

The principle of justifiable granularity and allocation of information granularity comprise the fundamental blocks of granular computing. Now let us look at other theory development.

The paper [8] is a theory study on the measure of information granularity (knowledge granularity). The authors have proven that these information-theoretic measures decrease monotonously as partition becomes coarser under complete information systems and their inverse relationships do not hold generally and present an additional condition under which the inverse relationships are valid. By generalizing Shannon's entropy to incomplete information systems, the relationship between the generalized Shannon's entropy (termed as rough information entropy) and knowledge granularity based on covering generalized rough sets is discussed. One information-theoretic measure is Shannon's entropy, conditional entropy, and another information-theoretic measure that is a good candidate for quantifying the degree of granularity of knowledge in complete information system is mutual information.

A concept of granular neural networks and their development is described in paper [11] through the use of allocation of information granularity. The proposed granular network is formed on the basis of a given (numeric) neural network whose structure is augmented by the formation of granular connections (being realized as intervals) spanned over the numeric ones.

Another type of granular neural network is developed in Ref. [23]. The architectures are formed as a direct result reconciliation of results produced by a collection of local neural networks constructed on a basis of individual data sets. The design exploits the concept of justifiable granularity which has been introduced in Ref. [29].

Compared to neural networks, fuzzy models provide a fuzzy aspect to build models which have been successfully developed in many studies. The concept of granular fuzzy models thus adopts information granularity to offer people some flexibilities. Please refer to [26]. Here the granular fuzzy model is built by some individual local fuzzy models and these models being considered as sources of knowledge, are engaged in some collective pursuits of a collaborative development to establish modeling outcomes of global character. Information granules are completed through the use of the principle of justifiable granularity.

In paper [12], a study to elaborate the essence of measuring a fuzzy-information granularity of a fuzzy granular structure is given. The authors develop an axiomatic constraint with a partial-order relation that is defined in terms of the size of each fuzzy-information granule from a fuzzy-binary granular structure. This work is inspired by the ways in which humans granulate information and reason with it. To reveal the essence of measuring a fuzzy information granularity, a partial-order relation with set-size character has first been introduced, and the relationship between the proposed partial-order relation and the other two partial-order relations have been also established. Some thermos and their proof are given in this paper.

A theory study enables FCMs to effectively deal with a double-layered temporal granularity is proposed in Ref. [13], extending the standard idea of B-time that characterizes the iterative nature of a cognitive inference engine and offering model checking techniques to test the cognitive and dynamic comportment of the framework being designed. Taking advantages of fuzzy logic and cognitive maps theories, FCMs enable system designers to model complex frameworks by defining degrees of causality between causal objects with linguistic granularity.

A concept of granular prototypes that generalizes the numeric representation of the clusters is proposed in paper [14] and, in this way, helps capture more details about the data structure. The design of granular prototypes is formulated as an optimization problem, which is guided by the coverage criterion, meaning that we maximize the number of data for which their granular realization includes the original data. The granularity of the prototypes themselves is treated in this paper as an important design asset; hence, its allocation to the individual prototypes is optimized so that the coverage criterion becomes maximized. This study reflects that information granularity inherently promotes a certain global and abstract view of data, and it is quite convincing to anticipate that the resulting representation is of granular character.

A class of measures of granularity of partitions is investigated in paper [16] as the measurement of granularity is one of the foundational issues in granular computing. This paper first establishes a measurement-theoretic basis for a study of granularity. Second, the authors introduce a new class of measures of granularity of partitions based on the expected granularity of blocks in a partition. Third, they show that many existing measures are instances of the proposed class. The results presented in this paper are closely related to an axiomatic framework where a set of axioms is given to guarantee the existence of a unique measure of granularity. The proposed class of granularity measures is in the form of mathematical expectation.

A linguistic model is built at the level of information granules in Ref. [33]. The algorithm utilizes an augmented version of the clustering technique (context-based clustering) that is centered around a notion of linguistic contexts – a collection of fuzzy sets or fuzzy

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