GRANULAR COMPUTING:
A NEW PARADIGM IN INFORMATION PROCESSING

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INTRODUCTION

Granular computing (GrC) has emerged as one of the fastest growing information processing paradigm in computational intelligence and human-centric systems. It has been gaining popularity in the past ten years. GrC is often loosely defined as an umbrella term to cover any theories, methodologies, techniques, and tools that make use of granules in complex problem solving. As a new paradigm for the problem solving, GrC may be viewed differently from philosophical, methodological and application perspectives. In this talk, I will give a brief introduction to granular computing and discuss its present developments and research directions.

HISTORICAL VIEW OF GRANULAR COMPUTING

The concept of granular computing was initially called information granularity or information granulation related to the research of fuzzy sets in Zadeh's early paper (Zadeh 1979). The term granular computing first appeared within literature in 1997 (Yao 2007).

Although the term granular computing is new, the basic notions and principles of GrC occur under various forms in many disciplines and fields (Yao 2004, Zadeh 1997). Similar views are shared by research in belief functions, artificial intelligence, cluster analysis, chunking, data compression, databases, decision trees, divide and conquer, fuzzy logic, interval computing, machine learning, structure programming, quantization, quotient space theory, and rough set theory.

GRANULES, GRANULATION AND GRANULAR RELATIONSHIPS

Granules, granulations and relationships are some of the key issues in the study of GrC (Yao 2005).

A granule can be defined as any subset, class, object, or cluster of a universe. These granules are composed of finer granules that are drawn together by distinguishability, similarity, and functionality (Zadeh 1997). A group of concepts or objects can be considered as a granule by their spatial neighborhood, closeness, and cohesion. Although granular computing is intended to deal with imprecision, uncertainty and partial truth, the granules may be of crisp or fuzzy format. A granule may have different formats and meanings when used in a particular model. For example, in a set-theoretic setting, such as rough sets and cluster analysis, a granule may be interpreted as a subset of a universal set, while in structured programming, a granule can be a program module (Yao 2004). Granules at the lowest level are composed of elements or basic particles of the particular model that is used. For instance, the finest granules are words in an article universe. They are formed with basic particles, i.e., letters. They may be considered as singleton granules in some special cases.

Granulation involves the process of construction and decomposition of granules (Yao 2005). It is an operation performed on granules. Construction involves the process of forming a larger and higher level granule with smaller and lower level granules that share similarity, indistinguishability, and functionality. Decomposition is the process of dividing a larger granule into smaller and lower level granules. The former is a bottom-up process. The latter is a top-down process. This definition is slightly different with the dictionary definitions of granulation, the act or process of forming something into granules, i.e. decomposition of granulation. Writing an article could be viewed as granulation. The lower level granules, i.e., worlds, are constructed into an article, a high-level granule. Granulation and computation are two important and related issues of granular computing research. Granulation deals with the construction, interpretation, and representation of granules. Computation deals with the computing and reasoning with granules and granular structures.

Relationships amongst granules may be classified into two types, interrelationship and intrarelationship. Granulation, regardless of direction, is dealing with relationships between granules. The relationship involved in construction granulation is considered as an interrelationship and the decomposition granulation as an intrarelationship. Interrelationship is the basis of grouping small objects together. Granular computing involves

structured human thinking. A high-level granule represents a more abstract concept and a low-level a more specific concept. The level of abstraction may be represented in terms of coarse and fine relationships.

SCHOOLS OF GRANULAR COMPUTING RESEARCH

One of the important developments of granular computing is the triarchic theory of granular computing (Yao 2008). Instead of simply defining what granular computing research is, one may understand the scope of granular computing from the philosophical, methodological and computational perspectives. The philosophical perspective concerns structured thinking. Granular computing combines analytical thinking for decomposing a whole into parts and synthetic thinking for integrating parts into a whole. It is important to consider the conscious effects in thinking with hierarchical structures when using granular computing. The methodological perspective concerns structured problem solving. The techniques for effective human problem-solving, such as systematic approaches to finding a solution, effective problem definition principles, and practical heuristics and strategies to check solutions to a problem, builds major foundations to granular computing. The computational perspective concerns structured information processing. Granular computing also focuses on the application of its theory to knowledge-intensive systems.

Rough sets and fuzzy sets play important roles in GrC development (Yao 2007). An important fuzzy aspect in granular computing is to view granular computing as human-centric intelligent systems. Human-centered information processing was initiated with the introduction of fuzzy sets. The insights have led to the development of the granular computing paradigm (Bargiela and Pedrycz 2008, Zadeh 1997). Shifting from machine-centered approaches to human-centered approaches is considered one of the trends in GrC research. For example, one may integrate different agents in which each pursues its own agenda, exploits its environment, develops its own problem solving strategy and establishes required communication strategies, to form a more effective human-centered information system (Bargiela and Pedrycz 2008).

Another school of thought is rough-granular computing. One may form granules with different criteria from a rough computing point of view (Skowron and Stepaniuk 2007). Granules are constructed in computations aiming at solving optimization tasks. General optimization criterion based on the minimal length principle may be used. In searching for optimal solutions, it is necessary to construct many compound granules using some specific operations, such as generalization,

specification or fusion (Skowron and Stepaniuk 2007). The dominance-based rough set approach is another representation of rough set-based GrC methodology. This approach extends the classical rough set approach by utilizing background knowledge about ordinal evaluations of objects and about monotonic relationships between these evaluations (Slowinski 2008).

Other important granular computing research areas include interval computing, topology, rough logic, quotient space, neural networks, fractal analysis, and quotient space theory (Yao 2009).

FUTURE OF GRANULAR COMPUTING

In order to broaden and deepen the study of granular computing, one may focus on its foundations and definitions. Important issues, such as the formalization and understanding of granules, granulation, and granular relationships of various granular computing techniques should be emphasized. Applying individual techniques for real applications are essential. Communicating with other disciplines and adopting non-traditional techniques to granular computing research will broaden, enhance, and solidify granular computing research.

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