Granular Computing: An Introduction Read Online

A level consists of entities called granules whose properties characterize and describe the subject matters of study, such as a real world problem, a theory, a design, a plan, a program, or an information processing system.

Granules are formed with respect to a particular degree of granularity or detail. Granules in a level are defined and formed within a particular context and are related to granules in other levels.

There are two types of information and knowledge encoded in a level. A granule captures a particular aspect, and collectively, all granules in the level provide a granulated view. The granularity of a level refers to the collective properties of granules in a level with respect to their sizes. The granularity is reflected by the sizes of all granules involved. Granules in different levels are linked by the order relations and operations on granules.

The order relation on granules can be extended to granulated views levels. A level is above another level if each granule in the former level is ordered before a granule in the latter level, and each granule in the latter level is ordered after a granule in the former level, under the order relation.

The ordering of levels can be described by the notion of hierarchy. The theory of hierarchy provides a multi-layered framework based on levels. Mathematically, a hierarchy may be viewed as a partially ordered set [1]. For the study of granular computing, the elements of the ordered set are interpreted as hierarchical levels or granulated views. The ordering of levels in a hierarchy is based on criteria that are related to the order relations on granules.

Depending on the context, a hierarchy may consist of levels of interpretation, levels of abstraction, levels of organization, levels of observation, and levels of detail. A hierarchy represents relationships between different granulated views, and explicitly shows the structure of granulation. A granule in a higher level can be decomposed into many granules in a lower level, and conversely many granules in a lower level can be combined into one granule in a higher level. A granule in a lower level may be a more detailed description of a granule in a higher level with added information.

In the other direction, a granule in a higher level is a coarse-grained description of a granule in a lower level by omitting irrelevant details. With the introduction of the three components, one can examine three types of structures for modeling their interactions.

They are the internal structure of a granule, the collective structure of the all granules i. Although a granule is normally considered as a whole instead of many sub-granules at a given level, its internal structure needs to be examined.

The internal structure of a granule provides a proper description, interpretation, and characterization of the granule. A granule may have a complex structure itself. For examples, the internal structure of a granule may be a hierarchy consisting of many levels. The internal structure is also useful in establishing linkage among granules in different levels. All granules in a level may collectively show a certain structure.

This is the internal structure of a granulated view. Granules in a level, although may be relatively independent, are somehow related to a certain degree. This stems from the fact that they together form a granulated view.
On the other hand, it is expected that in many situations the relationships between different granules are much weaker. The internal structure of a level is only meaningful if all the granules in the level are considered together.

A hierarchy represents the overall structure of all levels. In a hierarchy, both the internal structure of granule and the internal structure of granulated views are reflected, to some degree, by the order relations. In a hierarchy, not any two granulated views can be compared based on the order relation.

In the special case, the hierarchy is a tree. The three structures as a whole is referred to as the granular structure. One can establish more connections between three structures.

For example, granules in a higher level may have greater integrity and higher bond strength than those in a lower level. The structures need to be fully explored to establish a basis of granular computing. The three basic components of granular computing can be easily illustrated by a concrete model known as the partition model of granular computing [28], which is based on rough set theory [12, 13] and quotient space theory [34, 35].

A central notion of the partition model is equivalence relations. In rough set theory, an equivalence relation on a set of objects can be concretely defined in an information table based on their values on a finite set of attributes [12, 31]. Two objects are equivalent if they have exact the same values on a set of attributes. An equivalence relation divides a universal set into a family of pair-wise disjoint subsets, called the partition of the universe.

A granulation criterion deals with the semantic issues and addresses the question of why two objects are put into the same granule. It is domain specific and relies on the available knowledge.

A granulated view is the partition induced by an equivalence relation, and its structure is defined by the properties of the partition. Different equivalence relations can be ordered based on set inclusion, which leads to a hierarchy of partitions. In an information table, we only consider partitions generated by different subsets of attributes.

The overall hierarchical structure is therefore induced by subsets of attributes. The partition model may be viewed as a special case of cluster analysis. Following the same argument, one can easily find the correspondence between basic components of granular computing and its structures in cluster analysis. In general, given any concrete model of granular computing, we can easily find the corresponding components and structures.

The discussions of this section summarize and extend the preliminary results reported in [23, 28]. The list of issues discussed should not be viewed as a complete one. It can only be viewed as a set of representatives. Based on the principles of granular computing, these issues may also be studied at different levels of detail. Granular computing may be studied based on two related issues, i.e., the algorithmic and the semantic aspect. The former deals with the construction, interpretation, and representation of the three basic components, and the latter deals with the computing and reasoning with granules and granular structures. Studies of granular computing cover two perspectives, namely, the algorithmic and the semantic [23, 28]. Algorithmic study concerns the procedures for constructing granules and related computation, and the semantic study concerns the interpretation and physical meaningfulness of various algorithms.

Studies from both aspects are necessary and important. The results from semantic study may provide not only interpretations and justifications for a particular granular computing model, but also guidelines that prevent possible misuses of the model.

The results from algorithmic study may lead to efficient and effective granular computing methods and tools. Granulation involves the construction of the three basic components, granules, granulated views and hierarchies. Two basic operations are the top-down decomposition of large granules to smaller granules, or the bottom-up combination of smaller granules into larger granules.

The notion of granulation can be studied in many different contexts. The granulation of a problem, a theory, or a universe, particularly the semantics of granulation, is domain and application dependent. Nevertheless, one can still identify some domain independent issues. For clarity, some of these issues are discussed in the set-theoretic setting.

In the set-theoretic setting, a granule may be viewed as a subset of the universe, which may be either fuzzy or crisp. A family of granules containing every object in the universe is called a granulated view of the universe. A granulated view may consist of a family of either disjoint or overlapping granules. There are many granulated views of the same universe. Different views of the universe can be linked together, and a hierarchy of granulated views can be established. Granulation criteria.

A granulation criterion deals with the semantic issues and addresses the question of why two objects are put into the same granule. It is domain specific and relies on the available knowledge.

In many situations, objects are usually grouped together based on their relationships, such as indistinguishability, similarity, proximity, or functionality [32].

One needs to build models to provide both semantical and operational interpretations of these notions. They enable us to formally and precisely define various notions involved, and to systematically study the meanings and rationale of a granulation criterion. Granulation methods. From the algorithmic aspect, a granulation method addresses the problem of how to put two objects into the same granule.

It is necessary to develop algorithms for constructing granules and granulated views efficiently based on a granulation criterion. The next issue is the interpretation of the results of a granulation method, i.e., once constructed, it is necessary to describe, to name and to label granules using certain languages. One may assign a name to a granule such that an element in the granule is an instance of the named category.
One may also provide a formal description of objects in the same granule. By pooling the representations of granules, one can obtain the overall representation of a granulated view.

Qualitative and quantitative characterization. One can associate quantitative measures to the three components, granules, granulated views, and hierarchies. The measures should reflect and be consistent with the three structures, the internal structure of a granule, the collective structure of a granulated view, and the overall structure of a hierarchy. Computing and reasoning with granules explore the three types of structures. They can be similarly studied from both the semantic and algorithmic perspectives.

One needs to design and interpret various methods based on the interpretation of granules and relationships between granules, as well as to define and interpret operations of granular computing. The connections between different levels of granulations can be described by mappings. At each level of the hierarchy, a problem is represented with respect to the granularity of the level. The mapping links different representations of the same problem at different levels of detail.

In general, one can classify and study different types of granulations by focusing on the properties of the mappings. Granularity conversion. A basic task of granular computing is to change views with respect to different levels of granularity. As we move from one level of detail to another, we need to convert the representation of a problem accordingly.

A move to a more detailed view may reveal information that otherwise cannot be seen, and a move to a simpler view can improve the high level understanding by omitting irrelevant details of the problem. Operators can precisely define the conversion of granularity in different levels. They serve as the basic building blocks of granular computing. There are at least two types of operators that can be defined.

One type deals with the shift from a fine granularity to a coarse granularity. A characteristic of such an operator is that it will discard certain details, which makes distinct objects no longer differentiable. Depending on the context, many interpretations and definitions are available, such as abstraction, simplification, generalization, coarsening, zooming-out, and so on. The other type deals with the change from a coarse granularity to a fine granularity.

A characteristic of such an operator is that it will provide more details, so that a group of objects can be further classified. They can be defined and interpreted differently, such as articulation, specification, expanding, refining, zooming-in, and so on.

Property preservation. Granulation allows different representations of the same problem in different levels of detail. It is naturally expected that the same problem must be consistently represented. Granulation and its related computing methods are meaningful only if they preserve certain desired properties.

Such a property can be explored to improve the efficiency of problem solving by eliminating a more detailed study in a coarse-grained space. One may require that the structure of a solution in a coarse-grained space is similar to the solution in a fine-grained space.

Such a property is used in top-down problem solving techniques. More specifically, one starts with a sketched solution and successively refines it into a full solution. In the context of hierarchical planning, one may impose similar properties, such as upward solution property, downward solution property, monotonicity, etc.

As an illustration, we discuss the basic issues of granular computing based on the results from the rough set theory. Many applications of the rough set theory are based on the exploration of those issues. The granulation criterion is an equivalence relation on a set of objects, which is concretely defined in an information table based on the values of a set of attributes.

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**Granular Computing: An Introduction Reviews**

An equivalence relation divides a universal set into a family of pair-wise disjoint subsets, called the partition of the universe. A granule of a partition model is therefore an equivalence class defined by an equivalence relation. The internal structure of an equivalence class is captured by the same values of some attributes. A granulated view is the partition induced by an equivalence relation, and its structure is defined by the properties of the partition. Different equivalence relations can be ordered based on set inclusion, which leads to a hierarchy of partitions.

In an information table, we only consider partitions generated by different subsets of attributes. The overall hierarchal structure is therefore induced by subsets of attributes.

The partition model may be viewed as a special case of cluster analysis. Following the same argument, one can easily find the correspondence between basic components of granular computing and its structures in cluster analysis. In general, given any concrete model of granular computing, we can easily find the corresponding components and structures. The discussions of this section summarize and extend the preliminary results reported in [23, 28]. The list of issues discussed should not be viewed as a complete one.
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Granulation involves the construction of the three basic components, granules, granulated views and hierarchies. Two basic operations are the top-down decomposition of large granules to smaller granules, or the bottom-up combination of smaller granules into larger granules. The notion of granulation can be studied in many different contexts. The granulation of a problem, a theory, or a universe, particularly the semantics of granulation, is domain and application dependent.

Nevertheless, one can still identify some domain independent issues. For clarity, some of these issues are discussed in the set-theoretic setting. In the set-theoretic setting, a granule may be viewed as a subset of the universe, which may be either fuzzy or crisp. A family of granules containing every object in the universe is called a granulated view of the universe. A granulated view may consist of a family of either disjoint or overlapping granules.

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Many applications of the rough set theory are based on the exploration of those issues. The granulation criterion is an equivalence relation on a set of objects, which is concretely defined in an information table based on the values of a set of attributes. The granulation method is simply the collection of equivalent objects. One associates a formula to each equivalence class, which provides a formal description of the equivalence class.

One also associates quantitative measures to equivalence classes and the partition induced by the equivalence relation. Computing with granules. Many of the applications of rough set theory can be viewed as concrete examples of computing with granules.

With respect to an information table, mappings between different granulated views are in fact defined by different subsets of attributes. The conversion of granularity is achieved by adding or deleting attributes. The rough set approximation operators are granularity conversion operators. An important application of rough set theory is to learn classification rules [12, 21].

One of the important steps is to find a reduct of attributes, i.e., a set of attributes that preserves the classification power of the full attribute set. It can be easily modeled as searching the partition hierarchy defined by all subsets of attributes. Even in this simple search process, we have to deal with the issues discussed earlier. The mappings between levels support the exploration of the equivalence classes in the context of particular applications. The notions of granules, granulated views and hierarchies are sufficient for us to discuss the basic issues of granular computing.

The sizes of granules, the granular structures, and the operations on granules provide the essential ingredients for the development of a theory of granular computing. Aih, V. Bargiela, A. Foster, C. Hobbs, J.


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