Granular Soft Computing:

A Paradigm in Information Processing

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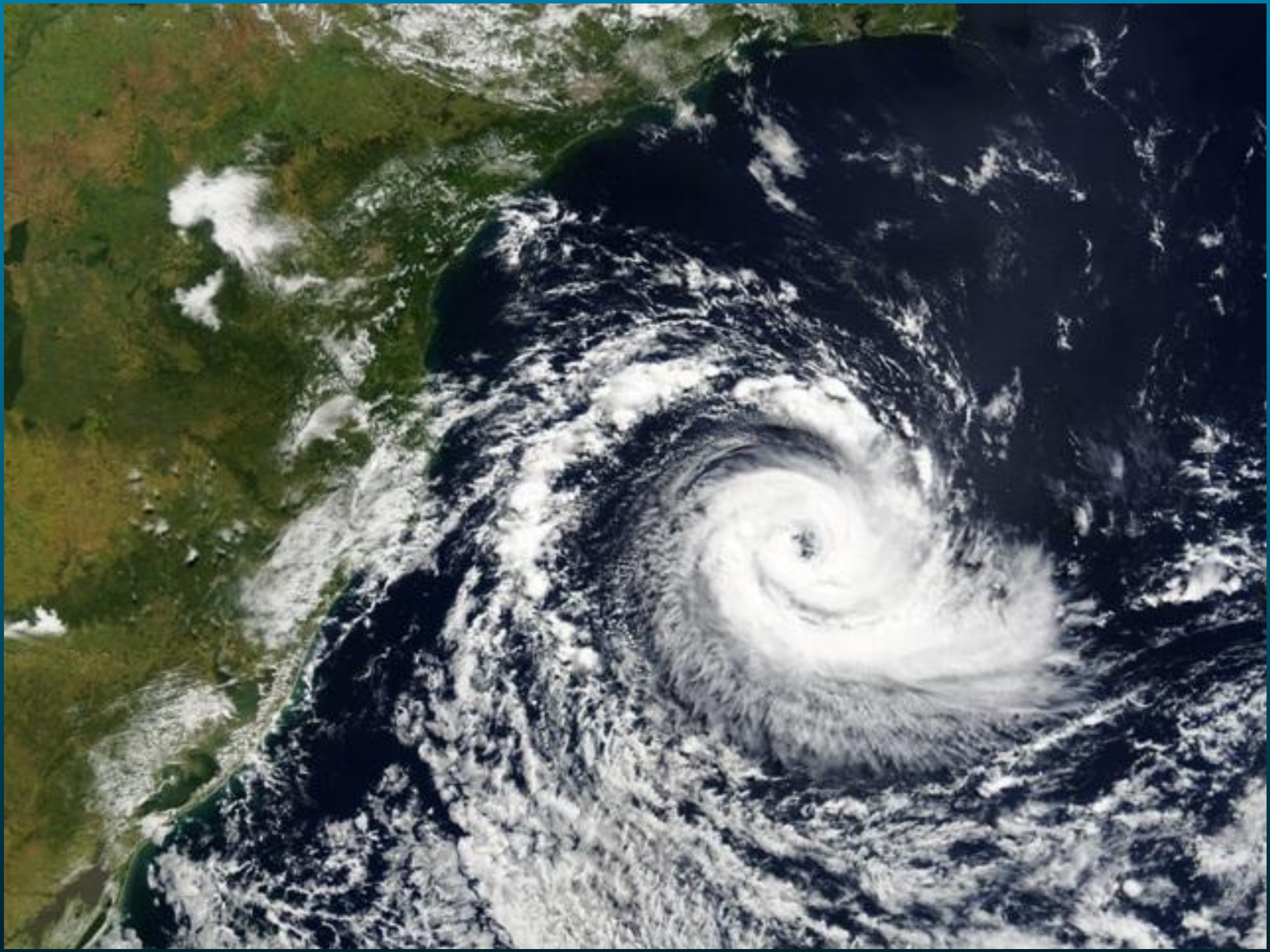
Granular computing (GrC): Outline

- Introduction
- Definitions and framework
- Background
- Philosophy
- Advantages
- Structure
- Basic issues
- Computing in GrC domain
- Concluding remarks

Granular Computing (examples)

1. For travelling one needs to know about the weather conditions like sunny, cloudy or rainy etc. instead of exact temperature,
2. While establishing a course view of the world-map, we deal with high-level information like continents, countries, and oceans. When more details are required, we move down to regions, provinces, states, seas, etc.
3. On a low-resolution satellite image, for example, one might notice interesting cloud patterns representing cyclones or other large-scale weather phenomena, while in a higher-resolution image, one misses these large-scale atmospheric phenomena but instead notices smaller-scale phenomena, such as the interesting pattern that is the streets, buildings, etc.

Granular Computing (examples)



Granular Computing (examples)

Technical writing:

One can easily observe multiple levels of processsing information in any technical writing:

High level of information

- title, abstract

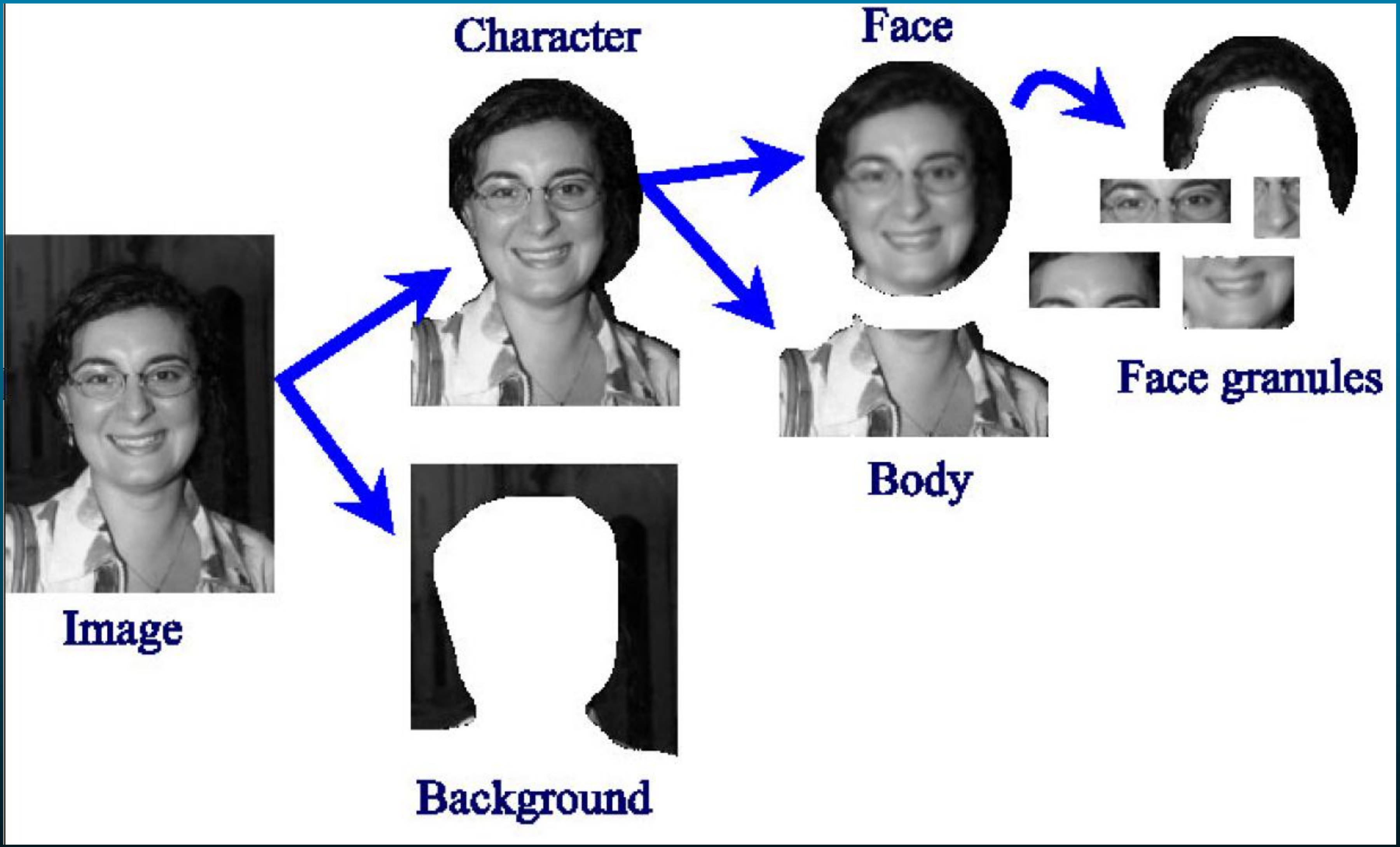
Middle levels of information

- chapter/section titles
- subsection titles
- subsubsection titles

Low level of information

- text

Granular Computing (examples)



Granular Computing in SUMMARY

- Similar interpretation also holds good OR generally true for all data:
- At different resolutions or granularities, different features and relationships emerge.
- The aim of granular computing is ultimately simply to try to take advantage of this fact in designing more-effective machine-learning and reasoning systems.

Motivation

- **Need for information abstraction (granule)**
- **Knowledge of abstraction level (granularity)**

DIVIDE AND CONQUER

Granular Computing (definition)

Granular Computing

- An umbrella term to cover any theories, methodologies, techniques, and tools that make use of granules in problem solving.
- Process of performing computation and operations on granules.

A Framework of GrC

Basic components:

- Granules
- Granulated views
- Hierarchies.

Basic structures:

- Internal structure of a granule
- Collective structure of granulated view (a family of granules)
- Overall structures of a family of granulated views

Information granularity (more examples)

- We granulate information over time by forming information granules – aggregates over-predefined time intervals. For instance, one computes a moving average with its confidence intervals.
- In any computer model we granulate memory resources by subscribing to the notion of pages of memory as its basic operational chunks (then we may consider various swapping techniques to facilitate an efficient access to individual data items).
- We granulate information available in the form of digital images - the individual pixels are arranged into larger entities and processed as such. This leads us to various issues of scene description and analysis.
- In describing any problem, we tend to shy away from numbers and start using aggregates and building rules (*if * then statements) that dwell on them.*
- We live in an inherently analog world. Computers, by tradition and technology, perform processing in a digital world. Digitization of this nature (that dwells on set theory - interval analysis) is an example of information granulation.
- All mechanisms of data compression are examples of information granulation that is carried in a certain sense.

A Framework of GrC with image

Granular Computing (GrC)

GrC

Interval analysis (mathematics)

Warmus, M., (1956), Calculus of approximations, *Bulletin de l'Academie Polonaise des Sciences,* 4(5), 253-259.

Fuzzy sets

Zadeh, L.A. (1965), Fuzzy sets, Information & Control, 8, 338-353.

Rough sets

Pawlak, Z. (1982), Rough sets, Int. J. of Computer and Information Sciences, 11, 341-356.

1956 **1965** **1982**

Granular Computing: diversity of formal environments

Set theory, interval analysis

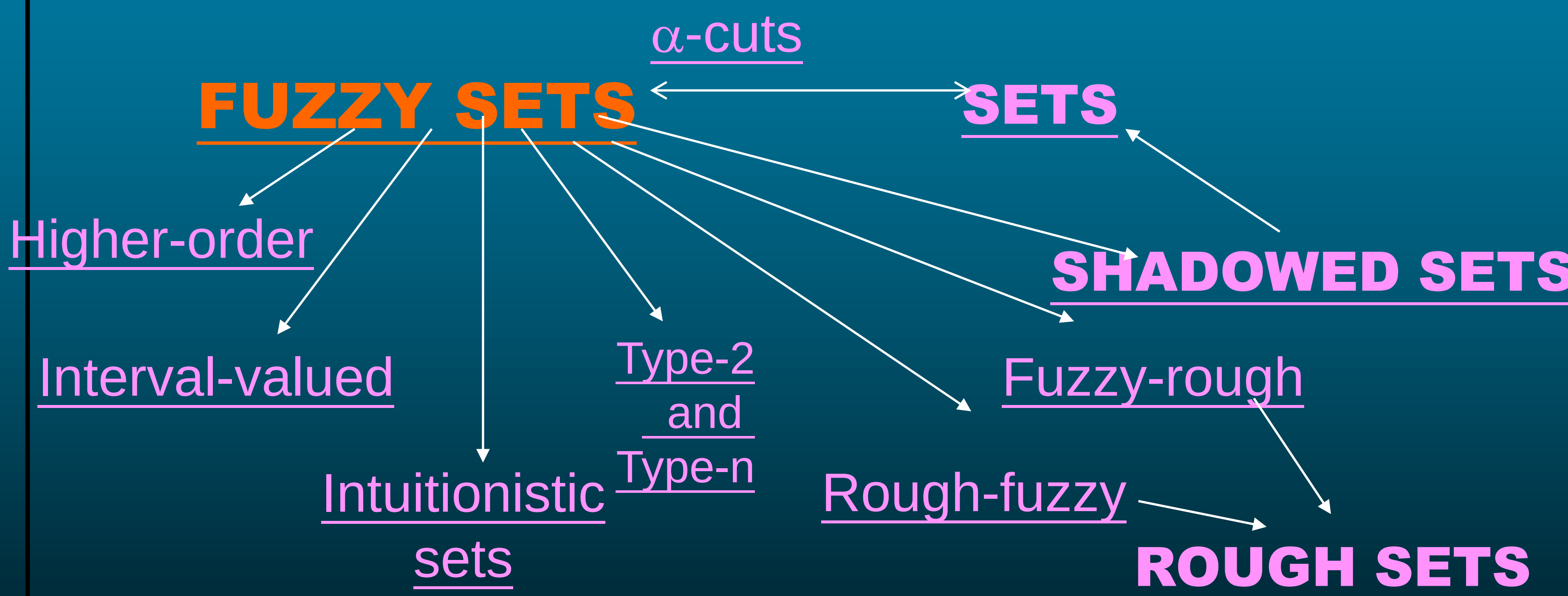
Probabilistic granules

Fuzzy sets

Rough sets

Shadowed sets

Granular Computing: Roadmap



A Framework of GrC

Historical notes

Main driving force of GrC

- Fuzzy set, and
- Rough set theories

However, the connections to other fields and the generality, flexibility, and potential of GrC have not been fully explored, such as

- Wavelet transform and others
- Neural networks

The Concept of GrC is not New…

The basic ideas and principles of GrC have appeared in many fields:

- Artificial intelligence,
- Cluster analysis, Interval computing,
- Quotient space theory,
- Belief functions,
- Machine learning, Data mining,
- Databases, and many more.

Human Problem Solving

GrC = Problem solving based on different levels of granularity (detail / abstraction).

Level of granularity is essential to human problem solving.

GrC

- attempts to capture the basic principles and methodologies used by human in problem solving.
- models human problem solving qualitatively and quantitatively.

Philosophy: Human Knowledge

- Human knowledge is normally organized in a multiple level of hierarchy.
- The lower (basic) level consists of directly perceivable concepts.
- The higher levels consists of more abstract concepts.
- Human perceives and represents real world at different levels of granularity.
- Human understands real world problems, and their solutions, at different levels of abstraction.
- Human can focus on the right level of granularity and change granularity easily

CAN WE COMPUTE THESE ?

Granules (visualization)

Granules are regarded to as the primitive notion of granular computing.

A granule may be interpreted as one of the numerous small particles forming a larger unit.

A granule may be considered as a localized view or a specific aspect of a large unit.

Granules (examples)

- In a set-theoretic model, a granule may be a subset of a universal set (rough sets, fuzzy sets, cluster analysis, etc.).
- In planning, a granule may be a sub-plan.
- In theorem proving, a granule may be a sub-theorem.

Granules (properties)

- Shape
- Size

It may be interpreted as the degree of abstraction, concreteness, or details.

In a set-theoretic setting, the cardinality may be used to define the size of a granule.

Granules (relationship)

Connections and relationships between granules can be modeled by binary relations (not necessarily).

They may be interpreted as dependency, closeness, overlapping, etc.

For example,

Based on the notion of size, one can define order relations, such as “greater than or equal to”, “more abstract than”, coarser than”, etc.

But, if we want to know what is greater/more

Is it .5 / .9 / or which interval ?

Granules (operations)

Operations can also be defined on granules.

One can combine many granules into one

OR

decompose a granule into many.

The operations must be consistent with the relationships between granules.

However,

One can consider operation (size / shape) as class-dependent, as an example. (Later discussed).

Advantages of GrC

- GrC leads to clarity and simplicity.
- GrC leads to multiple level understanding.
- GrC is more tolerant to uncertainty.
- GrC reduce costs by focusing on approximate solutions (solution at a higher level of granularity).

… … …

Granular Structures

Internal structure of a granule:

At a particular level, a granule is normally viewed as a whole.

The internal structure of a granule need to be examined. It provides a proper description, interpretation, and the characterization of a granule.

Such a structure is useful in granularity conversion.

Granular Structures

Overall structure of a hierarchy:

It reflects both the internal structures of granules, and collective structures of granules in a granulated view.

Two arbitrary granulated views may not be comparable.

Basic Issues of GrC

Two major tasks:

- **Granulation, and**
- **Computing and reasoning with granules.**

Basic Issues of GrC

Algorithmic vs. semantic studies:

Algorithmic studies focus on procedures for granulation and related computational methods.

Semantics studies focus on the interpretation and physical meaningfulness of various algorithms.

Granulation (criteria)

- Why two objects are put into the same granule.
- Meaningfulness of the internal structure of a granule.
- Meaningfulness of the collective structures of a family of granules.
- Meaningfulness of a hierarchy.

Criteria leads to granulation methods:

How to put objects together to form a granule?

Construction methods of granules, granulated views, and Hierarchies are important.

Granulation

Representation/description:

Interpretation of the results from a granulation method.

Find a suitable description of granules and granulated views.

Computing With Granules

Granularity conversion:

A basic task of computing with granules is to change granularity when moving between different granulated views.

A move to a detailed view reveals additional relevant information.

A move to a coarse-grained view omits some irrelevant details.

Computing With Granules

Property preservation:

Computing with granules is based on principles of property preservation.

A higher level must preserve the relevant properties of a lower level, but with less precision or accuracy.

Concluding Remarks

GrC is an interesting research area with great potential.

One needs to focus on different levels of study of GrC.

- The conceptual development.
- The formulation of various concrete models (at different levels).

The philosophy and general principles of GrC is of fundamental value to effective and efficient problem solving.

GrC may play an important role in the design and implementation of next generation information processing systems.

Thanks for the Patience