On Granular Knowledge Structures

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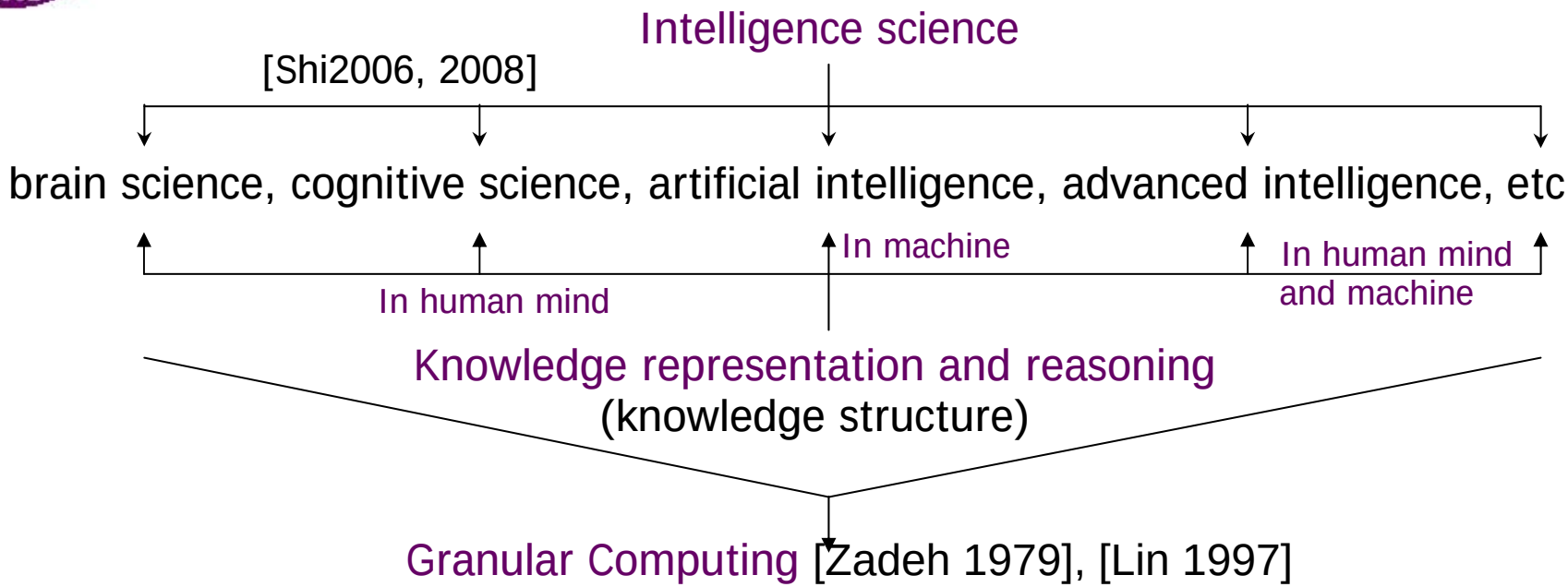
Important Ideas in This Talk



- Interpreting Knowledge representation from the viewpoint of Granular Computing by using granular knowledge structures.
- Operations for inducing different granular knowledge structures.
- Examples and concrete meanings for each granular knowledge structures.
- The use of granular knowledge structures.

Motivations from Perspectives

The importance of knowledge structure in the theory of knowledge:

" No small fragment of knowledge can have any meaning unless it is part of some larger structure that has connections to other parts of our network of knowledge."

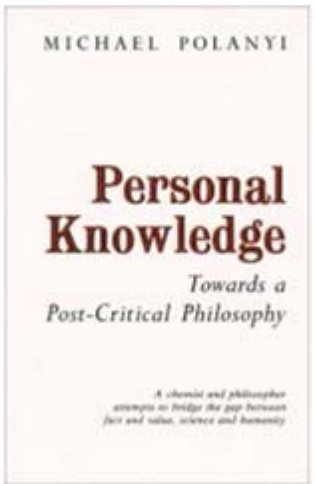
---- Marvin Minsky, The Emotion Machine, 2006.

Multi-view understanding of knowledge:

" If you 'understand' something in only one way, then you scarcely understand it at all-because when something goes wrong, you'll have no place to go. But if you represent something in several ways, then when one method fails, you can switch to another. That way, you can turn things around in your mind to see them from different points of view..."

---- Marvin Minsky, The Emotion Machine, 2006.

Motivations from Perspectives (cont.)



Multi-view, personalized understanding of knowledge:

" the scientist's personal participation in his knowledge, in both its discovery and its validation, is an indispensable part of science itself. Even in the exact sciences, `knowing' is an art, of which the skill of the knower, guided by his personal commitment and his passionate sense of increasing contact with reality, is a logically necessary part....The tendency to make knowledge impersonal in our culture has split fact from value, science from humanity."

---- Michael Polanyi, Personal Knowledge: Towards a Post-Critical Philosophy, 1974.

Motivations from Perspectives (cont.)

- The Semantic Network Approach [Collins and Quillian 1969]

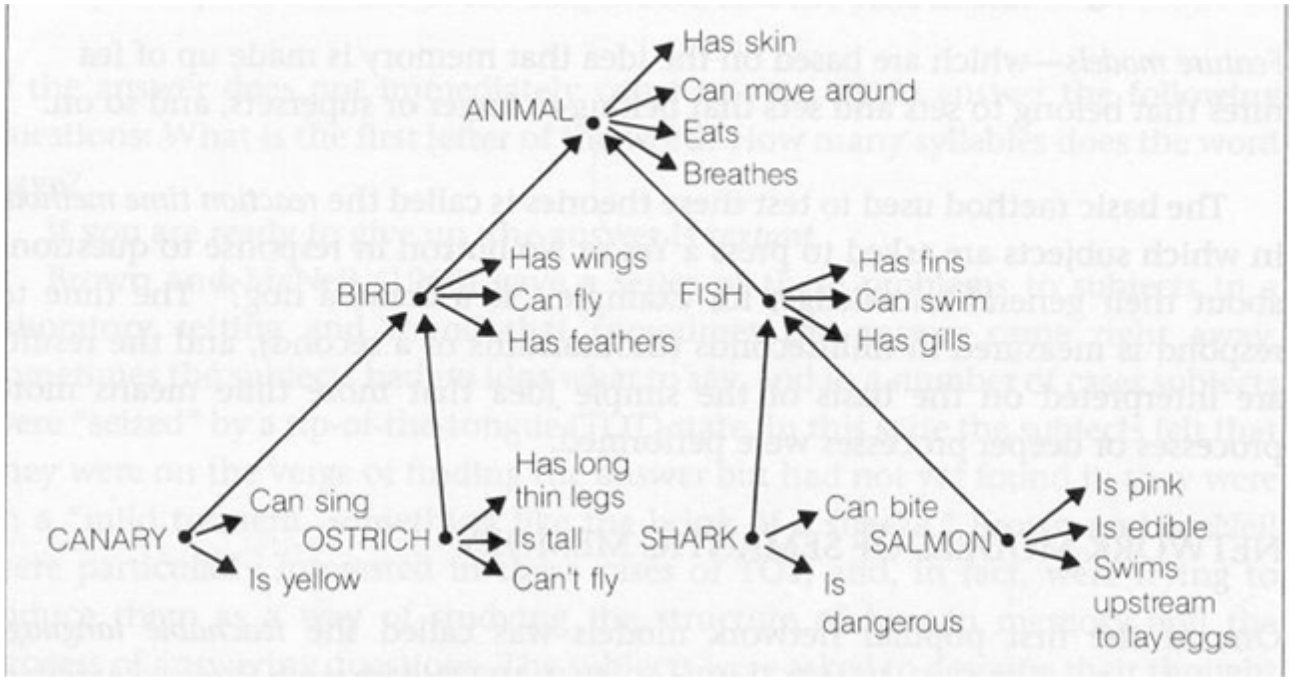


Figure 1. An Example of Semantic Network

- Contributions: Hierarchical organization of concepts, establishment of relations among concepts and features.
- Limitations: Do not overtly specify what the nature of those connections are [Segal2001]. Hard to inference.

[Collins1969] Collins, A.M. and Quillian, M.R. Retrieval time from semantic memory. Journal of Verbal Learning and Verbal Behaviour, 8, 240-247.

A diagram is (sometimes) worth than ten thousand words! [Larkin and Simon 1987]

Think about the way back : an easily understandable, visualized, structured, knowledge representation methodology.

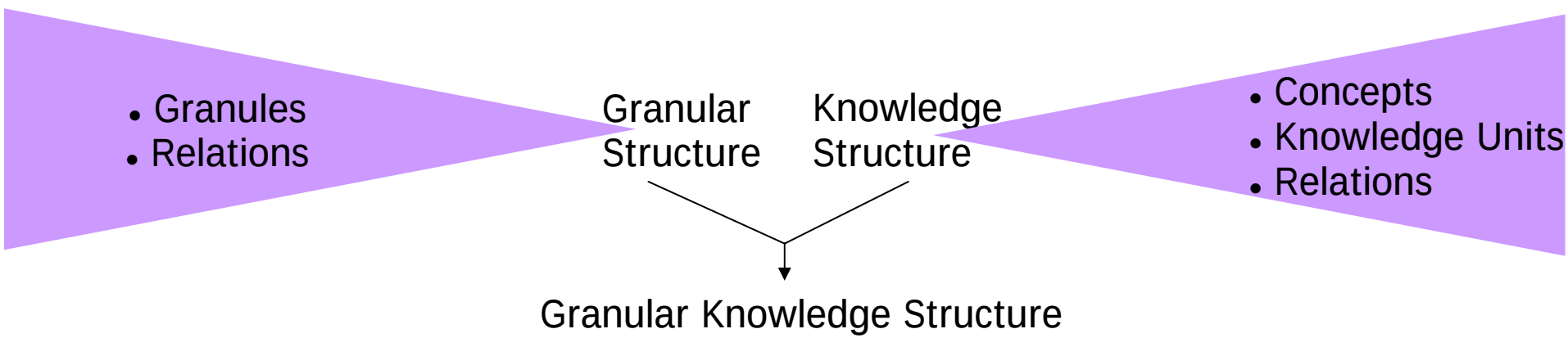
Motivations from Perspectives (cont.)

- Knowledge and its structure can be and should be presented in multiple levels and multiple views [Minsky2006, Yao2007a, Yao2007b].

- Multi-level representation presents knowledge in a hierarchical way, which satisfy people's needs in different level of granularities.

- Multi-view representation provides different understandings of the same knowledge source from different viewpoints, which may help people understand the knowledge source from different perspectives [Minsky2006, Yao2007b].

- Granular Computing can provide an interpretation for multi-level and multi-view understanding of knowledge through granular knowledge structures.



Motivations from Perspectives (cont.)

Granular Knowledge Structure provide understandings :

- From a spatial point of view : one can do spatial reasoning through visualized structures, the structures provide an easily acceptable way for users to understand knowledge. In fact, the visualized structure shows how those set theoretic and logical representations are organized [Homenda2001].
- From set theoretic and logic point of view : through representation of a granular knowledge structures based on concept granules and their relations.

"Science is organized knowledge. Wisdom is organized life."
by Immanuel Kant (German Philosopher) 1724-1804.

- Literature as a source of recorded knowledge.
- Knowledge structure : through reading, analyzing by human
  by machine through some analysis method
  [Goman1966, Goman1971, Yao2007a].
- Granular Knowledge Structure : an intelligent, knowledgeable way for organizing literatures, which can help people understand those literatures.

Defining Granular Knowledge Structures

- Information, concept and knowledge are built based upon former ones [landauer1998, Zhong2000, Zhong2004, Zhong2008].
- Concepts and relations among them can be used to represent knowledge [James1992, Sowa1984].

Definition 1: (Information Table) Formally, an information table can be represented as follows [Yao2004, Yao2007c]:

$$T = (U, At, V_a, R_a, I_a),$$

where $a \in At$, U represents a finite nonempty set of objects, At represents a finite nonempty set of attributes, V_a represents a nonempty set of values for $a \in At$, R_a represents a set of binary relations on V_a, $I_a : U \to V_a$ is an information function for $a \in At$ [Yao2004, Yao2007c].

Defining Granular Knowledge Structures (cont.)

Definition 2: (Atomic Formula) In the context of information table, objects can be grouped together as granules based on formulas. A formula (denoted as ϕ) can be an atomic formula or a combination of atomic formulas (Through logical operations defined in the language $\mathcal{L}$) [Yao2007c]. An atomic formula can be represented as [Yao2004]:

$$(a, r, v)$$

where $r \in Ra$, denotes a binary relation between an attribute ($a \in At$) and the corresponding attribute value ($v \in Va$). [Yao2004]. Possible binary relations are equality relation, equivalence relation, similarity relation, etc [Yao2002, Yao2004b].

Defining Granular Knowledge Structures (cont.)

Definition 3: (Concept Granule) A concept is considered to be the basic unit of human thoughts and the component of knowledge [Sowa84], and it can be conveniently represented by its intension and extension [Buchheit1993]. In the context of granular computing, a concept can be interpreted as a concept granule, and it can be formally defined as [Yao2002]:

$$(\phi, m(\phi))$$

where the formula ϕ , represents the intension of a concept granule, while $m(\phi)$ is the set of objects satisfying ϕ and represents the extension of a concept granule [Yao2002].

Defining Granular Knowledge Structures (cont.)

Definition 4: (Partial Ordered Relation) Since the extension of a concept granule corresponds to a set of elements satisfying its intension, a partial ordered relation on two concept granules can be defined based on set inclusion [Chen2008]:

$$(\phi, m(\phi)) \preceq (\varphi, m(\varphi)) \Leftrightarrow m(\phi) \subseteq m(\varphi)$$

Partial ordered relation can be used to describe relations among sub-concept granules and super-concept granules.

A concept granule $(\phi, m(\phi))$ is regarded to be a sub-concept granule of another concept granule $(\varphi, m(\varphi))$, or $(\varphi, m(\varphi))$ a super-concept granule of $(\phi, m(\phi))$ if $m(\phi) \subseteq m(\varphi)$ [Yao2004a].

Defining Granular Knowledge Structures (cont.)

Definition 5: (Granular Knowledge Structure) A granular knowledge structure can be defined as follows:

$$GKS = (\{(\phi_n, m(\phi_n)) \mid n \in I^+\}, \{\mathcal{R}_i \mid i \in I^+\}),$$

where $\{\mathcal{R}_i \mid i \in I^+\}$ denotes the set of binary relations among the set of concept granules $\{(\phi_n, m(\phi_n)) \mid n \in I^+\}$, and I^+ denotes the set of positive integers. Each two concept granules on one binary relation form an ordered pair. Let $i, j \in I^+$, the ordered concept granule pair can be represented as

$$< (\phi_i, m(\phi_i)), (\phi_j, m(\phi_j)) >$$

where $(\phi_i, m(\phi_i))$ and $(\phi_j, m(\phi_j))$ are two concept granules.

Defining Granular Knowledge Structures (cont.)

Table 1: A partial information table describing papers from proceedings of RSFDGrC 2005 and RSKT 2006 (from[Yao2007a]).

Paper	Initial Page	Theory	Application Domain	Domain
No.05	p1-94	Rough-Algebra (R-A)	–	Rough Set
No.12	p1-345	Rough-Fuzzy Hybridization (RFH)	–	Rough Set
No.25	p2-342	Logics and Reasoning (LR)	Medical Science (MS)	Rough Set
No.21	p2-263	Data Reduction (DR)	Image Processing (IP)	Rough Set
No.29	p2-383	Logics and Reasoning (LR)	Bioinformatics (BI)	Rough Set
No.97	p3-522	Formal Concept Analysis (FCA)	–	Rough Set
No.30	p2-430	Data Reduction (DR)	Bioinformatics (BI)	Rough Set

An example of a concept granule : $((Theory, =, FCA), m(Theory, =, FCA))$

An example of partial ordered relation :

$$((Theory, =, FCA), m(Theory, =, FCA)) \preceq$$
$$((Discipline, =, Rough\ Sets), m(Discipline, =, Rough\ Sets)).$$

Operations for Building Granular Knowledge Structures

- Different operations can induce different granular knowledge structures.
- Each granular knowledge structure implies an unique understanding of the knowledge source.

Union Operation : $GKS_1 : m(\phi) = m(\phi_1) \cup m(\phi_2) \cup \ldots \cup m(\phi_n)$

$GKS_2 : m(\phi) = m(\phi_{n+1}) \cup m(\phi_{n+2}) \cup \ldots \cup m(\phi_{n+p})$

$m(\phi) = m(\phi_1) \cup m(\phi_2) \cup \ldots \cup m(\phi_k)$, where $n, p, k \in I^+$.

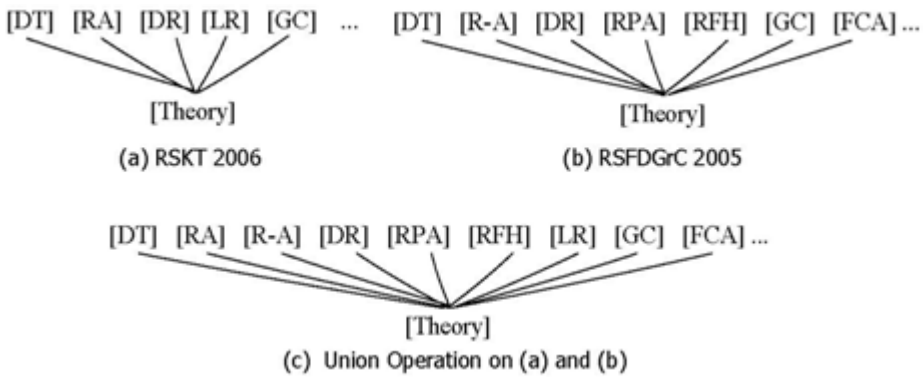


Figure 2. Union operation on GKS.

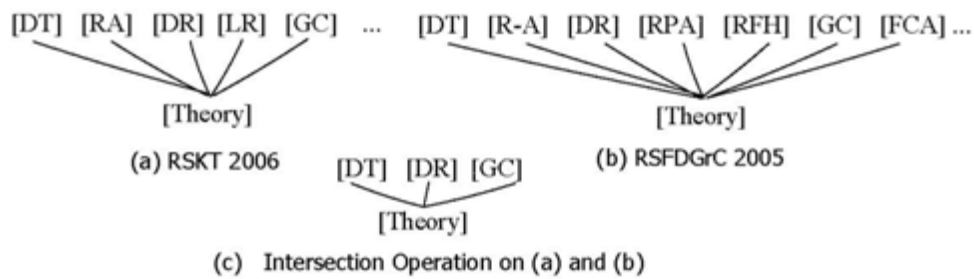


Figure 3. Intersection operation on GKS.

Intersection Operation : $\{m(\tau_k) \mid (m(\tau_k) \subset \{m(\phi_i)\}) \wedge (m(\tau_k) \subset \{m(\varphi_j)\})$ where $i, j, k \in I^+$. $m(\phi_i)$ and $m(\varphi_j)$ are extensions of all the sub-concept granules of $(\phi, m(\phi))$ and $(\varphi, m(\varphi))$.

Operations for Building Granular Knowledge Structures (cont.)

Difference Operation : $(\phi, m(\phi)) - (\varphi, m(\varphi))$

$$\{m(\tau_k) \mid (m(\tau_k) \subset \{m(\phi_i)\}) \wedge (m(\tau_k) \not\subset \{m(\varphi_j)\})$$

Product Operation : $m(\phi) = m(\phi_1) \cup m(\phi_2) \cup \ldots \cup m(\phi_n)$

$$m(\varphi) = m(\varphi_1) \cup m(\varphi_2) \cup \ldots \cup m(\varphi_p)$$

$$\{m(\phi_i \wedge \varphi_j) \mid i = 1, \ldots, n;\ j = 1, \ldots, p\}$$

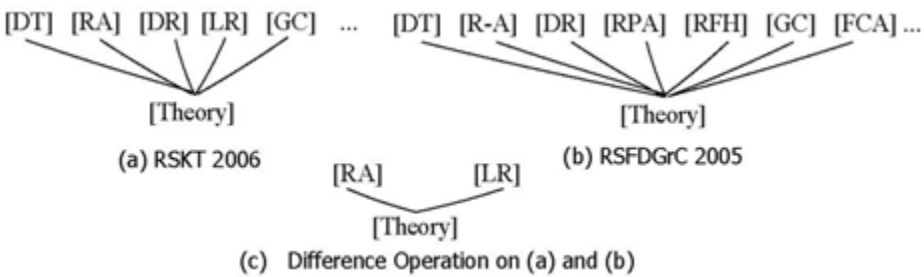


Figure 4. Difference operation on GKS.

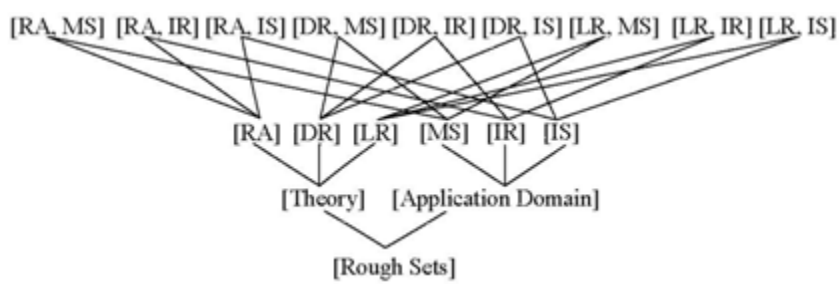


Figure 5. Product operation on GKS.

Operations for Building Granular Knowledge Structures (cont.)

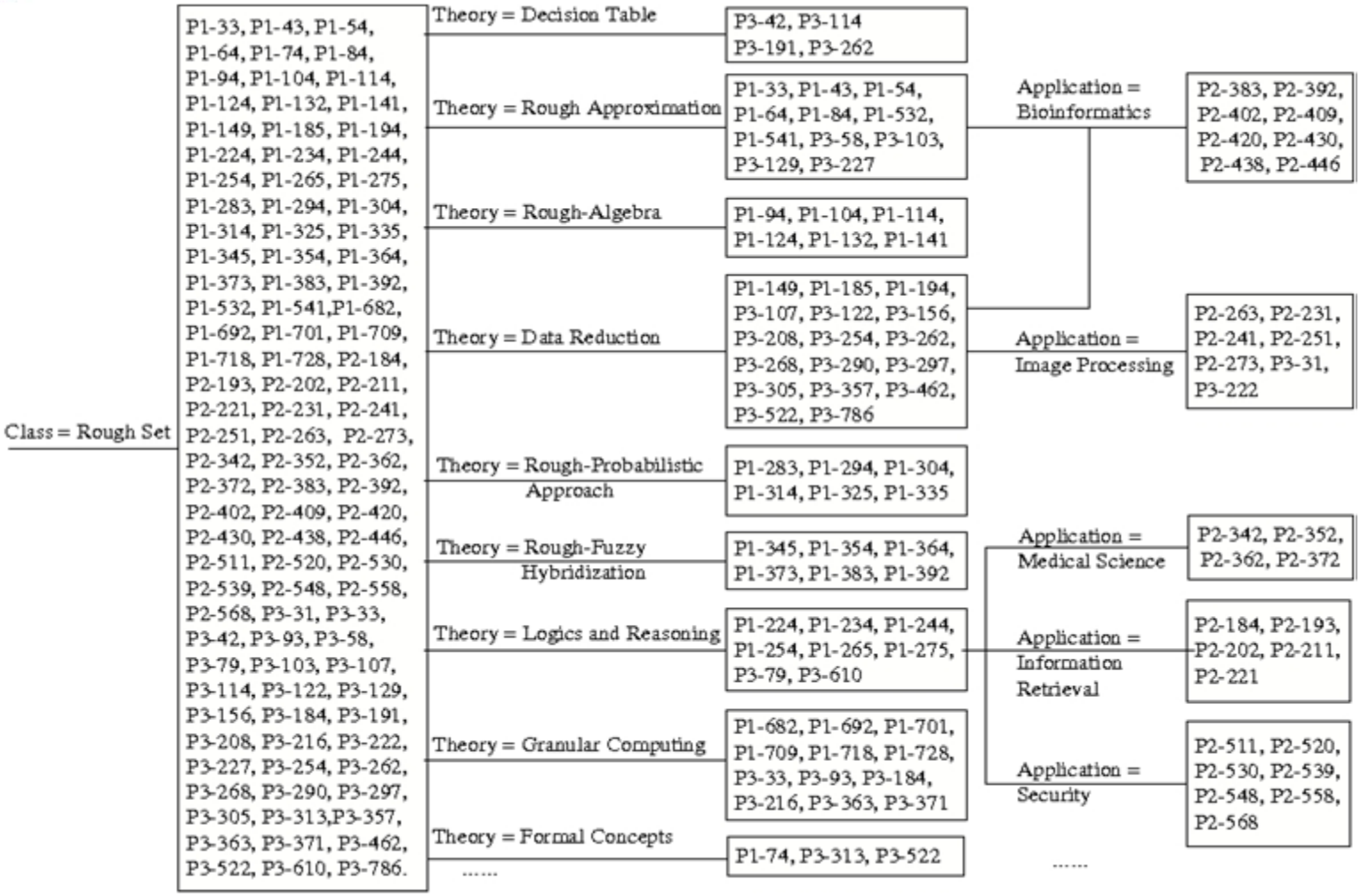


Figure 6. Implications by GKS based on Product operation : Prediction of Future Research.

Yiyu Yao, Yi Zeng, and Ning Zhong. Supporting Literature Exploration with Granular Knowledge Structures. In: Lecture Notes in Artificial Intelligence 4482, Springer, 2007, 182-189.

Using Granular Knowledge Structures

Level selection and switch

- Zoom-in Operation : $\omega((\phi_i, m(\phi_i))) = (\phi_{11}, m(\phi_{11})),\ldots(\phi_{np}, m(\phi_{np}))$
- Zoom-out Operation : $\omega^{-1}((\phi_{11}, m(\phi_{11})),\ldots(\phi_{np}, m(\phi_{np}))) = (\phi_i, m(\phi_i))$

$\{(\phi_i, m(\phi_i)) \mid i \in I^+\}$ is a set of concept granules in the same level of a granular knowledge structure, and $\{(\phi_{11}, m(\phi_{11})),\ldots(\phi_{np}, m(\phi_{np})) \mid n, p \in I^+\}$ is the set of sub-concept granules one level finer than $\{(\phi_i, m(\phi_i)) \mid i \in I^+\}$.

View selection and switch

- It is emphasized that people with different background knowledge and purpose will have different understanding when learning from the same knowledge source [Bransford2000].
- Even for the same granular knowledge structure, one can get different understanding when different viewpoint is selected [Bransford2000].

Tracking the exploration structure

- The structures which have been explored can be used to support understandings of the learning process.

Demo

- Multi-level and multi-view granular knowledge structures.
- Level selection and view selection.
- Tracking the exploration structure.

Our Publications on Granular knowledge Structures

- On Granular knowledge Structures, Yi Zeng, Ning Zhong. In: Proceedings of the first International Conference on Advanced Intelligence, Beijing, China, October 18-22, 2008 (The talk is based on this paper).

- Supporting Literature Exploration with Granular Knowledge Structures, Yiyu Yao, Yi Zeng, and Ning Zhong. In: Proceedings of the 11th International Conference on Rough Sets, Fuzzy Sets, Data Mining, and Granular Computing, Lecture Notes in Artificial Intelligence 4482, Springer, Toronto, Canada, May 14-16, 2007, 182-189.

- Granular Structure-Based Knowledge Retrieval [In Chinese], Yi Zeng, Yiyu Yao, Ning Zhong. Computer Science, Vol.35, No.3, 2008, 194-196, 224.
(This paper is recommended to the journal of "Computer Science" by Joint Conference of The Seventh National Conference of Rough Set and Soft Computing, the First National Conference of Granular Computing, the First National Conference of Web Intelligence, Taiyuan, Shanxi, China, August 19-23, 2007. [Excellent Student Paper Award])

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Thank you!

“ Granular knowledge structure ” is part of our work on “knowledge retrieval”. For more information, please visit:
http://www.iwici.org/~yizeng/publication.htm
or
http://sites.google.com/site/knowledgeretrieval/