# INTERACTIVE ROUGH-GRANULAR COMPUTING IN WISDOM TECHNOLOGY

Andrzej Skowron
Institute of Mathematics
The University of Warsaw
skowron@mimuw.edu.pl

Andrzej Jankowski
Institute of Computer Science
Warsaw University of Technology
Andrzej.AdgaM@gmail.com

Roman Swiniarski
Department of Computer Science, San Diego State University
and Institute of Computer Science
Polish Academy of Sciences
rswiniarski@mail.sdsu.edu

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for the invitation

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# AGENDA

## MOTIVATION

## RS & GRANULAR COMPUTING: APPROXIMATION OF (COMPLEX) VAGUE CONCEPTS

## INTERACTIVE COMPUTATIONS ON COMPLEX GRANULES

## TOWARD RISK MANAGEMENT IN COMPLEX SYSTEMS

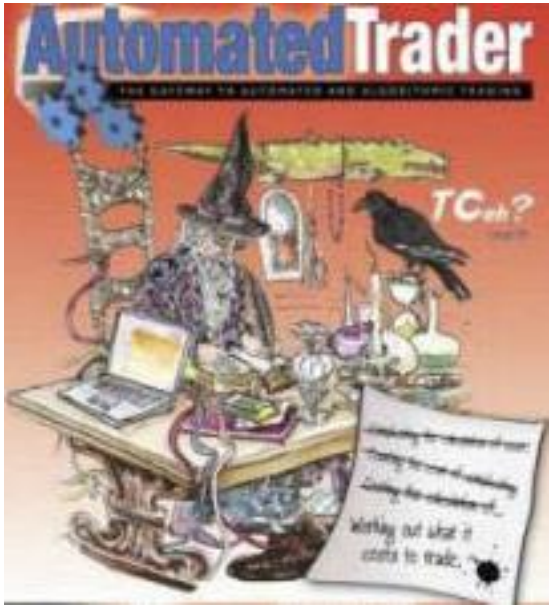
# APPROXIMATION OF COMPLEX VAGUE CONCEPTS AND REASONING ABOUT THEM

- Making progress in constructing of the high quality intelligent systems
- Examples of tasks:
  - approximation of complex vague concepts such as guards of actions or behavioral patterns

# OBSTACLE AVOIDANCE

UAV

ROBO-CUP




# REAL-LIFE PROJECTS

**UAV control of unmaned helicopter (Wallenberg Foundation, Linkoeping University)**

**Medical decision support (glaucoma attacs, respiratory failure,…)**

**Fraud detection (Bank of America)**

**Logistics (Ford GM)**

**Dialog Based Search Engine (UNCC, Excavio)**

**Algorithmic trading (Adgam)**

**Semantic Search (SYNAT) (NCBiR)**

**Firefighter Safty (NCBiR)**

…

# LESLIE VALIANT: TURING AWARD 2010

March 10, 2011:

Leslie Valiant, of Harvard University, has been named the winner of the 2010 Turing Award for his efforts to develop computational learning theory.

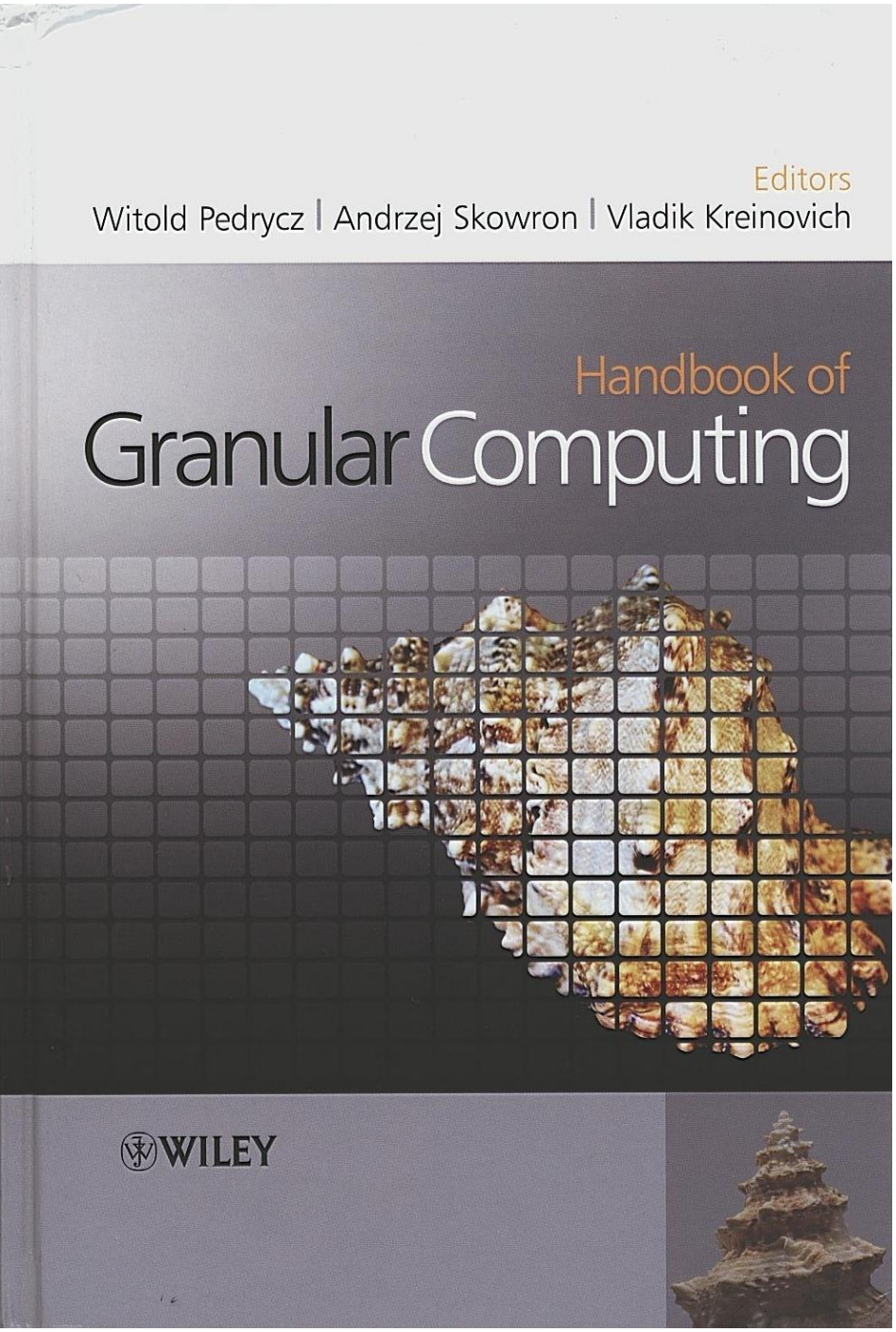
http://www.techeye.net/software/leslie-valiant-gets-turing-award#ixzz1HVBeZWQL

Current research of Professor Valiant

http://people.seas.harvard.edu/~valiant/researchinterests.htm

**A fundamental question for artificial intelligence is to characterize the computational building blocks that are necessary for cognition.**

**INFORMATION GRANULES**

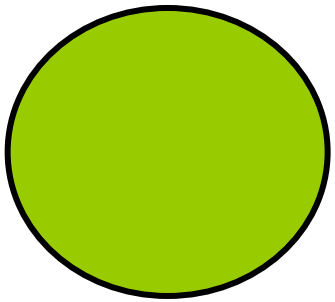


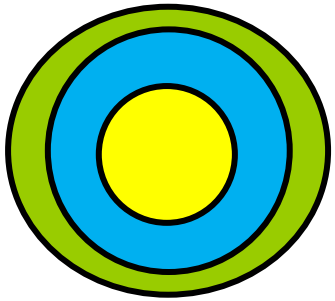

Plays a key role in implementation of the strategy of divide-and-conquer in human problem-solving – Lotfi Zadeh

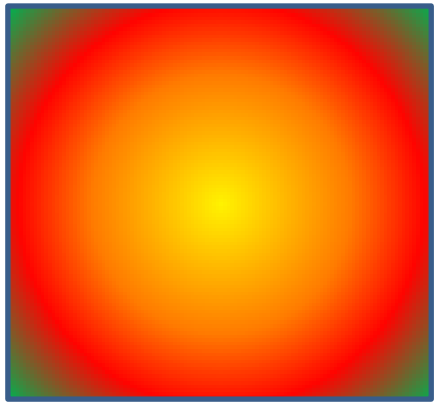
*Zadeh, L. A. (1979) Fuzzy sets and information granularity. In: Gupta, M., Ragade, R., Yager, R. (eds.), Advances in Fuzzy Set Theory and Applications, Amsterdam: North-Holland Publishing Co., 3-18*

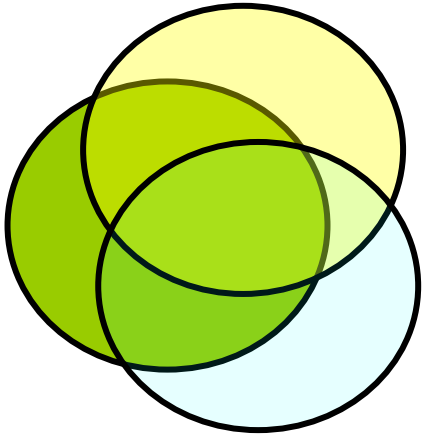
*Zadeh, L.A. (2001) A new direction in AI-toward a computational theory of perceptions. AI Magazine 22(1): 73-84*

# ELEMENTARY GRANULES + OPERATIONS ON GRANULES = CALCULI OF GRANULES









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# DEFINABLE GRANULES

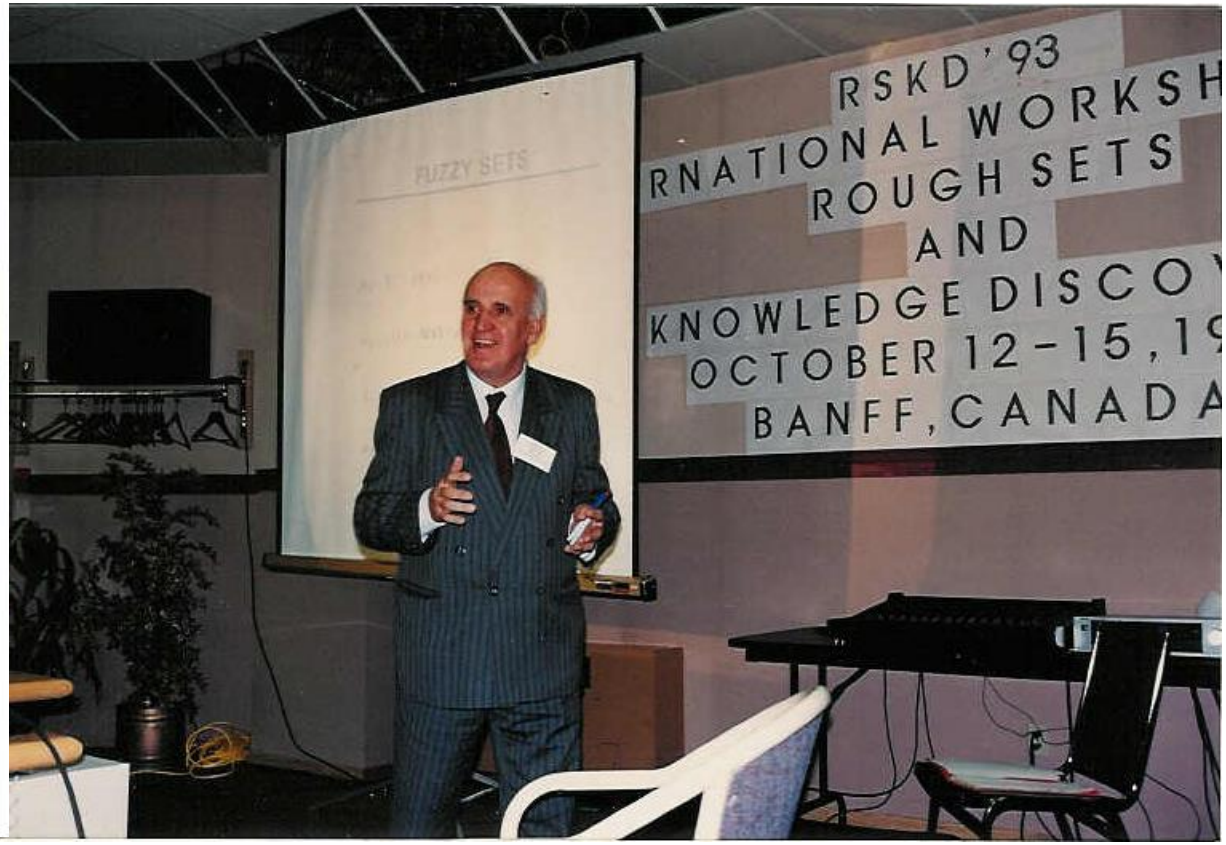
# ROUGH GRANULES

# APPROXIMATION OF GRANULES

# ROUGH SETS

*Pawlak, Z.: Rough sets. International Journal of Computer and Information Sciences 11 (1982)*

*Pawlak, Z.: Rough sets. Theoretical Aspects of Reasoning About Data. Kluwer (1991)*



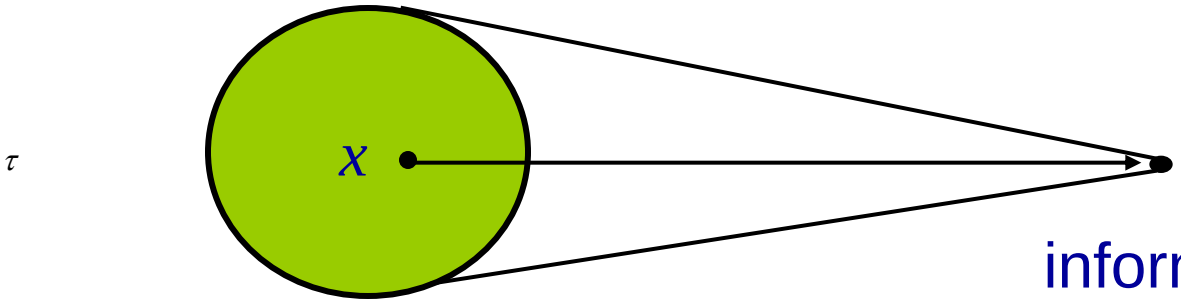

Now thousands of papers http://rsds.univ.rzeszow.pl/

# INDISCERNIBILITY RELATIONS

infromation system
(data table)

| | $a_1$ | $a_2$ | ... | $a_m$ | $d$ |
|---|---|---|---|---|---|
| $x_1$ | $v_1$ | $v_2$ | ... | $v_m$ | 1 |
| | ... | ... | ... | ... | ... |
| | | | | | |

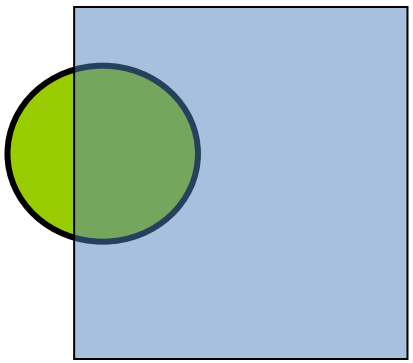
$N(x)=(Inf_A)^{-1}(u)$




$u=Inf_A(x)$

information signature of $\boldsymbol{x}$

neighborhood of $x$



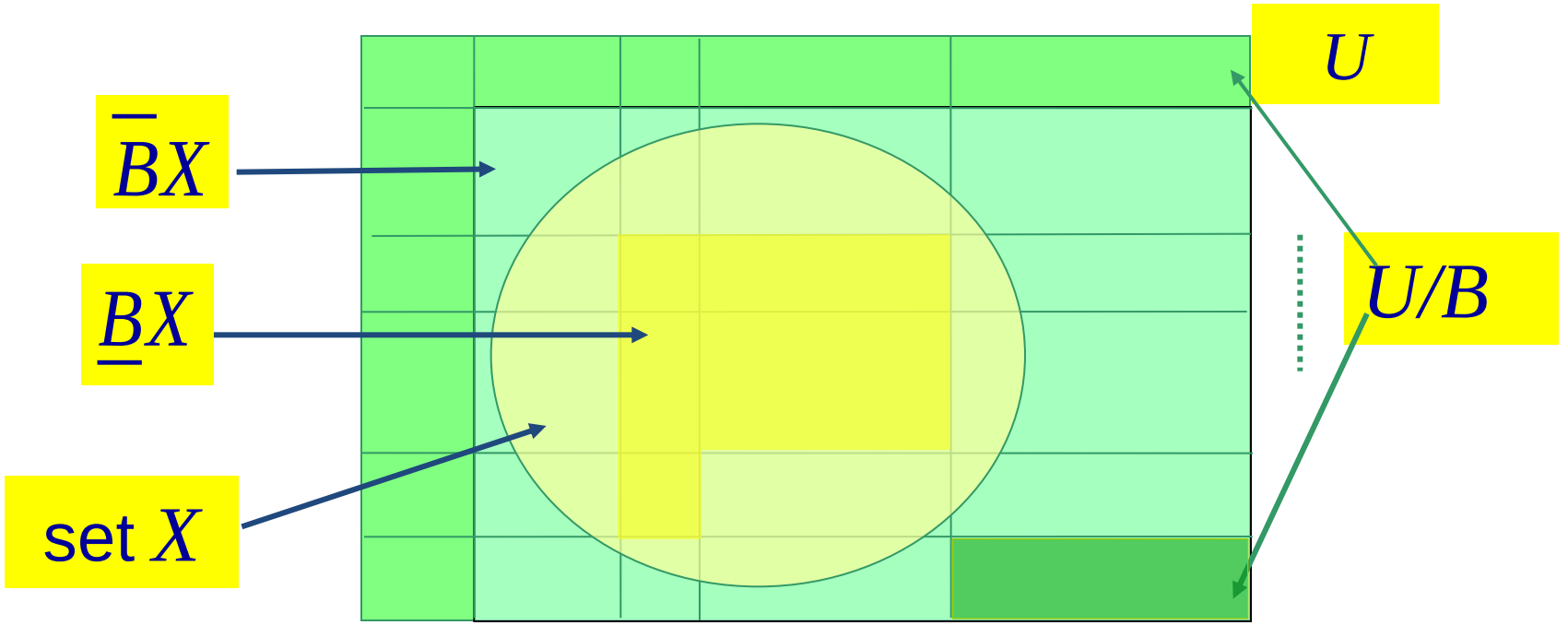
$xIND(A)y \;\; iff \;\; Inf_A(x) = Inf_A(y)$

$\tau$

tolerance or similarity

# LOWER AND UPPER APROXIMATION

$$\underline{B}X = \bigcup \{Y \in U / B : Y \subseteq X\}$$




$$\overline{B}X = \bigcup \{Y \in U / B : Y \cap X \neq 0\}$$

# ROUGH SETS
# AND
# VAGUE CONCEPTS

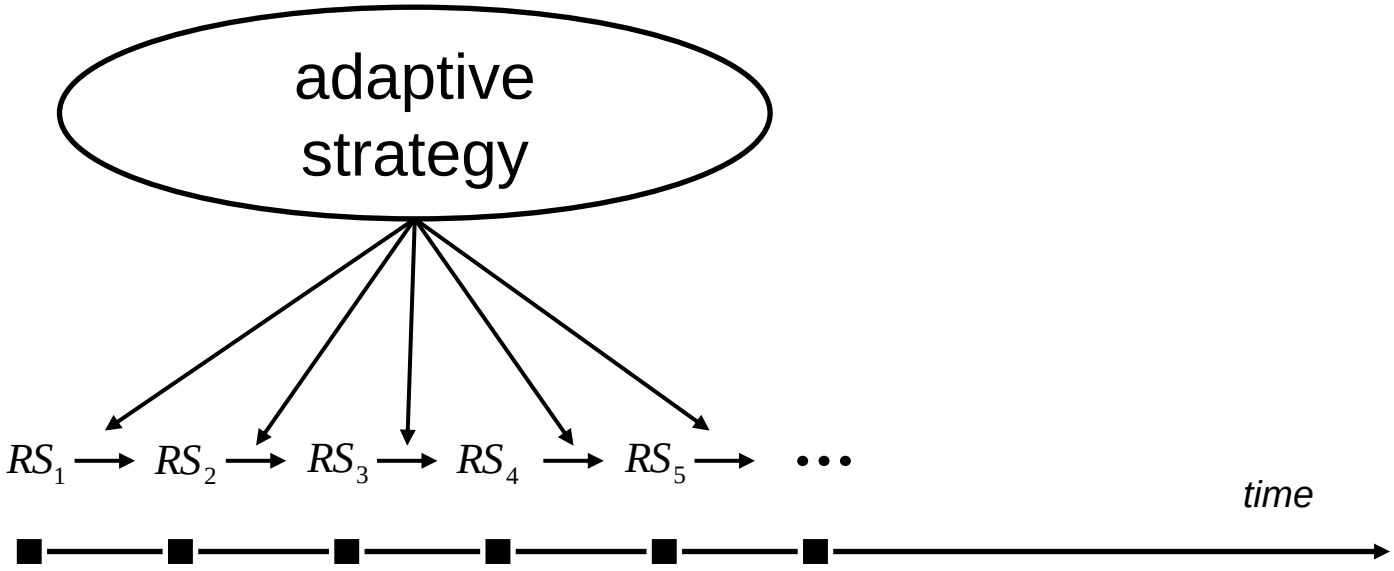
# VAGUENESS IN PHILOSOPHY

Discussion on vague (imprecise) concepts includes the following :

1. The presence of borderline cases.
2. Boundary regions of vague concepts are not crisp.
3. Vague concepts are susceptible to sorites paradoxes.

*Keefe, R. (2000) Theories of Vagueness. Cambridge Studies in Philosophy, Cambridge, UK)*

# ROUGH SETS AND VAGUE CONCEPTS
# ADAPTIVE ROUGH SETS




Boundary regions of vague concepts are not crisp
ADAPTIVE ROUGH SETS

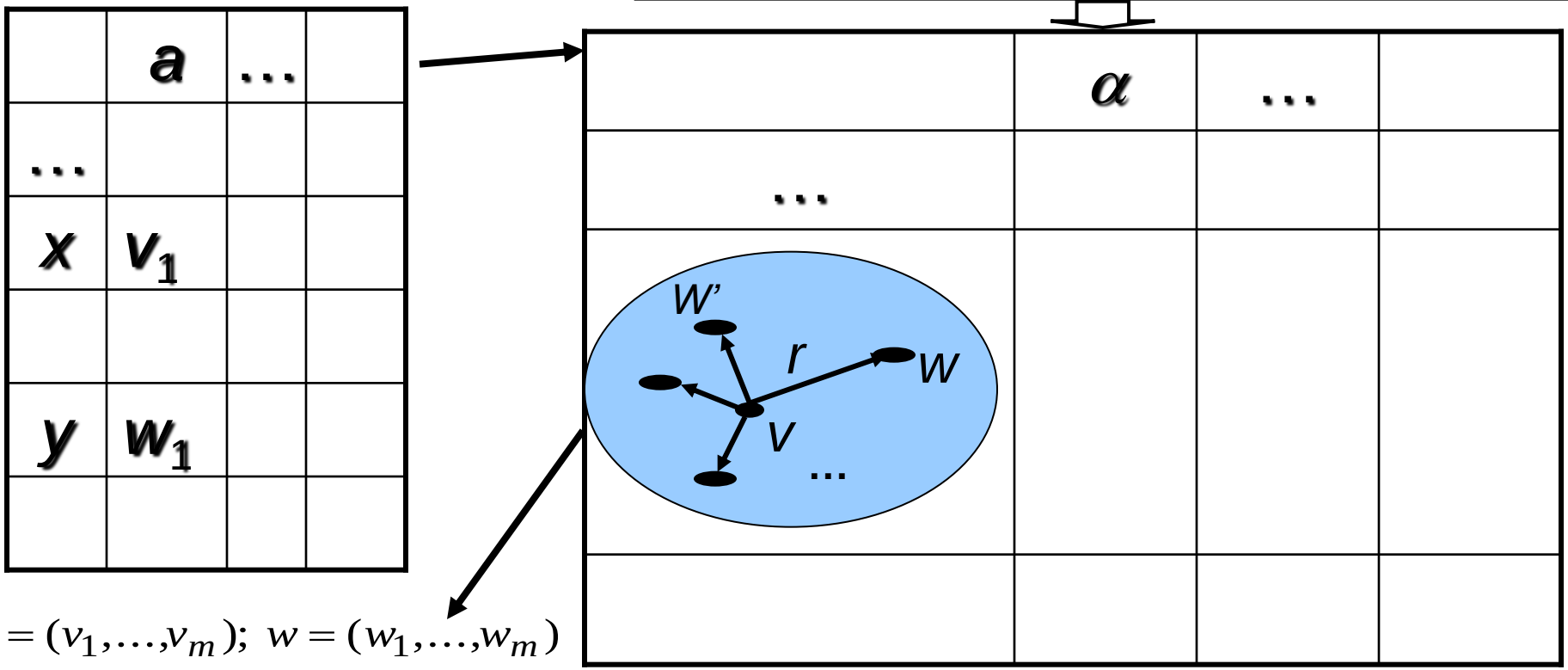
# STRUCTURAL OBJECTS

# CONTEXT INDUCING

# SEARCHING FOR RELEVANT FEATURES

# GENERALIZATIONS OF GRANULES: TOLERANCE GRANULES

invariants over tolerance classes; compare invariants in the Gibson approach




$v = (v_1,\ldots,v_m);\ w = (w_1,\ldots,w_m)$

$v\ r\ w\ iff\ \ v_i r_i w_i\ \ for\ i = 1,..m$

$r(v) = \{w : v\ r\ w\}$

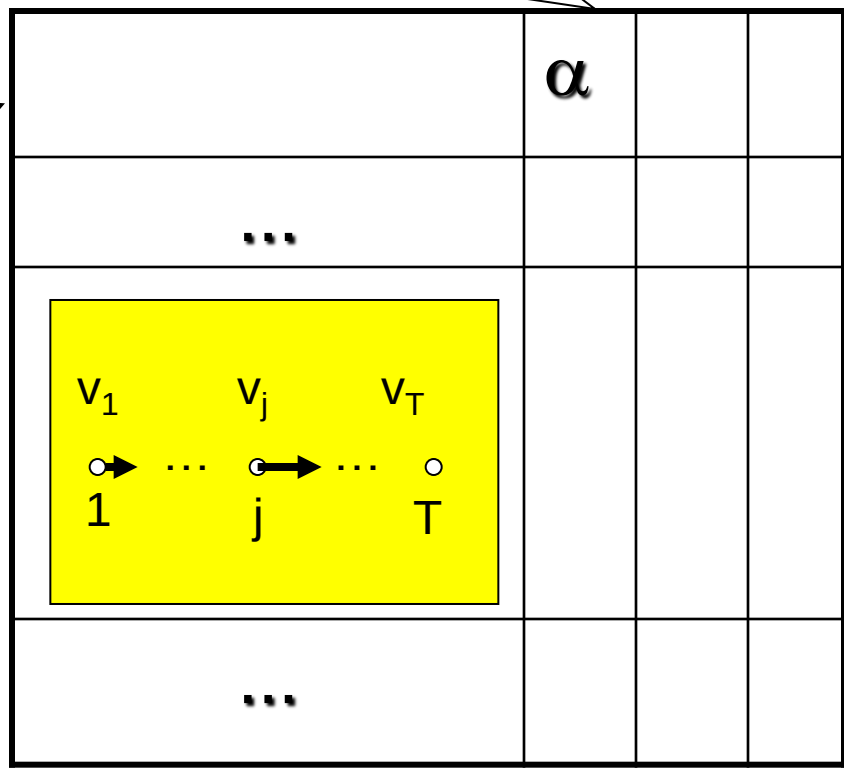
$\|r(v)\| = \cup\{\|w\| : w \in r(v)\}$

**GENERALIZATION from *v* to *r(v)***

# GRANULES REPRESENTING STRUCTURES OF OBJECTS

properties of time windows

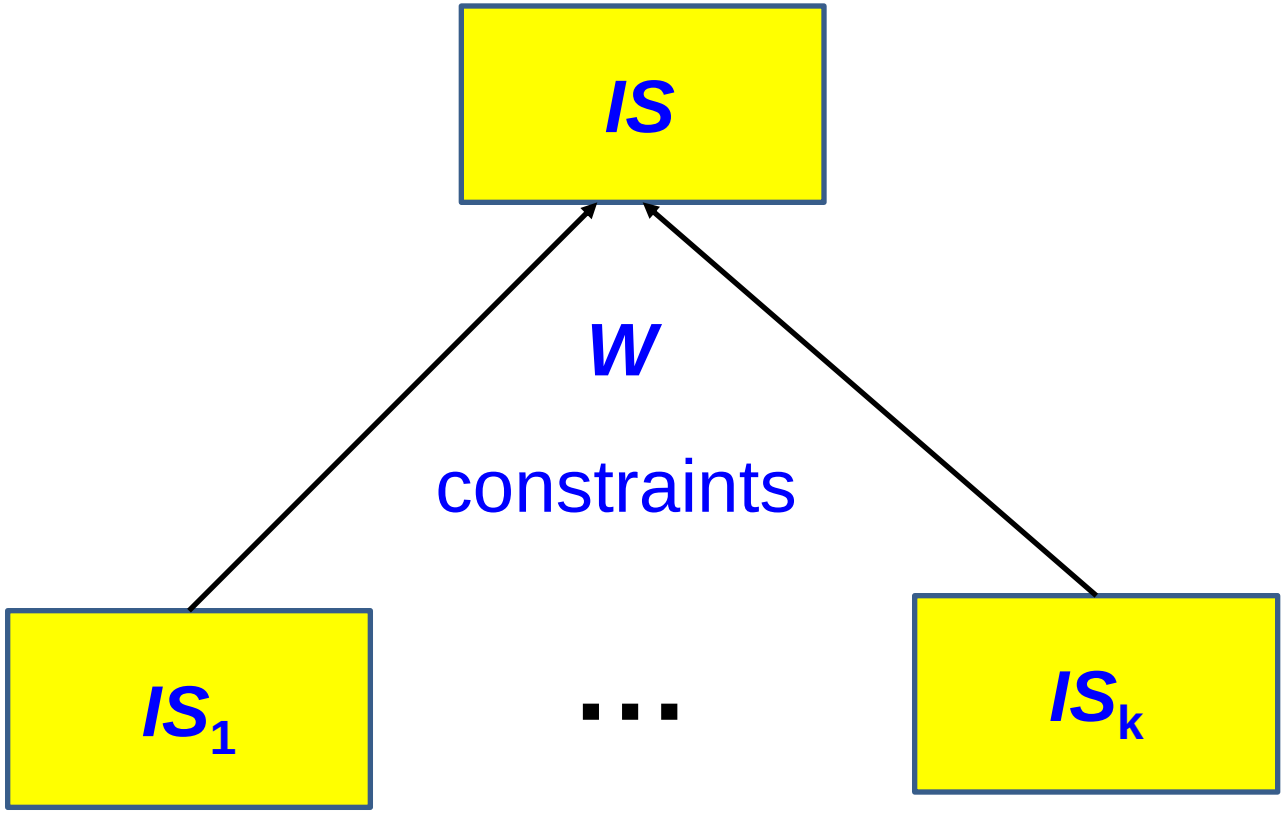
TIME WINDOWS




| | t | $t_T$ | $a_1$ | ... |
|---|---|---|---|---|
| ... | ... | ... | | |
| x | i | mod(i,T) | $V_{1,i}$ | ... |
| ... | ... | | | |

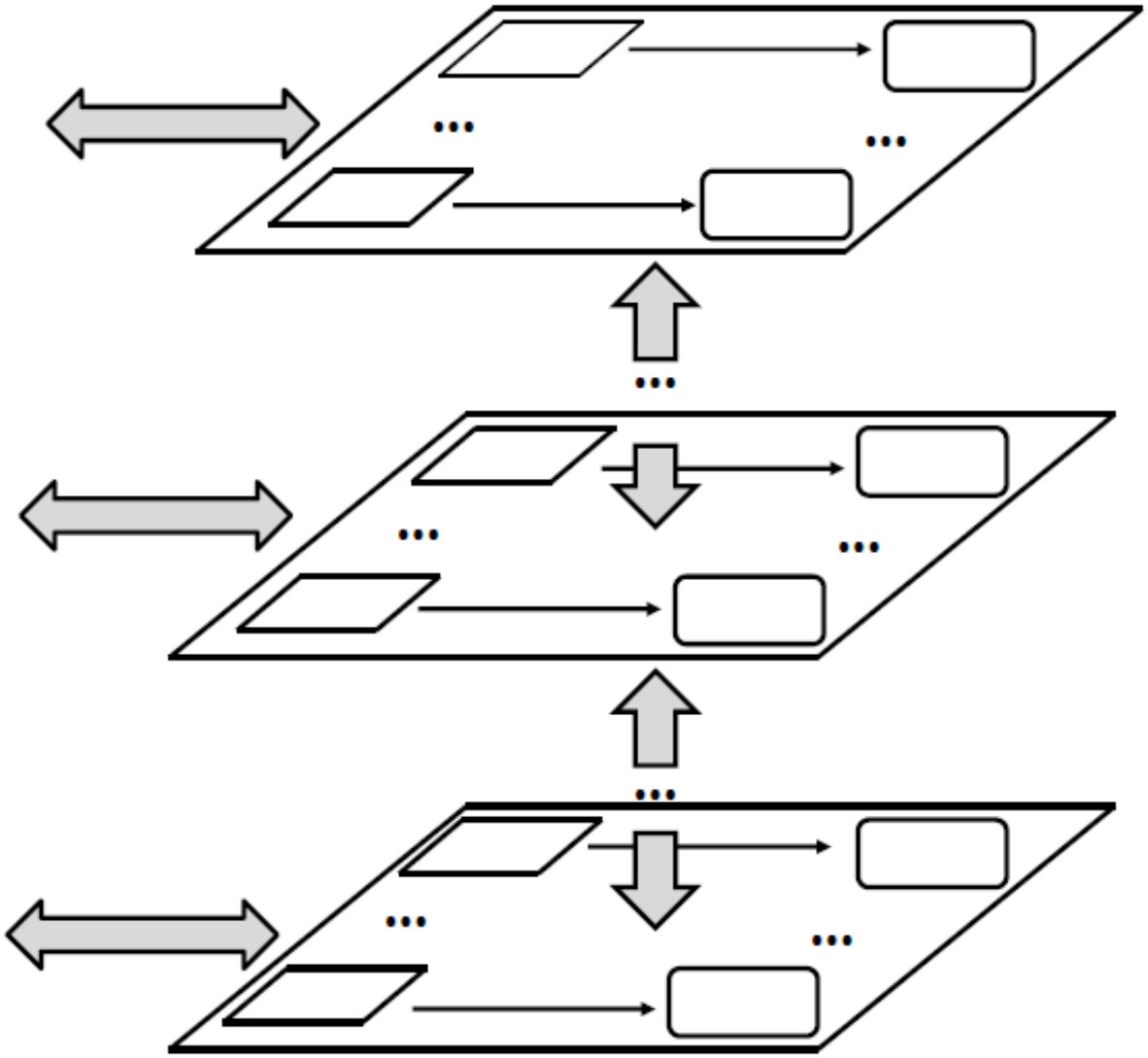
$V_i=(v_{1,i},\ldots,v_{m,i})$

# JOIN WITH CONSTRAINTS

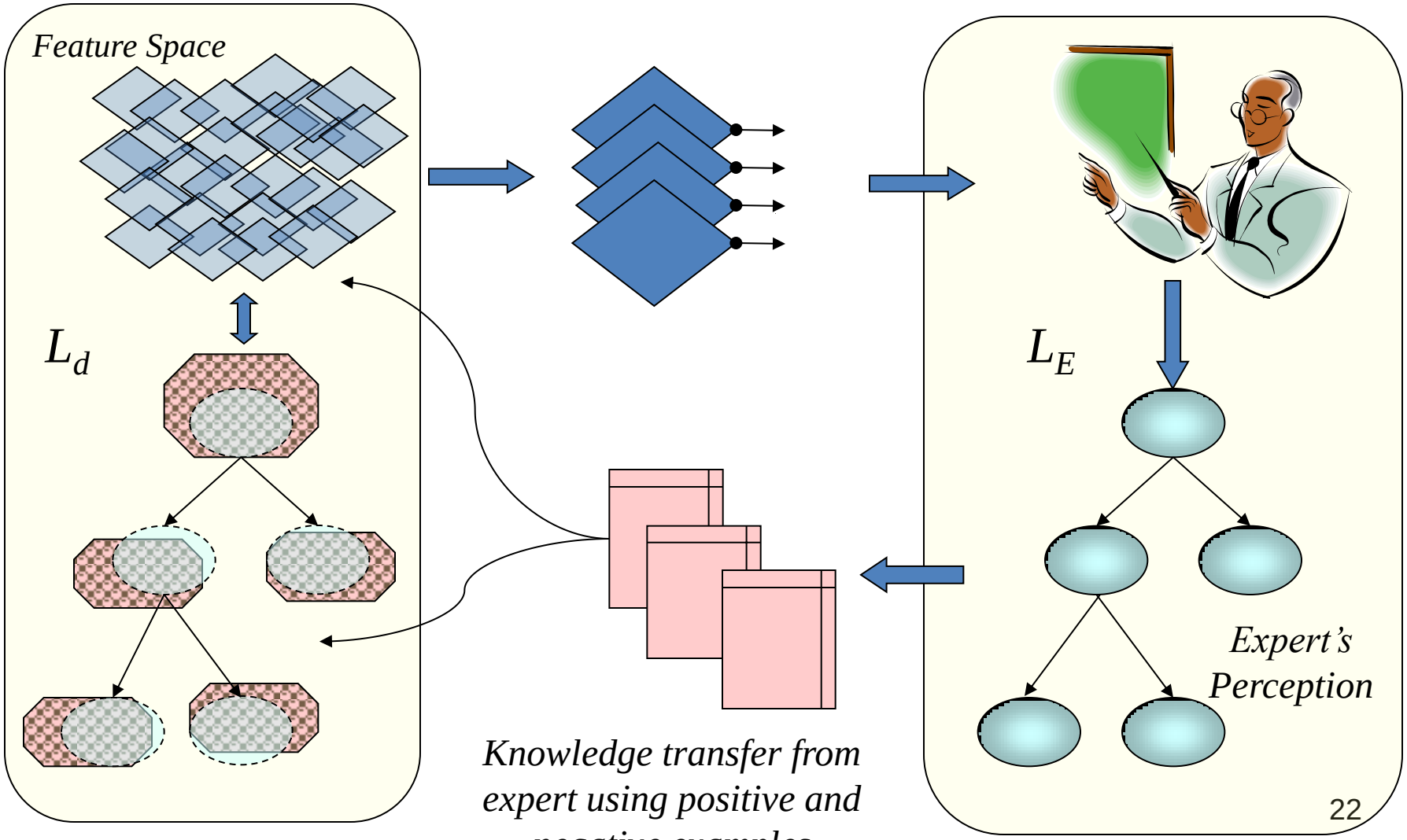



Objects (granules) in *IS* are composed out of attribute value vectors from $IS_1 \ldots IS_k$ satisfying *W*

# (INTERACTIVE) HIERARCHICAL STRUCTURES

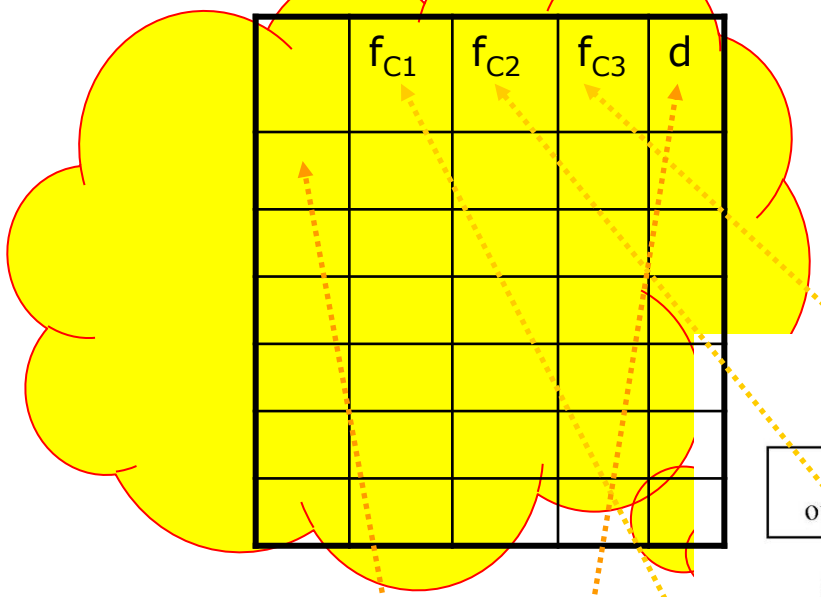


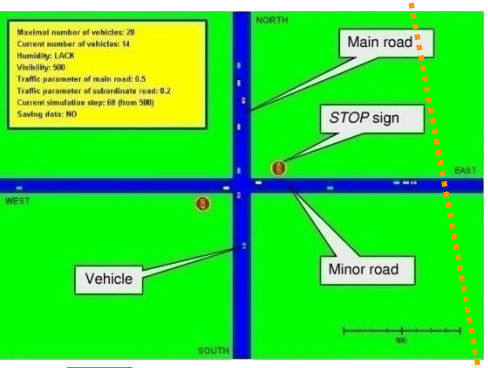
# ROUGH SET BASED ONTOLOGY APPROXIMATION

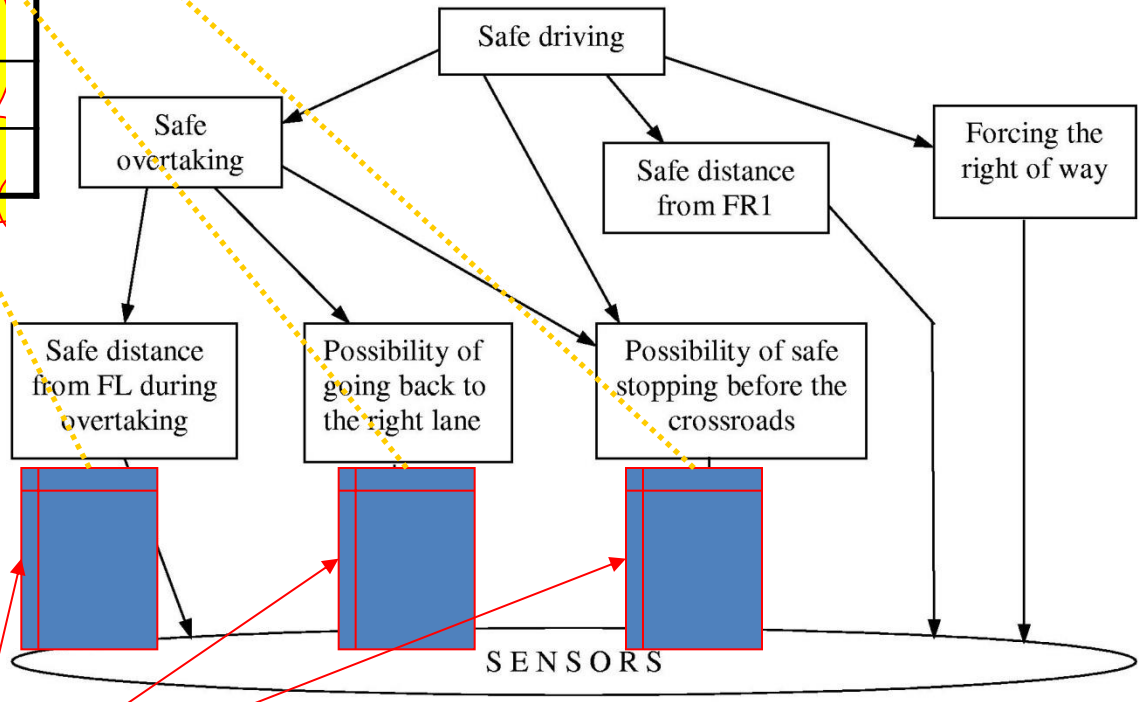


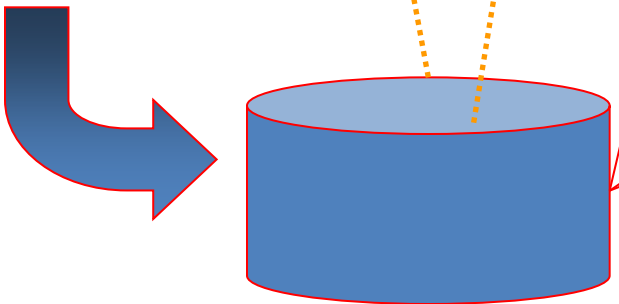
# UAV

# COMPLEX CONCEPT APPROXIMATION



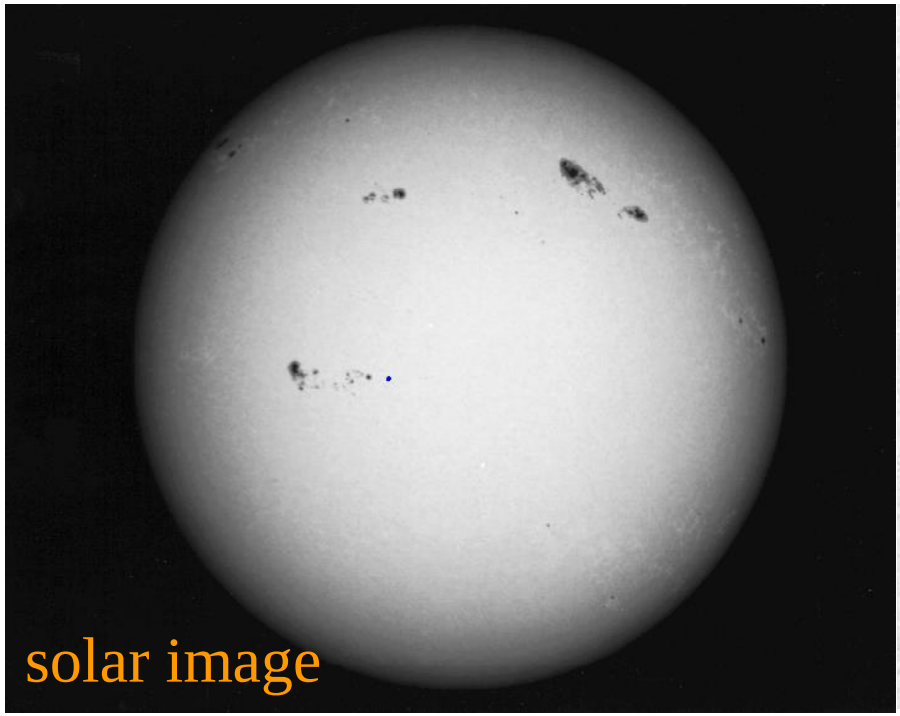



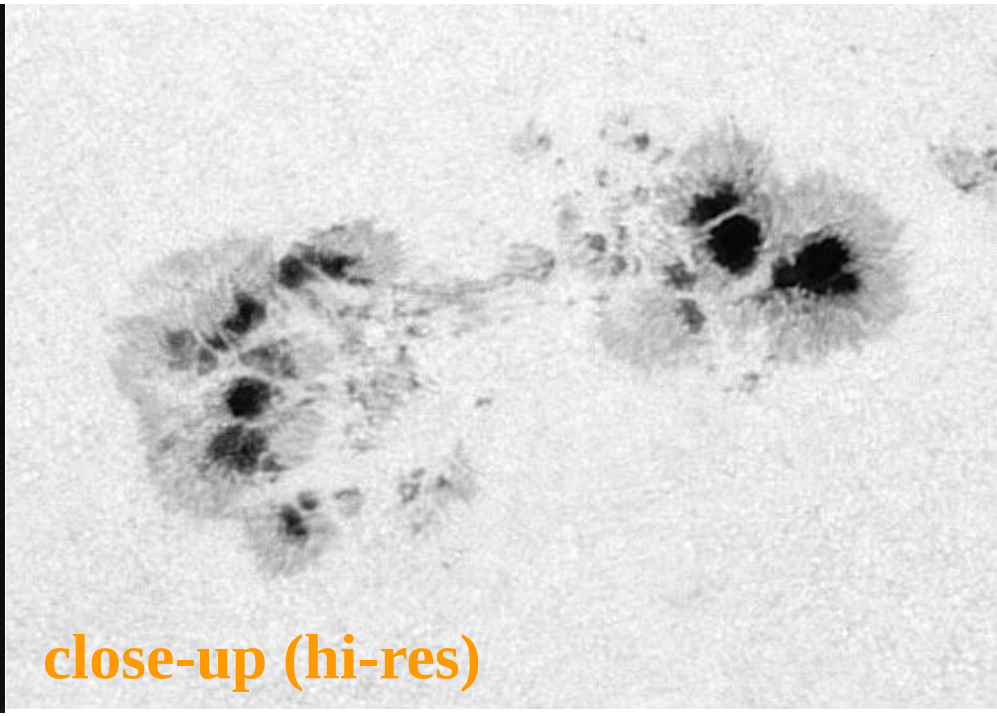



*J. Bazan, S.H. Nguyen. H.S. Nguyen, A. Skowron (RSCTC 2004)*

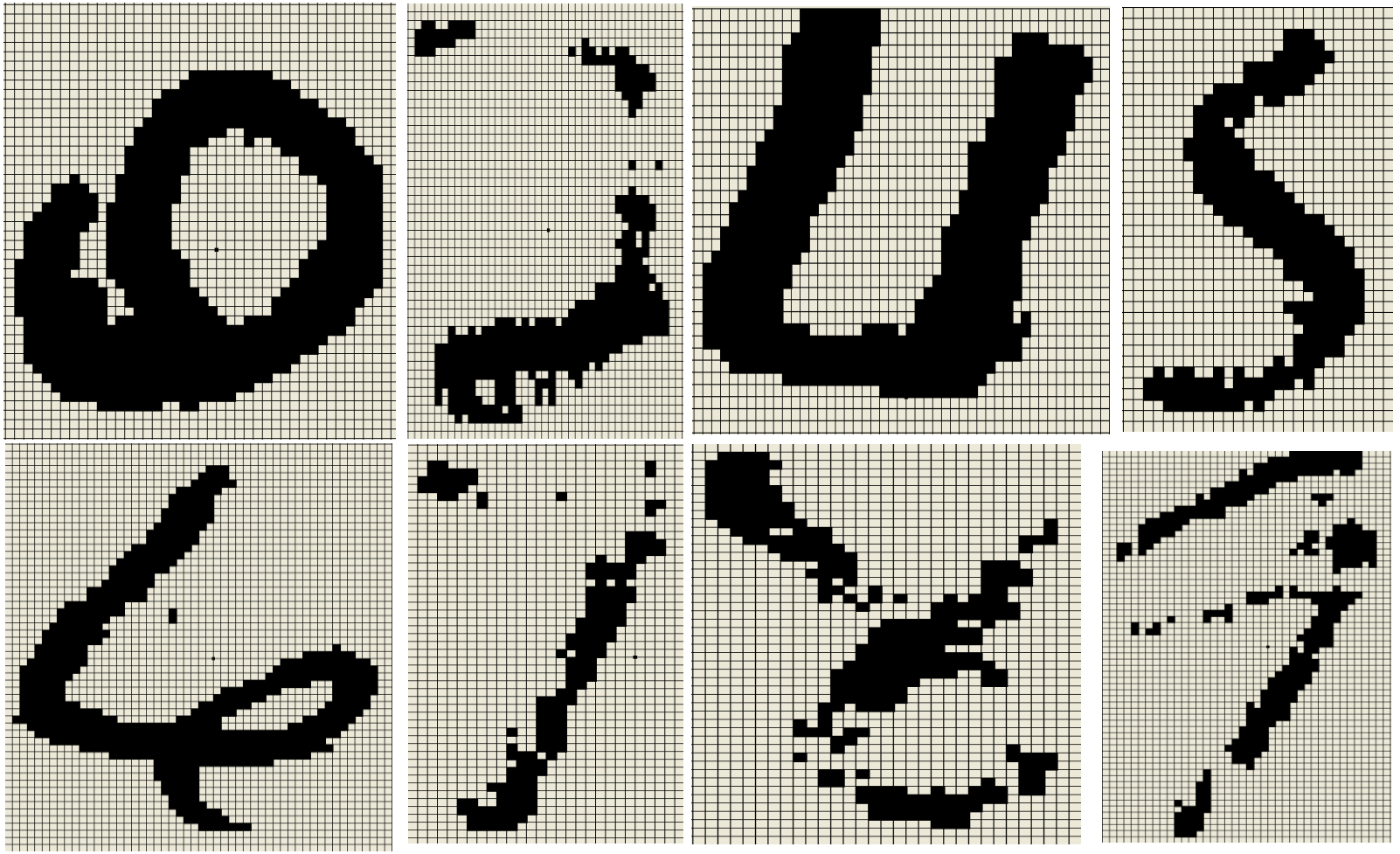
# SUNSPOT CLASSIFICATION




*T.T. Nguyen, C.P. Willis, D.J. Paddon, S.H. Nguyen, H.S. Nguyen: Learning Sunspot Classification. Fundamenta Informaticae 72(1-3): 295-309 (2006)*

# HARD SAMPLES



*Nguyen, T.T., Skowron, A.: Rough-granular computing in human-centric information processing. In; Bargiela, A., Pedrycz, W. (eds.), Human-Centric Information Processing Through Granular Modelling, Springer, Heidelberg (2009) 1-30*

# MEDICAL DIAGNOSIS AND THERAPY SUPPORT RESPIRATORY FAILURE

**Jan Bazan et al, Cooperation with Polish-American Pediatric Institute, Jagiellonian University Medical College, Cracow, Poland**

# IN DEALING WITH COMPLEX SYSTEMS:

# MORE COMPLEX VAGUE CONCEPTS SHOULD BE APPROXIMATED AND NEW KIND OF REASONING ABOUT COMPUTATIONS PROGRESSING BY ITERACTIONS AMONG LINKED MENTAL AND/OR PHYSICAL OBJECTS IS NEEDED

# EXAMPLES OF COMPLEX SYSTEMS

**SOFTWARE PROJECTS**
**MEDICAL SYSTEMS**
**ALGORITHMIC TRADING**
**SYSTEMS INTEGRATING TEAMS OF ROBOTS AND HUMANS**
**TRAFFIC CONTROL SYSTEMS**
**SYSTEMS IN ACTIVE MEDIA TECHNOLOGY**
**PERCEPTION BASED SYSTEMS**
**…**

# INTERACTIONS

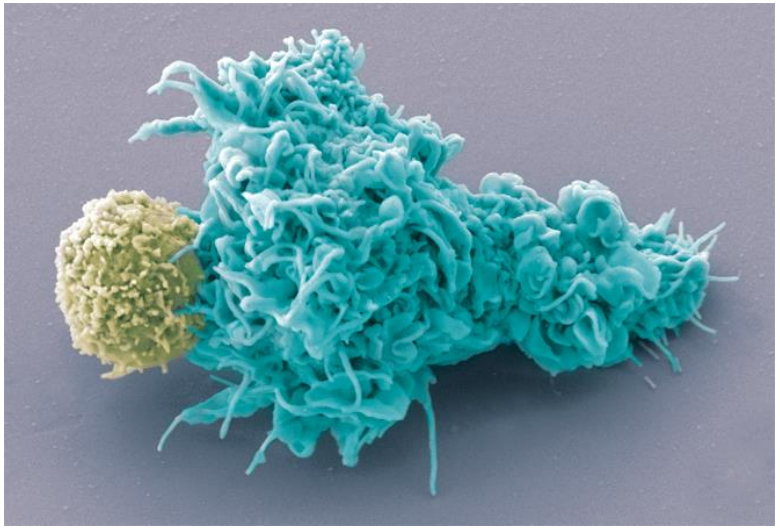
# INTERACTIONS

[…] **interaction** is a critical issue in the understanding of complex systems of any sorts: as such, it has emerged in several well-established scientific areas other than computer science, like biology, physics, social and organizational sciences.

*Andrea Omicini, Alessandro Ricci, and Mirko Viroli, The Multidisciplinary Patterns of Interaction from Sciences to Computer Science. In: D. Goldin, S. Smolka, P. Wagner (eds.): Interactive computation: The new paradigm, Springer 2006*

# INTERACTIONS

[…] One of the fascinating goals of natural computing is to understand, in terms of information processing, the functioning of a living cell. An important step in this direction is understanding of **interactions** between biochemical reactions. … the functioning of a living cell is determined by **interactions** of a huge number of biochemical reactions that take place in living cells.



A human dendritic cell (blue pseudo-color) in close interaction with a lymphocyte (yellow pseudo-color). This contact may lead to the creation of an immunological synapse.

*The Immune Synapse by Olivier Schwartz and the Electron Microscopy Core Facility, Institut Pasteur*
http://www.cell.com/Cell_Picture_Show

*Andrzej Ehrenfeucht, Grzegorz Rozenberg: Reaction Systems: A Model of Computation Inspired by Biochemistry, LNCS 6224, 1–3, 2010*

# INTERACTIONS OF PHYSICAL OBJECTS

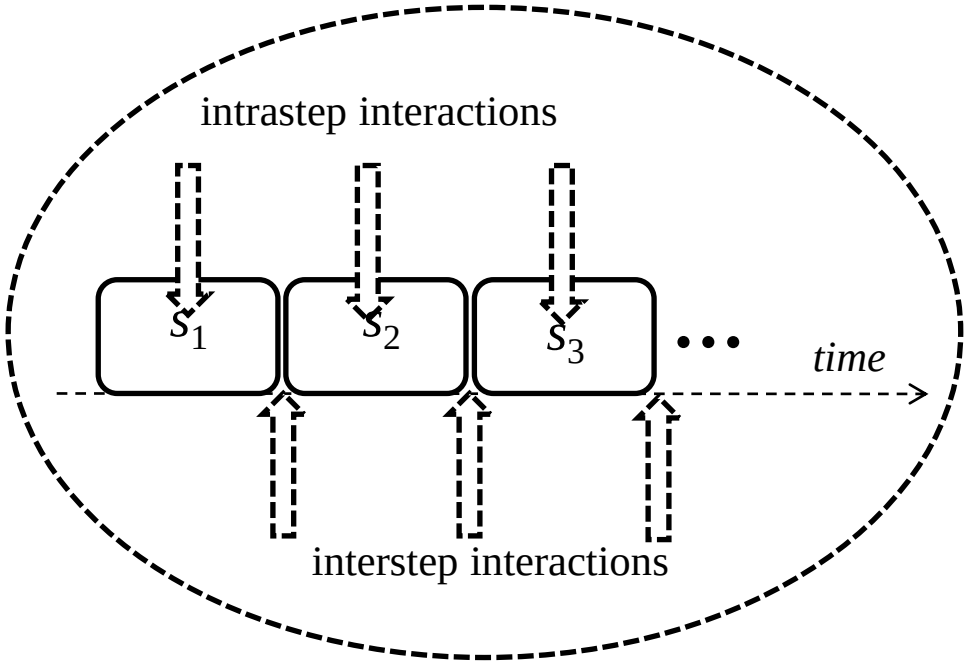
As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality.

(*Albert Einstein, Geometry and Experience, 1921*)

Constructing the physical part of the theory and unifying it with the mathematical part should be considered as one of the main goals of statistical learning theory.

(*Vladimir Vapnik, Statistical Learning Theory, Epilogue, p. 721*)

# INTERSTEP vs INTRASTEP INTERACTIONS

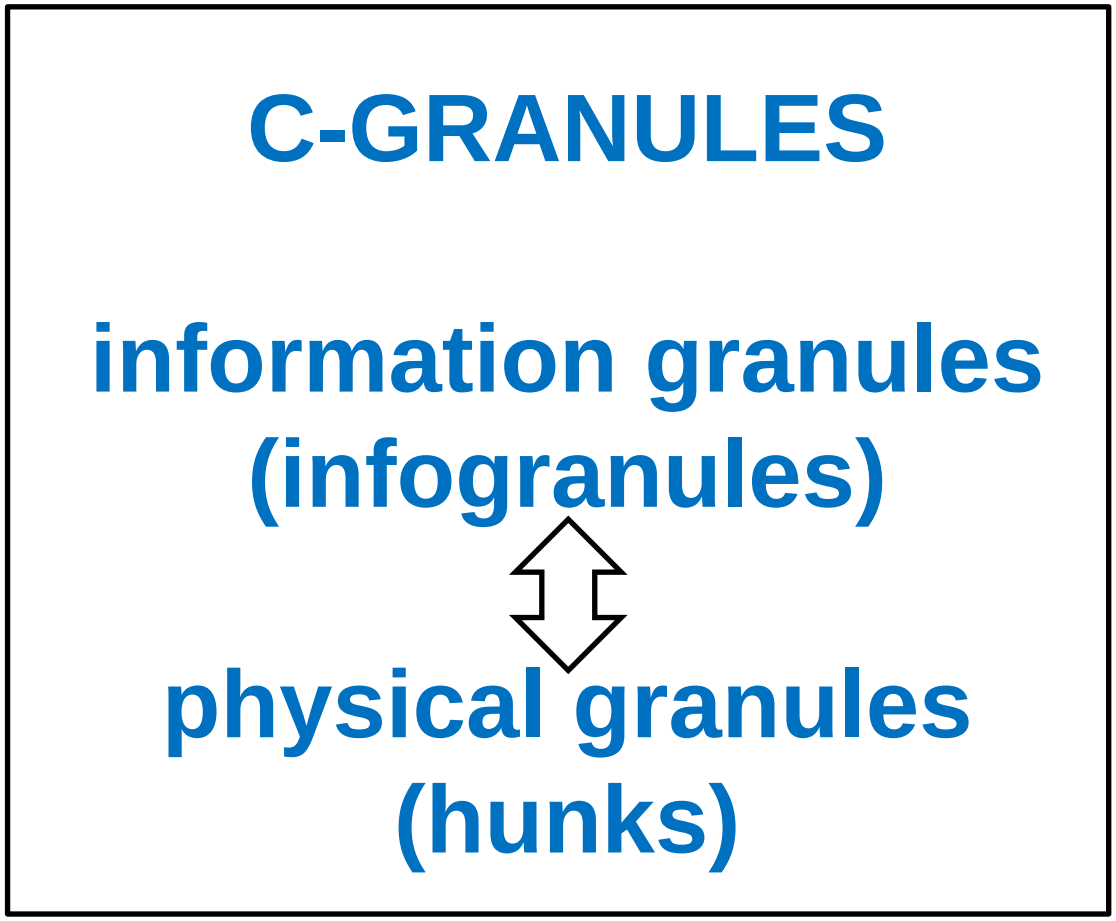



*Gurevich, Y.: Interactive Algorithms . In: D. Goldin, S. Smolka, P. Wagner (eds.): Interactive computation: The new paradigm, Springer 2006*

# FROM GC TO INTERACTIVE GC

## COMPUTATIONS BASED ON INTERACTIONS OF COMPLEX GRANULES

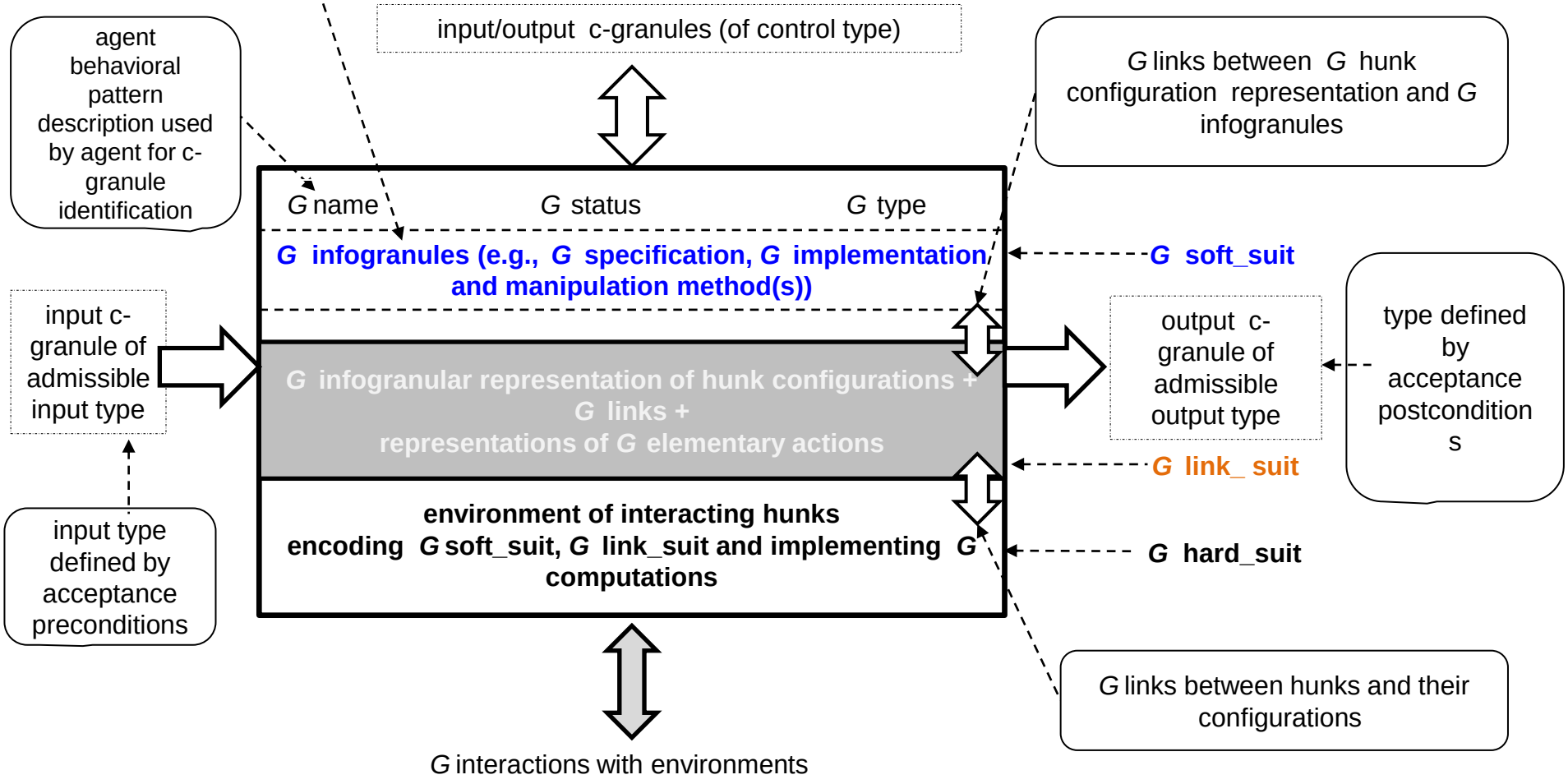
# TOWARD COMPUTATIONAL MODELS OF INTERACTIVE COMPUTATIONS BASED ON COMPLEX GRANULES (C-GRANULES)



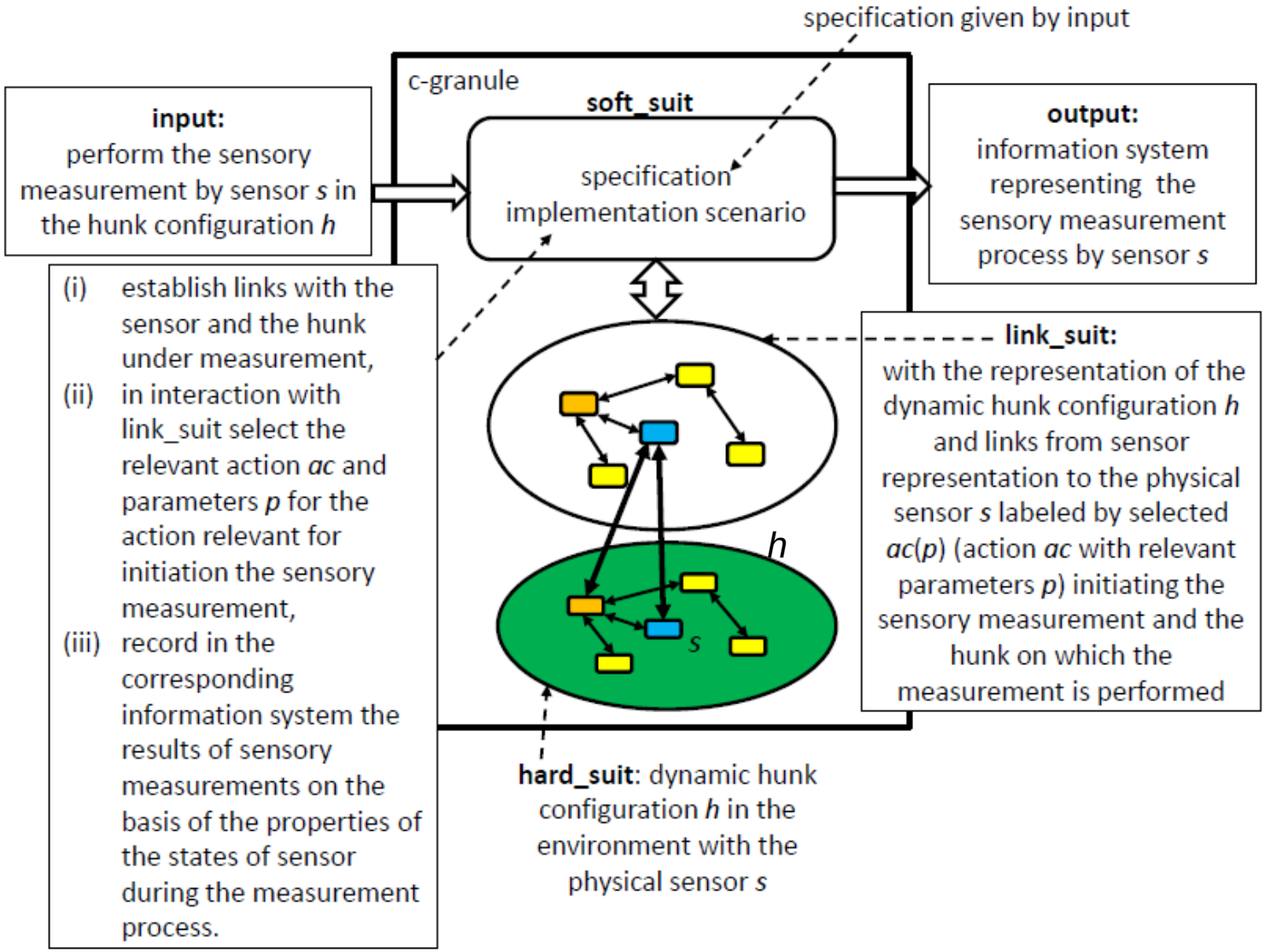
# c-GRANULE *G*

(at the local agent *ag* time)

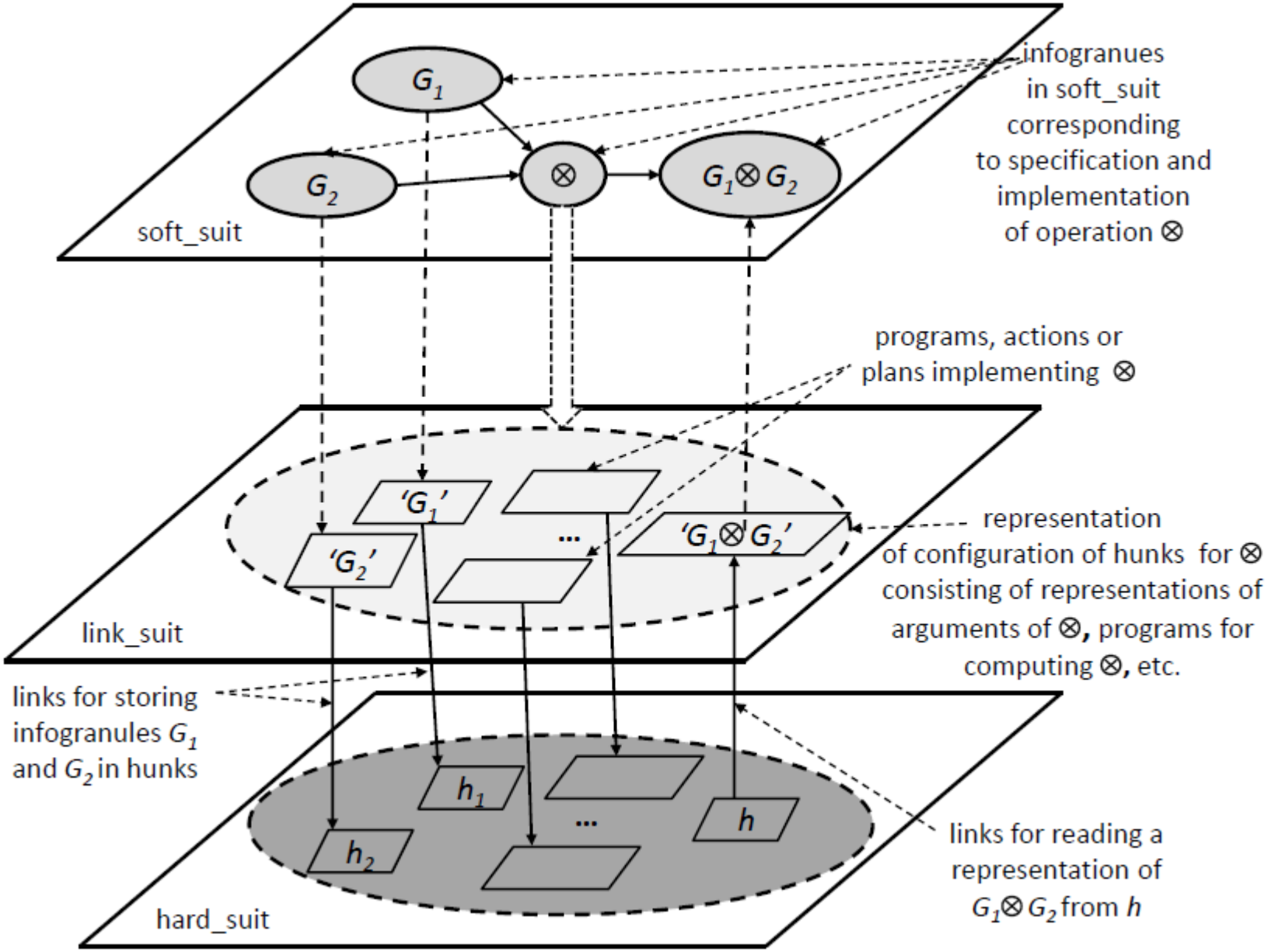
*operational semantics: implementation and manipulation method(s)* of admissible cases of interpretation (implementation) of interactive computations with goals specified by *specification (abstract semantics), i.e.,* procedures for performing interactive computations by the agent *ag* control; this includes checking the expected properties of I/O/C c-granules and other conditions, e.g., after sensory measurements and/or action realization using links to hunk configuration(s) with the structure defined by *G* link_suit; possible cases of interpretation are often defined relative to different universes of c-granules and hunks)



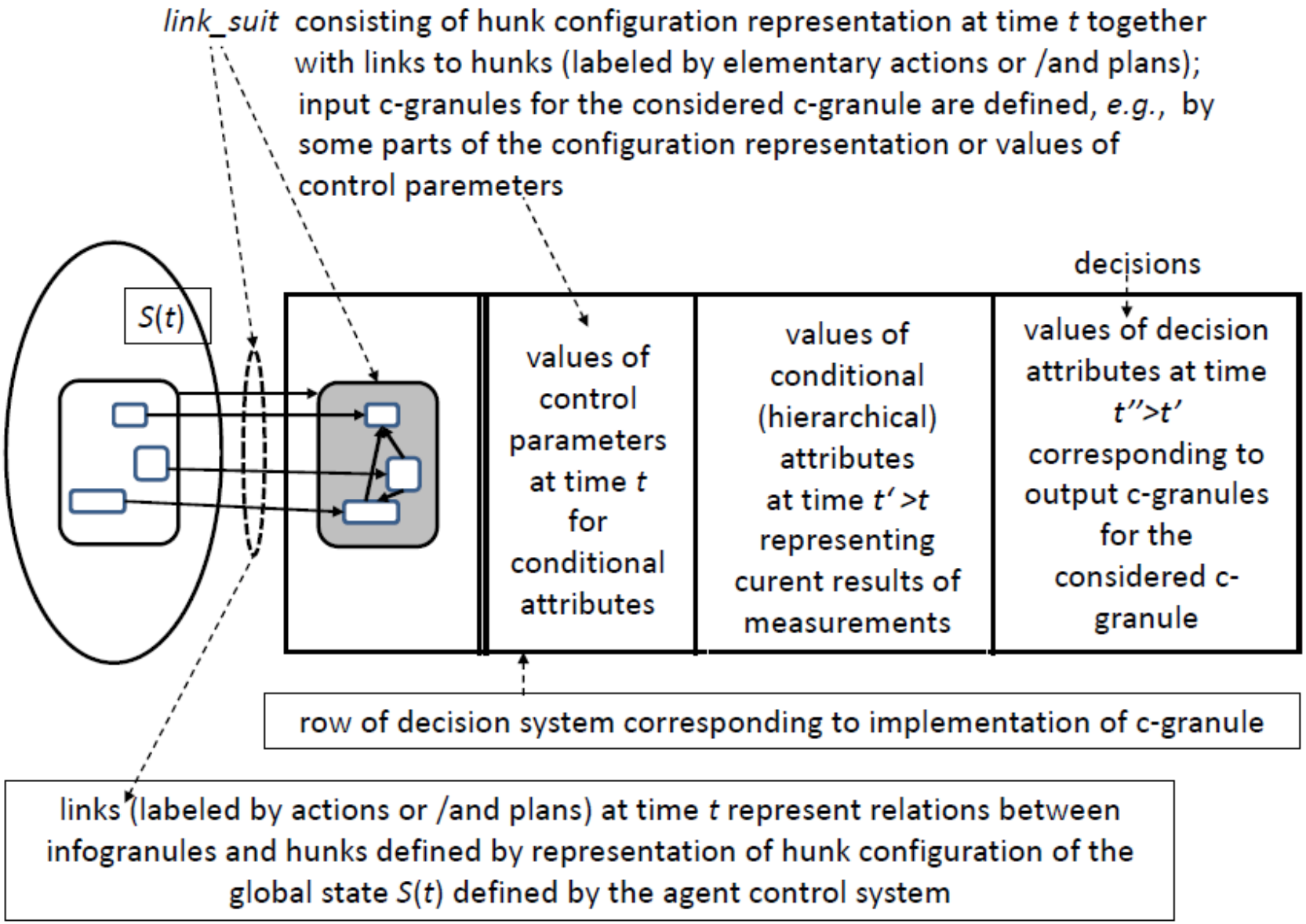
# SENSORS


specification given by input
c-granule
soft_suit
input:
perform the sensory measurement by sensor s in the hunk configuration h
specification
implementation scenario
output:
information system representing the sensory measurement process by sensor s
(i) establish links with the sensor and the hunk under measurement,
(ii) in interaction with link_suit select the relevant action ac and parameters p for the action relevant for initiation the sensory measurement,
(iii) record in the corresponding information system the results of sensory measurements on the basis of the properties of the states of sensor during the measurement process.
link_suit:
with the representation of the dynamic hunk configuration h and links from sensor representation to the physical sensor s labeled by selected ac(p) (action ac with relevant parameters p) initiating the sensory measurement and the hunk on which the measurement is performed
h
s
hard_suit: dynamic hunk configuration h in the environment with the physical sensor s

# INTERACTIVE COMPUTABILITY vs TURING COMPUTABILITY



# INTERACTIVE INFORMATION (DECISION) SYSTEMS



# ADAPTIVE JUDGMENT

# ADAPTIVE JUDGMENT

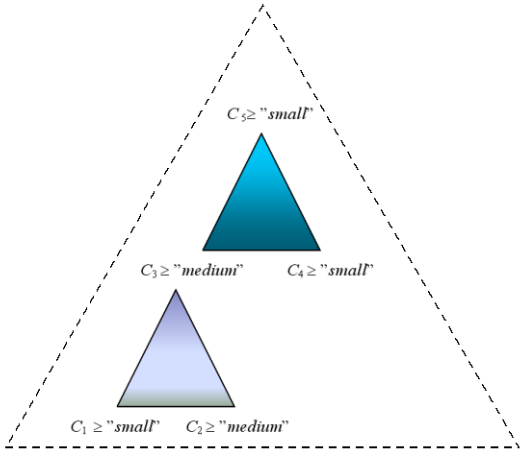
**JUDGEMENT**
**is a reasoning process for reaching decisions or drawing conclusions under uncertainty, vagueness and/or imperfect knowledge performed by agents on complex granules**
**ADAPTIVE JUDGEMENT is based on adaptive techniques for continuous judgement performance improvement.**

# ADAPTIVE JUDGEMENT

*D. Kahneman: Thinking, Fast and Slow. Farrar, Straus and Giroux, New York 2011.*

## INTUITIVE AND RATIONAL JUDGEMENT

FAST HEURISTICS BASED ON CLASSIFIERS FOR COMPLEX VAGUE CONCEPTS




APPROXIMATE REASONING SCHEMES

# ADAPTIVE JUDGEMENT

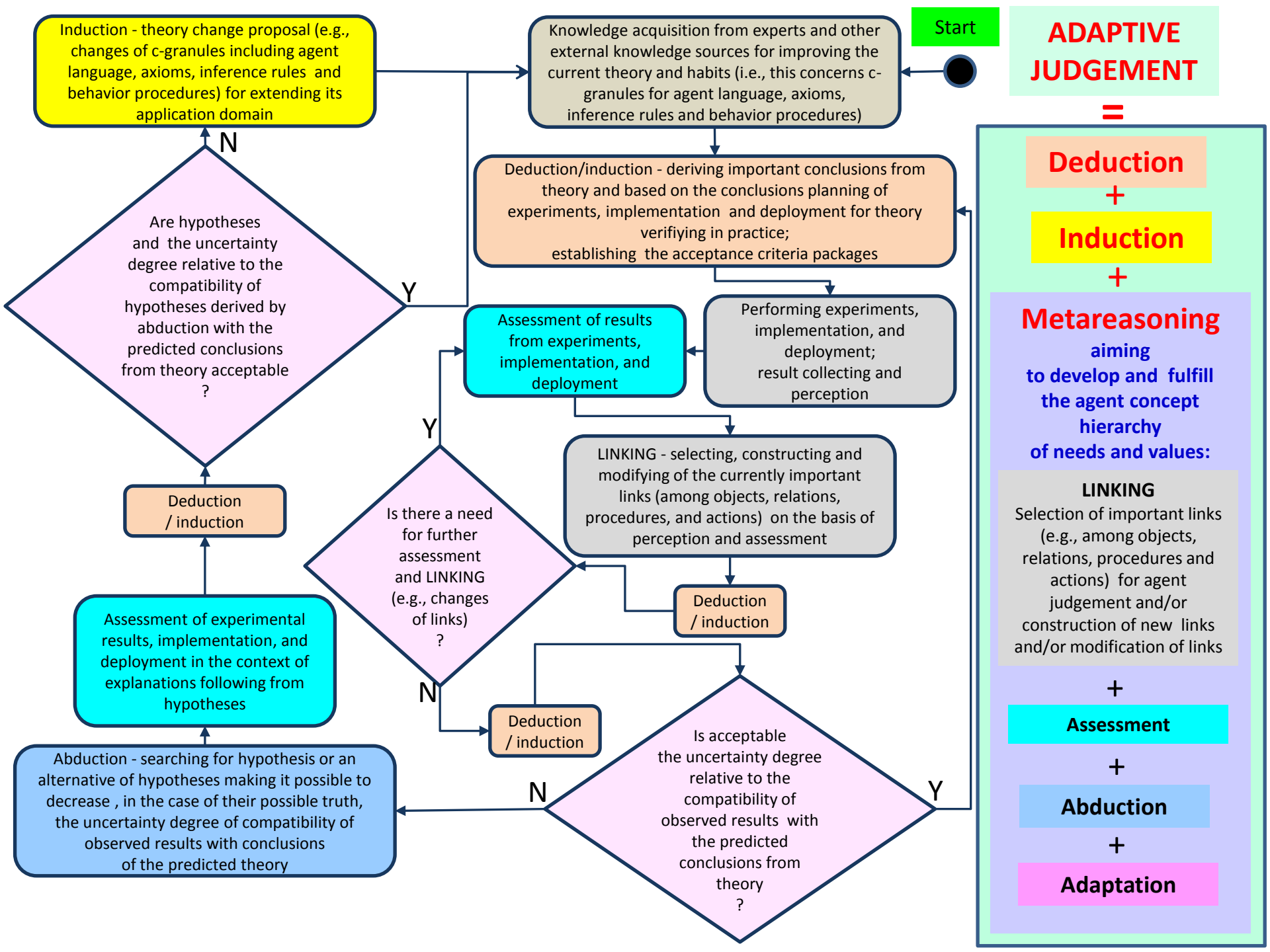
Reasoning of this kind is the least studied from the theoretical point of view and its structure is not sufficiently understood, in spite of many interesting theoretical research in this domain. The meaning of *common sense reasoning*, considering its scope and significance for some domains, is fundamental and rough set theory can also play an important role in it but more fundamental research must be done to this end.

*Z. Pawlak, A. Skowron: Rudiments of rough sets. Information Sciences, 177(1):3-27, 2007*

**Aristotle's man of practical wisdom, the *phronimos*, does not ignore rules and models, or dispense justice without criteria. He is observant of principles and, at the same time, open to their modification. He begins with *nomoi* – established law – and employs practical wisdom to determine how it should be applied in particular situations and when departures are warranted. Rules provide the guideposts for inquiry and critical reflection.**

**Practical judgment is not algebraic calculation. Prior to any deductive or inductive reckoning, the judge is involved in selecting objects and relationships for attention and assessing their interactions. Identifying things of importance from a potentially endless pool of candidates, assessing their relative significance, and evaluating their relationships is well beyond the jurisdiction of reason.**

*Leslie Paul Thiele: The Heart of Judgment Practical Wisdom, Neuroscience, and Narrative. Cambridge University Press 2006*


Induction - theory change proposal (e.g., changes of c-granules including agent language, axioms, inference rules and behavior procedures) for extending its application domain
Knowledge acquisition from experts and other external knowledge sources for improving the current theory and habits (i.e., this concerns c-granules for agent language, axioms, inference rules and behavior procedures)
Start
ADAPTIVE JUDGEMENT
=
Deduction
+
Induction
+
Metareasoning
aiming to develop and fulfill the agent concept hierarchy of needs and values:
LINKING
Selection of important links (e.g., among objects, relations, procedures and actions) for agent judgement and/or construction of new links and/or modification of links
+
Assessment
+
Abduction
+
Adaptation
Deduction/induction - deriving important conclusions from theory and based on the conclusions planning of experiments, implementation and deployment for theory verifiying in practice; establishing the acceptance criteria packages
Performing experiments, implementation, and deployment; result collecting and perception
Assessment of results from experiments, implementation, and deployment
LINKING - selecting, constructing and modifying of the currently important links (among objects, relations, procedures, and actions) on the basis of perception and assessment
Deduction / induction
Is there a need for further assessment and LINKING (e.g., changes of links) ?
Y
N
Deduction / induction
Is acceptable the uncertainty degree relative to the compatibility of observed results with the predicted conclusions from theory ?
N
Y
Abduction - searching for hypothesis or an alternative of hypotheses making it possible to decrease , in the case of their possible truth, the uncertainty degree of compatibility of observed results with conclusions of the predicted theory
Assessment of experimental results, implementation, and deployment in the context of explanations following from hypotheses
Deduction / induction
Are hypotheses and the uncertainty degree relative to the compatibility of hypotheses derived by abduction with the predicted conclusions from theory acceptable ?
N
Y

# ADAPTIVE JUDGEMENT

- Searching for relevant approximation spaces
  - new features, feature selection
  - rule induction
  - measures of inclusion
  - strategies for conflict resolution
  - …
- Adaptation of measures based on the minimal description length: quality of approximation vs description length
- Reasoning about changes
- Selection of perception (action and sensory) attributes
- Adaptation of quality measures over computations relative to agents
- Adaptation of object structures
- Strategies for knowledge representation and interaction with knowledge bases
- Ontology acquisition and approximation
- Language for cooperation development and evolution
- …

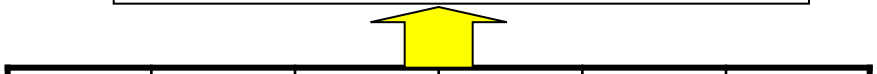
# PERCEPTION BASED COMPUTING

The main idea of this book is that perceiving is a way of acting. It is something we do. Think of a blind person tap-tapping his or her way around a cluttered space, perceiving that space by touch, not all at once, but through time, by skillful probing and movement. This is or ought to be, our paradigm of what perceiving is.

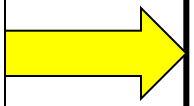
*Alva Noë: Action in Perception, MIT Press 2004*

interaction: agent → sensory and action attributes - only activated by agent attributes $A(t)$ at time $t$ are performing measurements and actions

history of sensory measurements and selected lower level actions over a period of time



| | time | $a_1$ | … | $ac_1$ | … |
|---|---|---|---|---|---|
| $x_1$ | 1 | | | | |
| $x_2$ | 2 | | | | |
| … | … | | | | |



| | features of histories | higher level action |
|---|---|---|
| | | |
| | | |
| … | | |

# *CROCUS* FRAMEWORK FOR WISDOM TECHNOLOGY BASED APPLICATION DEVELOPMENT

## SENSORS & ACTUATORS

Discovery , evolution and construction of sensors/actuators, adaptive control of sensor/actuator parameters, discovery of physical world structures and phenomena

## DOMAIN KNOWLEDGE

The acquisition, representation, management and governance of domain knowledge (e.g., ontology, rules for using language, history, applicable laws); selection of relevant knowledge for supporting solutions of prioritized tasks/actions

## FEATURES

Feature discovery, computation and exploration up to maximally large and meaningful sets of potentially relevant features for important observed and contextual phenomena; selection of potentially high quality and small subsets of features

**INTERACTIONS and ADAPTIVE JUDGEMENT (including GRANULATION) used for control of perceived interactions by agent**

## ADAPTIVE PLANNING

Problems identification and specification; tasks/actions prioritization (based on constrains specification); planning adaptation/change control, especially change of paradigms for dealing with vague complex concepts and classifier construction

## DATA

Data acquisition, assessment, cleansing, structuring, management and governance

## EXPERIMENTS

Improvement of acceptance criteria computation for satisfiability degrees of vague complex concepts relevant to application requirements; scenario of testing experiments; preparation and execution experiments; results collecting and assessment

## CLASSIFIERS

Selection and implementation of techniques for interactive learning of vague complex concepts, including adaptation and use of inference and decision rules as arguments „for” or „against" decisions and conflict resolution - toward construction of classifier societies (and/or intelligent agents)

# COMPLEX GRANULES
# IN
# DEALING WITH PROBLEMS
# BEYOND ONTOLOGIES

## EVOLVING LANGUAGES
## FOR PERCEIVING, REASONING AND ACTING
## TOWARD ACHIEVING GOALS

***

## RISK MANAGEMENT IN COMPLEX SYSTEMS

# GOTTFRIED WILHELM LEIBNIZ

[…] If controversies were to arise, there would be no more need of disputation between two philosophers than between two accountants. For it would suffice to take their pencils in their hands, and say to each other: *Let us calculate*.

[...] Languages are the best mirror of the human mind, and that a precise analysis of the signification of words would tell us more than anything else about the operations of the understanding.

*Leibniz, G.W. : Dissertio de Arte Combinatoria (1666).*
*Leibniz, G.W.: New Essays on Human Understanding (1705), (translated by Alfred Gideon Langley, 1896), (Peter Remnant and Jonathan Bennett (eds.)). Cambridge University Press (1982).*

# COMPUTING WITH WORDS
# LOTFI A. ZADEH

[…] Manipulation of perceptions plays a key role in human recognition, decision and execution processes. As a methodology, computing with words provides a foundation for a computational theory of perceptions - a theory which may have an important bearing on how humans make - and machines might make – perception - based rational decisions in an environment of imprecision, uncertainty and partial truth.

[…] computing with words, or CW for short, is a methodology in which the objects of computation are words and propositions drawn from a natural language.

*Lotfi A. Zadeh1: From computing with numbers to computing with words – From manipulation of measurements to manipulation of perceptions. IEEE Transactions on Circuits and Systems 45(1), 105–119 (1999)*

# LESLIE VALIANT: TURING AWARD 2010

.

A specific challenge is to build on the success of machine learning so as to cover broader issues in intelligence.

**This requires, in particular a reconciliation between two contradictory characteristics -- the apparent logical nature of reasoning and the statistical nature of learning.**

Professor Valiant has developed a formal system, called robust logics, that aims to achieve such a reconciliation.

# JUDEA PEARL- TURING AWARD 2011

for fundamental contributions to artificial intelligence through the development of a calculus for probabilistic and causal reasoning.

Traditional statistics is strong in devising ways of describing data and inferring distributional parameters from sample.

Causal inference requires two additional ingredients:

- *a science-friendly language for articulating causal knowledge*,

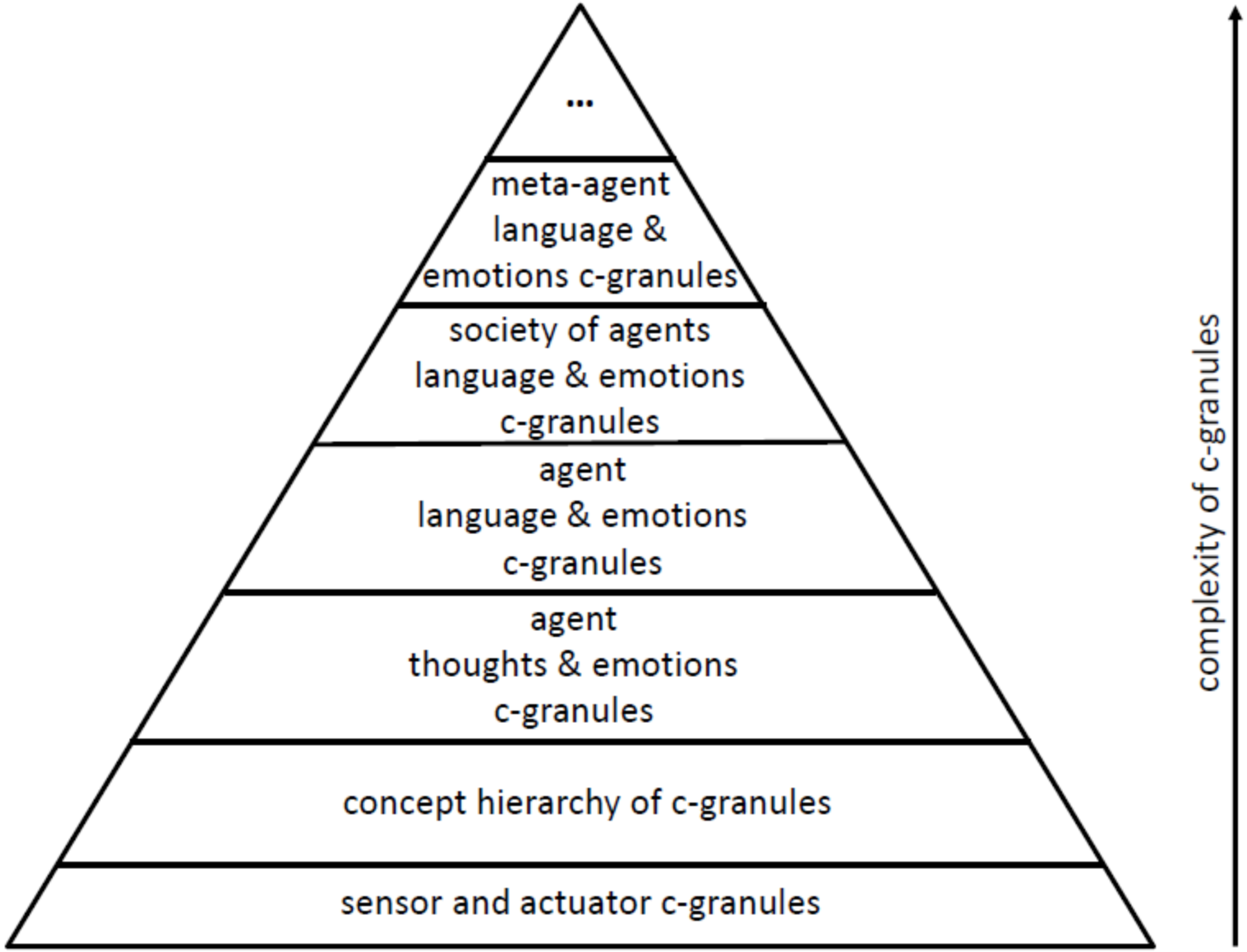
and

- *a mathematical machinery for processing that knowledge, combining it with data and drawing new causal conclusions about a phenomenon*.

*Judea Pearl: Causal inference in statistics: An overview. Statistics Surveys 3, 96-146 (2009)*

# THE WITTGENSTEIN IDEA ON LANGUAGE GAMES

*Wittgenstein, L.: Philosophical Investigations. (1953) (translated by G. E. M. Anscombe) (3rd Ed), Blackwell Oxford1967*


...
meta-agent language & emotions c-granules
society of agents language & emotions c-granules
agent language & emotions c-granules
agent thoughts & emotions c-granules
concept hierarchy of c-granules
sensor and actuator c-granules
complexity of c-granules

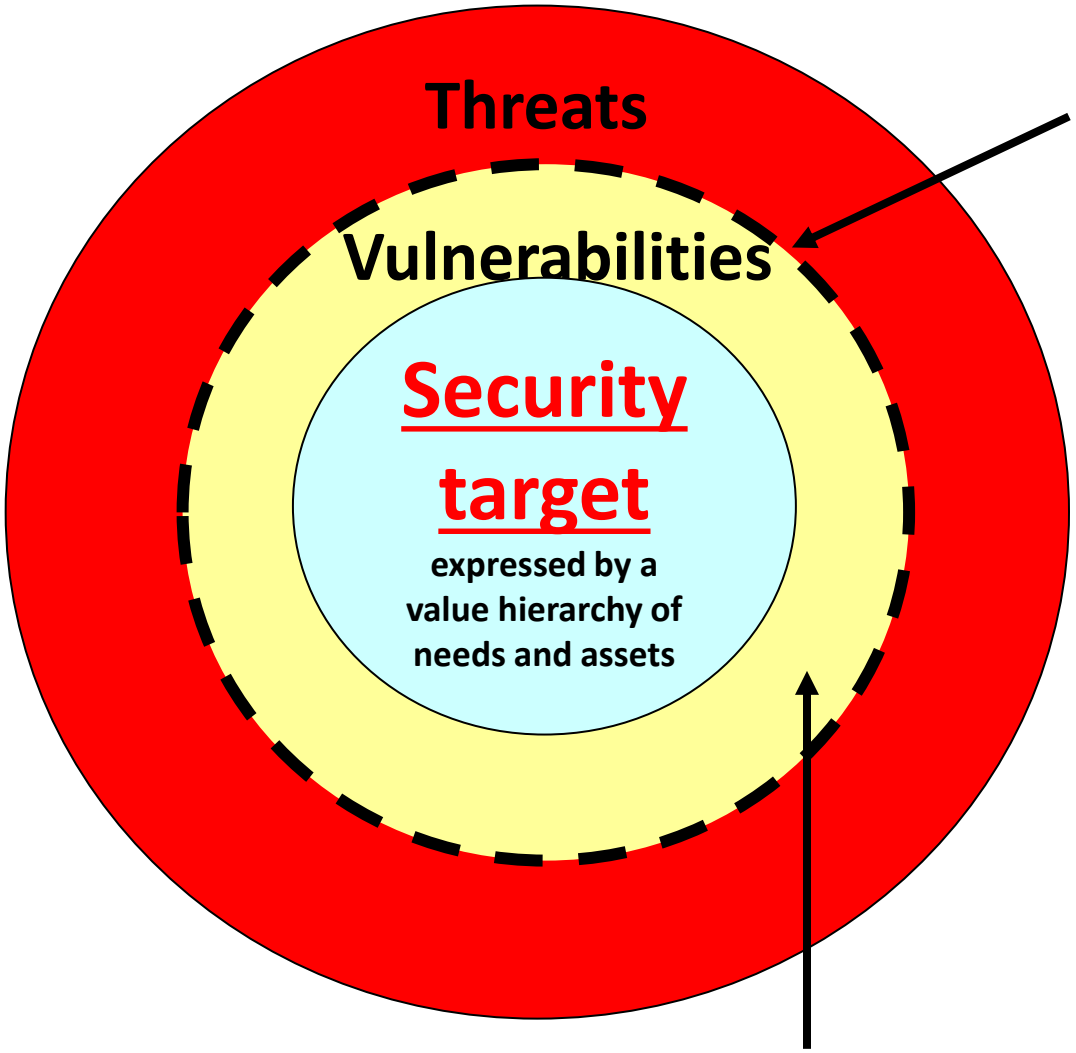
# HOW TO CONTROL COMPUTATIONS IN INTERACTIVE INTELLIGENT SYSTEMS (IIS) ?

***

# RISK MANAGEMENT IN IIS

*Jankowski, A., Skowron, A., Wasilewski, P.: Interactive Computational Systems. CS&P 2012*
*Jankowski, A., Skowron, A., Wasilewski, P.: Risk Management and Interactive Computational Systems. Journal of Advanced Mathematics and Mathematics 2012*

# THREATS AND VULNERABILITIES

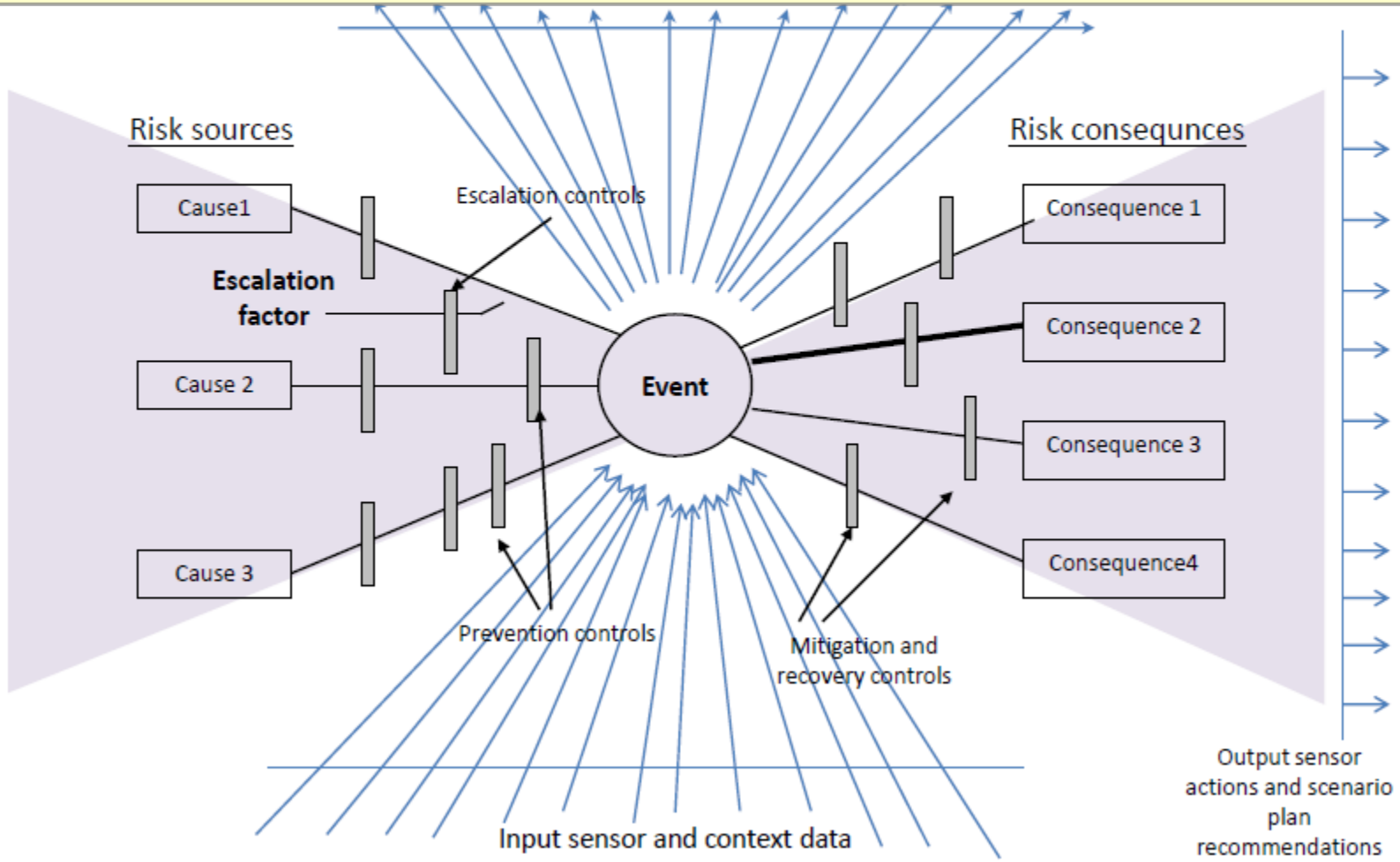



controls

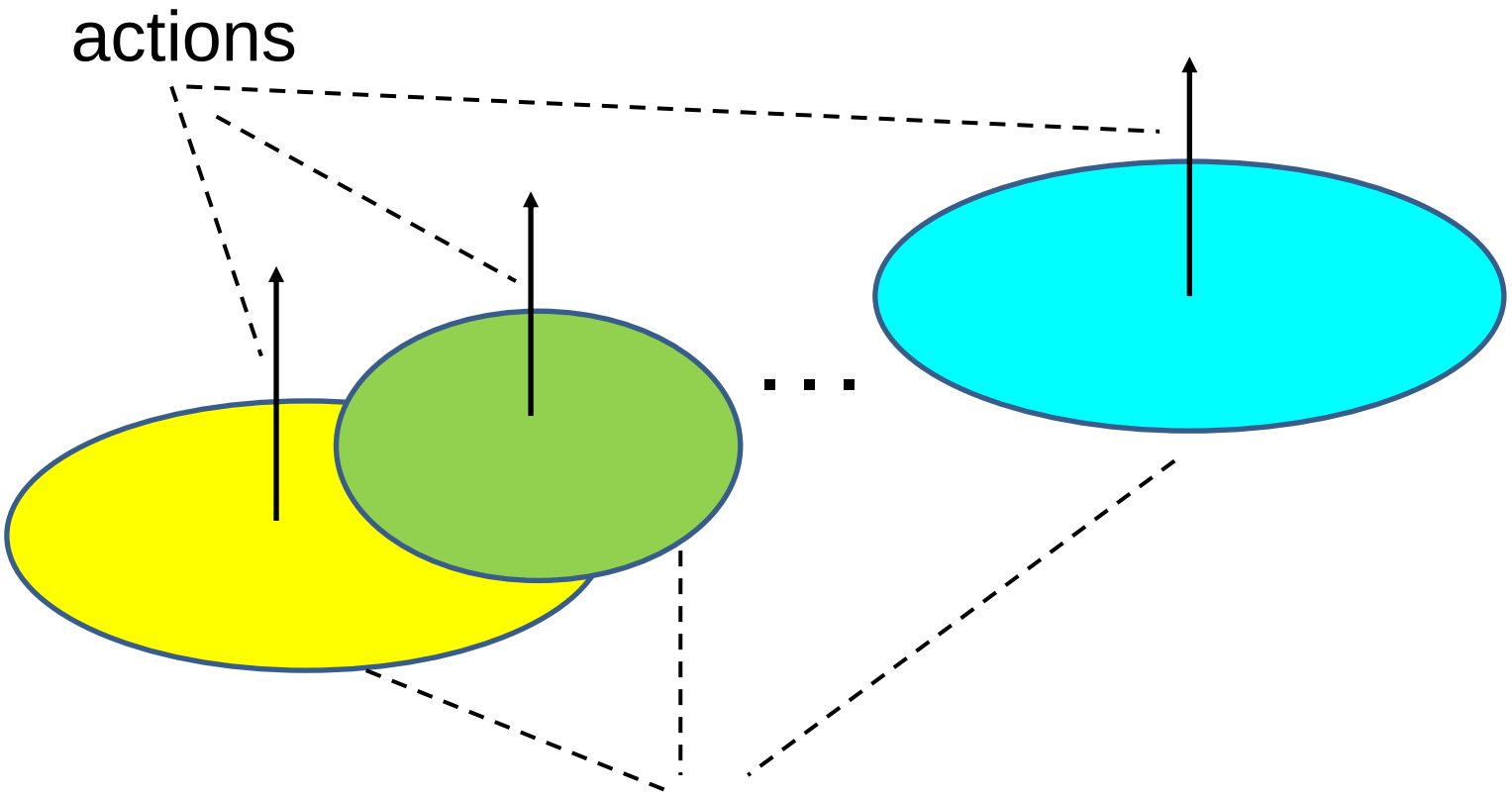
vulnerabilities used by threats

# EXAMPLE OF BOW TIE DIAGRAM FOR UNWANTED CONSEQUENCES

**Wisdom[RMA] = Interactions[RMA] + Adaptive Judgment[RMA] + Knowledge[RMA]**
**Adaptive Judgement[RMA] = Induction[RMA] + Deduction[RMA] + Metareasoning[RMA]**
Metareasoning is aiming to develop and fulfil the agent concept hierarchy of needs and values
**Metareasoning[RMA] = Linking[RMA] + Assessment[RMA] + Abduction[RMA] + Adaptation[RMA]**



# DISCOVERY OF COMPLEX GAMES OF INTERACTIONS



# SUMMARY

## RS IN COMPLEX SYSTEMS:

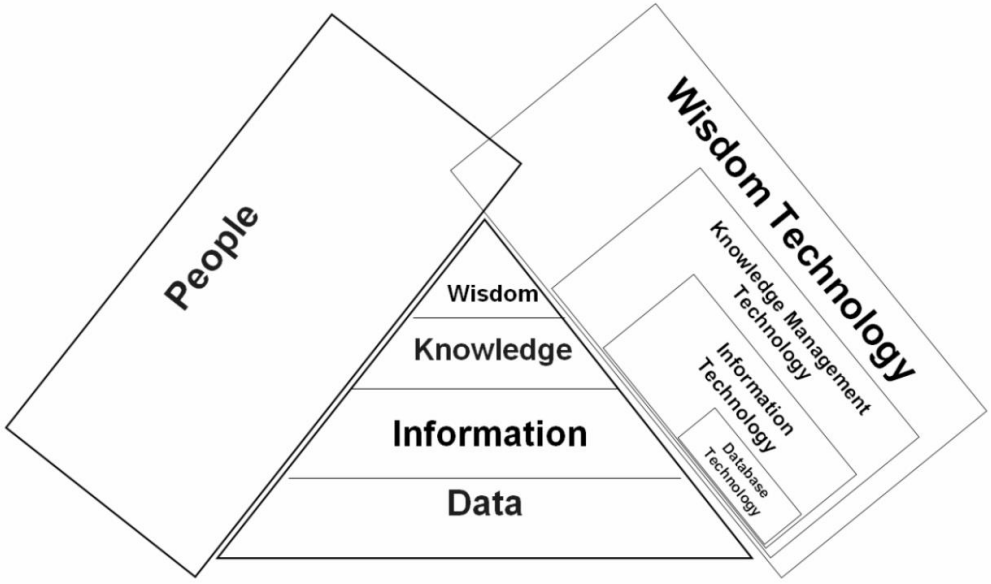
## INTERACTIVE COMPUTATIONS
## ON
## COMPLEX GRANULES

## TOWARD RISK MANAGEMENT IN COMPLEX SYSTEMS

*Jankowski, A., Skowron, A.: Practical Issues of Complex Systems Engineering: Wisdom Technology Approach. Springer 2014 (in preparation)*

# WISDOM TECHNOLOGY (WisTech)

**WISDOM= INTERACTIONS + ADAPTIVE JUDGEMENT + KNOWLEDGE BASES**




IRGC = systems based on interactive computations on complex granules with use of domain (expert) knowledge, process mining, concept learning, …

*Jankowski, A. Skowron: A wistech paradigm for intelligent systems, Transactions on Rough Sets VI: LNCS Journal Subline, LNCS 4374, 2007, 94–132*

# SUMMARY

**THE ROLE OF RS IN INTERACTIVE GRANULAR COMPUTING IS AND WILL BE IMPORTANT**

**IN REAL LIFE APPLICATIONS WE ARE FORCED TO DEAL WITH MORE AND MORE COMPLEX VAGUE CONCEPTS.**
**DUE TO UNCERTAINTY THESE CONCEPTS CAN BE APPROXIMATED ONLY.**

# THANK YOU !