PERCEPTUAL ROUGH SET APPROACH IN INTERACTIVE GRANULAR COMPUTING

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in cooperation
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Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU 2022) July 11-15, 2022, Milan, Italy

AGENDA

- Motivations for developing of new computing model
- Granular Computing (GrC)
- Interactive Granular Computing (IGrC):
  - complex granules (c-granules)
  - informational c-granules (ic-granules)
  - control of c-granules based on ic-granules and reasoning
- Domains of IGrC applications:
  - Perceptual Rough Sets
- Summary

SCIENCE, MANAGEMENT, LIFE,...

Tomorrow, I believe, we will use
DECISION SUPPORT SYSTEMS,
INTELLIGENT SYSTEMS
to support our decisions
in defining our research strategy and specific aims,
in managing our experiments,
in collecting our results, interpreting our data,
in incorporating the findings of others,
in disseminating our observations,
in extending (generalizing) our experimental observations
- through exploratory discovery and modeling -
in directions completely unanticipated

Bower, J.M., Bolouri, H. (Eds.): Computational Modeling of Genetic and Biochemical Networks. MIT Press, Cambridge, MA (2001)

DO WE HAVE
THE RELEVANT COMPUTING MODEL
FOR DEALING WITH PROBLEMS IN:

CYBER PHYSICAL SYSTEMS
INTERNET OF THINGS
WISDOM WEB
SOCIETY 5.0
MODELING COMPLEX ADAPTIVE SYSTEMS
NATURAL COMPUTING
MULTISCALE MODELING
…

… how intelligence can emerge from interactions among multiple agents - whether those agents be machines, animals, or human beings.

Melanie Mitchell: Frontiers in Collective Intelligence:
A Workshop Report 2021
arxiv.org/abs/2112.06864

MOTIVATIONS
BEYOND THE TURING TEST

The Turing test, as originally conceived, focused on language and reasoning; **problems of perception and action were conspicuously absent**. The proposed tests will provide an opportunity to bring four important areas of AI research (language, reasoning, perception, and action) back into sync after each has regrettably diverged into a fairly independent area of research.

C. L. Ortitz Jr. Why we need a physically embodied Turing test and what it might look like.
AI Magazine 37 (2016) 55–62.

TOOLS SUPPORTING DECISION MAKING BASED ON

construction of objects on which computations are performed

&

reasoning mechanisms about such computations

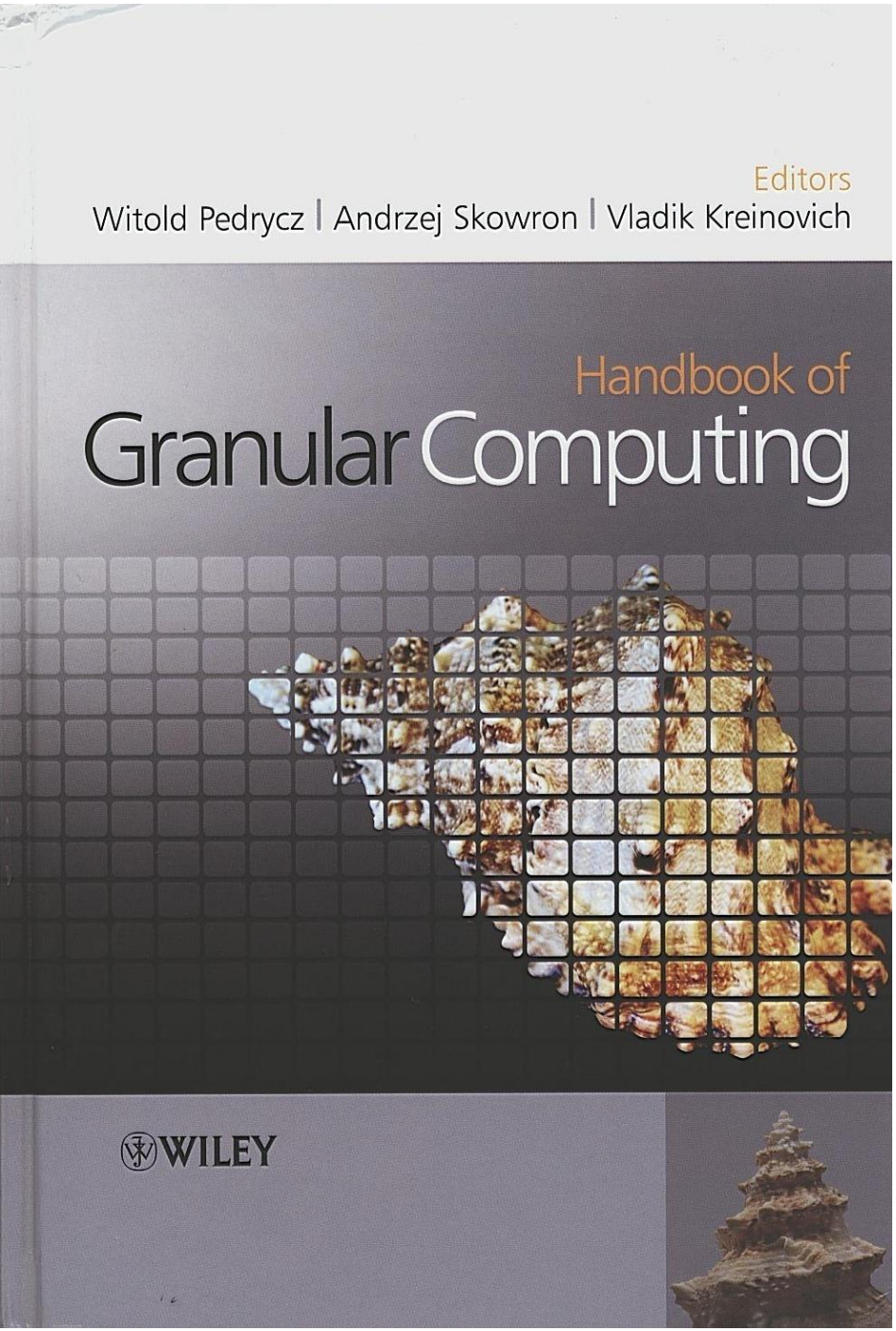
TWO APPROACHES

GRANULAR COMPUTING (GrC) based on modelling in abstract space

&

INTERACTIVE GRANULAR COMPUTING (IGrC) based on modelling in abstract and physical space

GRANULAR COMPUTING (GrC)

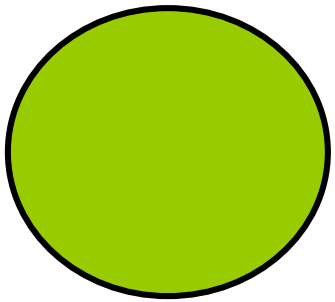


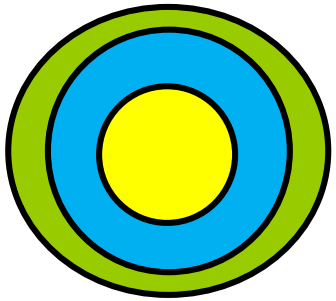
Plays a key role in implementation of the strategy of divide-and-conquer in human problem-solving – Lotfi Zadeh

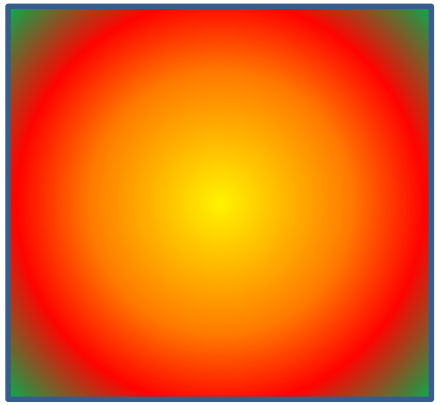
Zadeh, L.A. (1979) Fuzzy sets and information granularity. In: Gupta, M., Ragade, R., Yager, R. (eds.), Advances in Fuzzy Set Theory and Applications, Amsterdam: North-Holland Publishing Co., 3-18

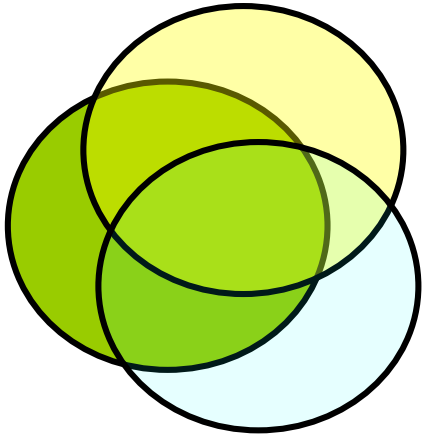
Zadeh, L.A. (2001) A new direction in AI-toward a computational theory of perceptions. AI Magazine 22(1): 73-84

ELEMENTARY GRANULES + OPERATIONS ON GRANULES = CALCULI OF GRANULES









...

ROUGH GRANULES:

ELEMENTARY GRANULES

DEFINABLE GRANULES

APPROXIMATION OF GRANULES

UNCERTAINTY IN OBJECT PERCEPTION
INDISCERNIBILITY RELATIONS

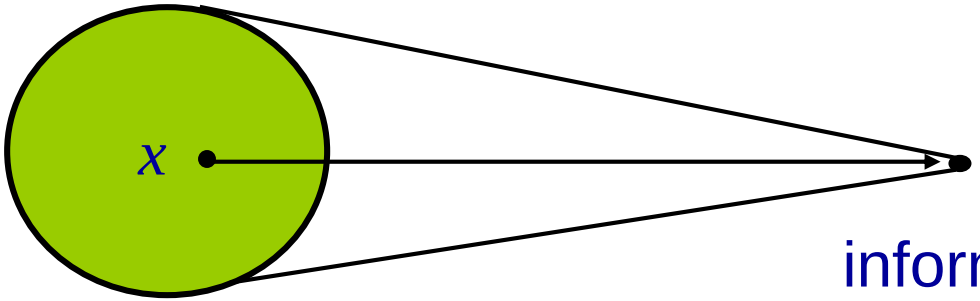
information system (data table)

$IS = (U, A)$

$U = \{x_1, \ldots, x_n\},\ A = \{a_1, \ldots, a_m\}$

	a_1	a_2	…	a_m
x_1	v_1	v_2	…	v_m
	…	…	…	…

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



neighborhood of x

$u = Inf_A(x)$

information signature of $\boldsymbol{x}$

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

τ

tolerance or similarity

$IND(B) \ \ for \ \ B \subseteq A$

$[x]_{IND(B)} = [x]_B = \{y \in U : xIND(B)y\}$

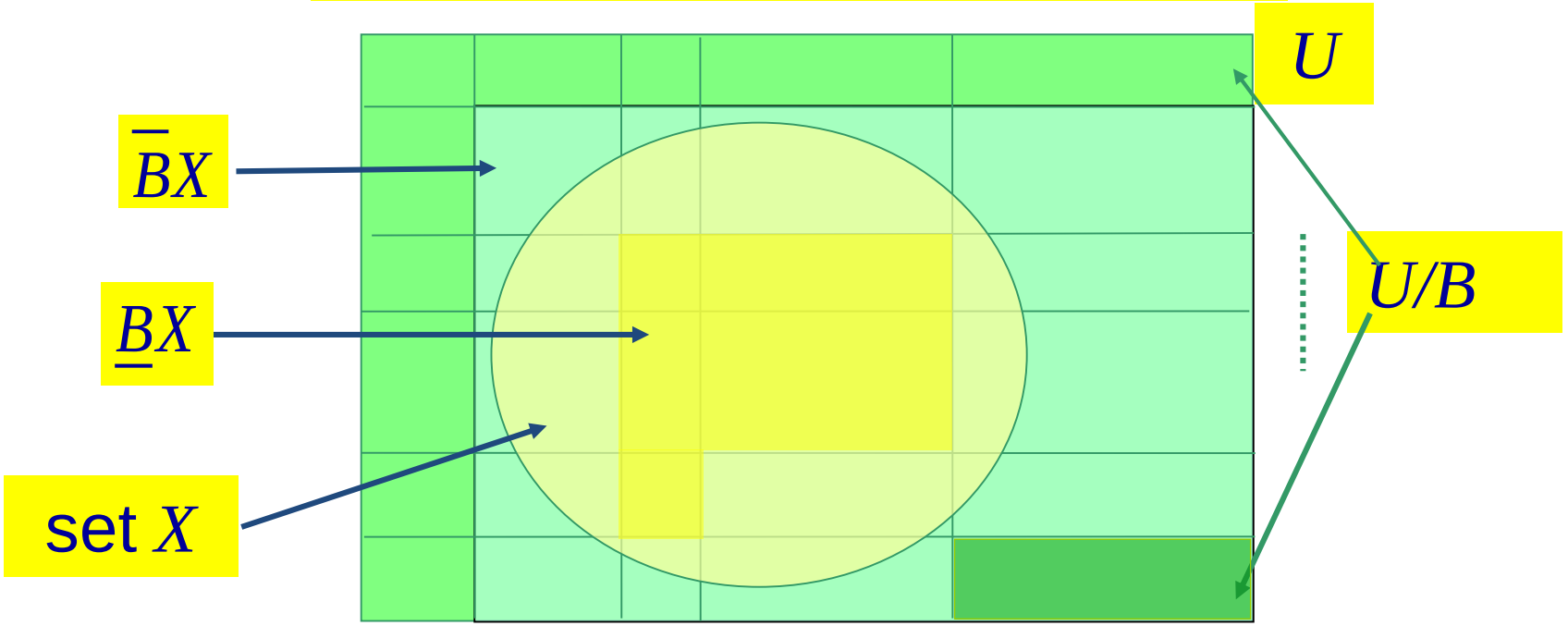
$U / B = \{[x]_B : x \in U\}$

LOWER AND UPPER APROXIMATION

$$X \subseteq U,\ B \subseteq A$$

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

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



BOUNDARY REGION

$$BN_B(X) = \overline{B}X \setminus \underline{B}X$$

ROUGH SETS

BOUNDARY REGION

$$BN_B(X) = \overline{B}X \setminus \underline{B}X$$

CRISP SET

$$BN_B(X) = \emptyset$$

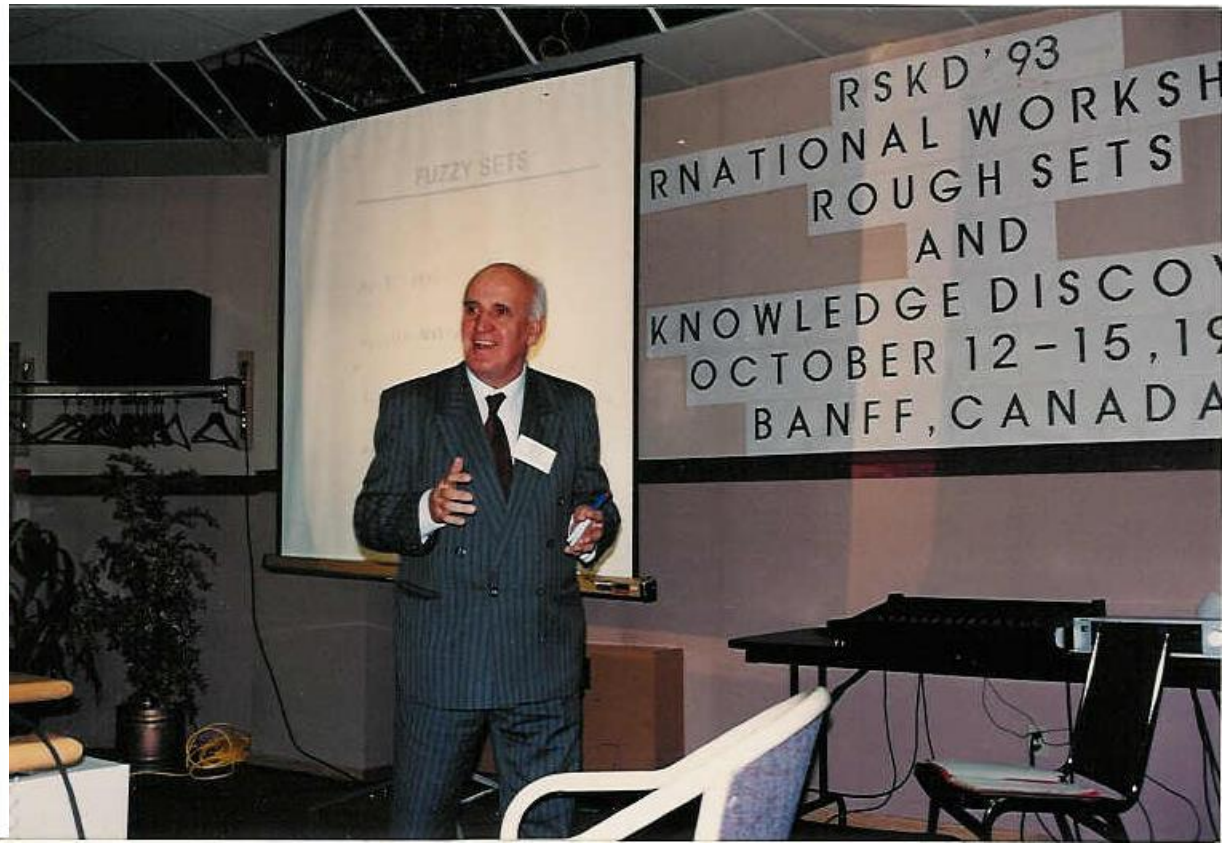
ROUGH SET

$$BN_B(X) \neq \emptyset$$

RUDIMENTS OF ROUGH SETS

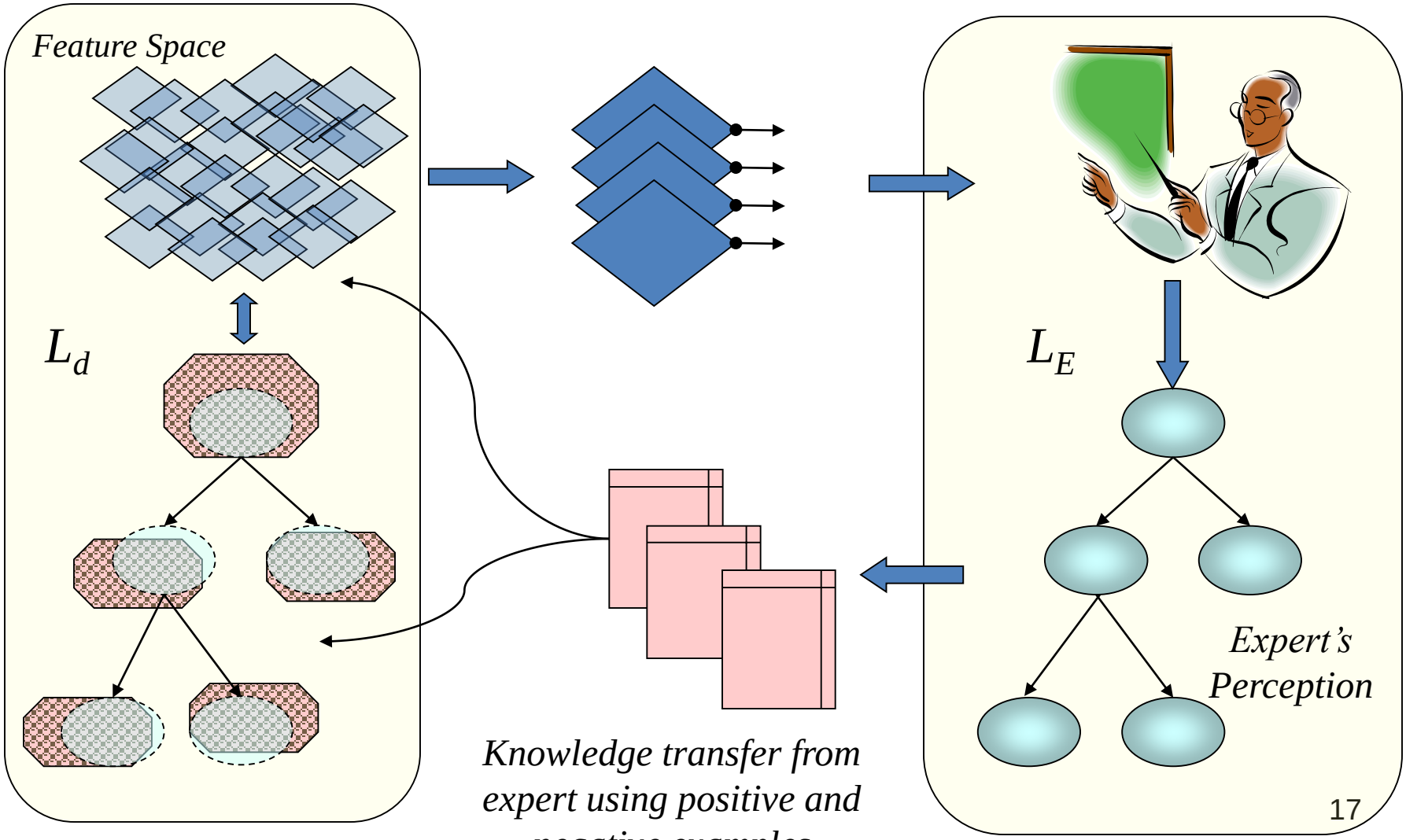
Pawlak, Z.: Rough sets. International Journal of Computer and Information Sciences 11 (1982)

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



Now thousands of papers http://rsds.ur.edu.pl

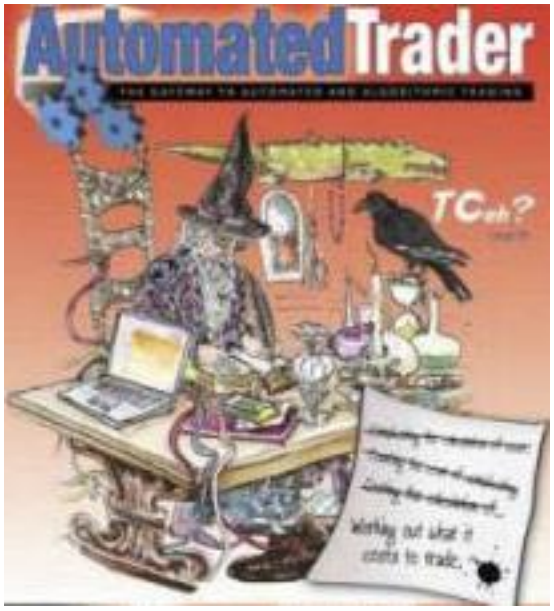
ROUGH SET BASED ONTOLOGY APPROXIMATION

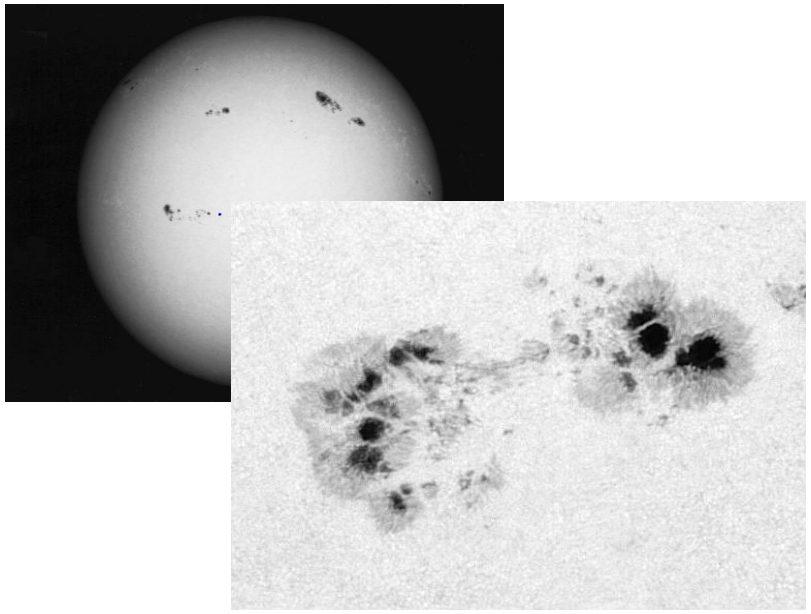


ROUGH SETS AND APPROXIMATION OF COMPLEX VAGUE CONCEPTS : ONTOLOGY APPROXIMATION

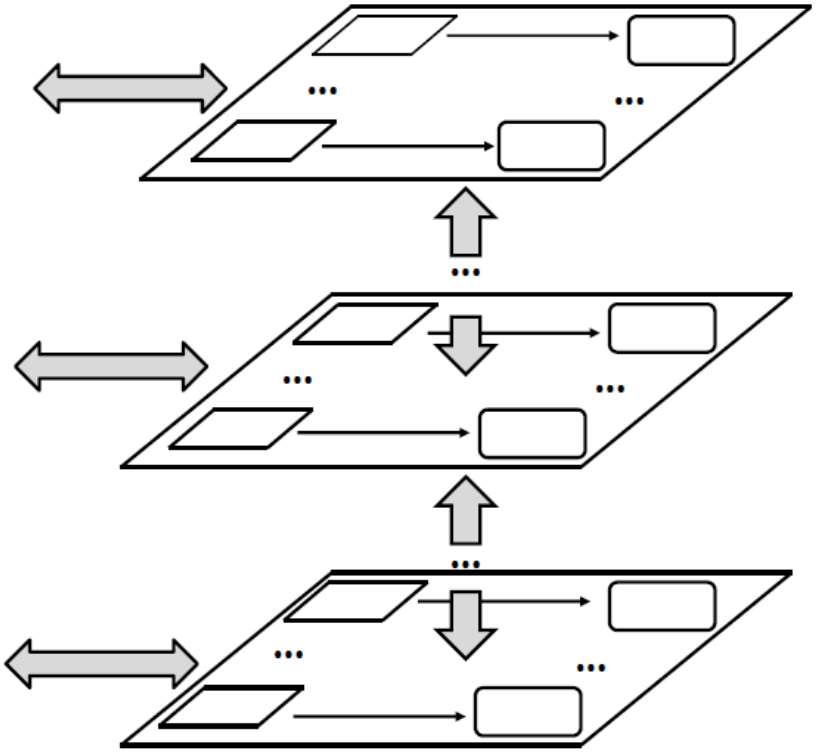
- Making progress in constructing of the high quality intelligent systems
- Examples: approximation of complex vague concepts such as guards of actions or behavioral patterns
- Reasoning about vague concepts

APPLICATIONS :
APROXIMATION OF COMPLEX VAGUE CONCEPTS





HIERARCHICAL STRUCTURES



i: $\mathcal{M}_i,\ L_i,\ \|=_i$

GRANULES: $(\alpha\ , \|\alpha\ \|),\ \propto\in L_i$

$\|\alpha\ \| = \{M \in \mathcal{M}_i : M\ \|=_i\ \alpha\},\ \propto\in L_i$

WHAT NEXT?

ISSUES RELATED TO DATA SCIENCE:

BIG DATA GENERATED
BY
COMPLEX PHENOMENA
&
PERCEPTION AND ACTION

PHENOMENOLOGY
originated by Edmund Husserl
as a method for exploring the nature of human experience and perception

Husserl was frustrated by the idea that science and mathematics were increasingly conducted on an abstract plane [treating nature itself as a mathematical manifold] that was disconnected from human experience and human understanding, independently of questions of truth and applicability. He felt that the sciences increasingly dealt with idealized entities and internal abstractions a world apart from the concrete phenomena of daily life.

Dourish, P.: Where the Action Is. The Foundations of Embodied Interaction. The MIT Press (2004)

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

The computational method of describing the ways information is processed is usually abstract but cognition is possible only when computation is realized physically, and the physical realization is not the same thing as its description.

[…] we also need to account for how the computation is physically implemented.

[…] we need to know how the computational mechanism is embedded in the environment, which, again, is not a purely computational matter.

Miłkowski, M.: Explaining the Computational Mind. The MIT Press, Cambridge MA (2013)

BEYOND THE TURING TEST & JUDGMENT

The Turing test, as originally conceived, focused on language and reasoning; **problems of perception and action were conspicuously absent**. The proposed tests will provide an opportunity to bring four important areas of AI research (language, reasoning, perception, and action) back into sync after each has regrettably diverged into a fairly independent area of research.

C. L. Ortitz Jr. Why we need a physically embodied Turing test and what it might look like. AI Magazine 37 (2016) 55–62.

COMPLEX SYSTEMS

Complex system: the elements are difficult to separate. This difficulty arises from the interactions between elements. Without interactions, elements can be separated. But when interactions are relevant, elements co-determine their future states. Thus, the future state of an element cannot be determined in isolation, as it co-depends on the states of other elements, precisely of those interacting with it.

Gershenson, C., Heylighen, F.: How can we think the complex? In: Richardson, K. (Ed.): Managing Organizational Complexity: Philosophy, Theory and Application, pp. 47–61. Information Age Publishing (2005)

CHALLENGES

Mathematics and the physical sciences made great strides for three centuries by constructing simplified models of complex phenomena, deriving, properties from the models, and verifying those properties experimentally.

This worked because the complexities ignored in the models were not the essential properties of the phenomena. **It does not work when the complexities are the essence**.

Frederick Brooks: The Mythical Man-Month: Essays on Software Engineering. Addison-Wesley, Boston, 1975. (extended Anniversary Edition in 1995).

WHAT IS A COMPUTATION ?

Two main problems of Computer Science:

What is a state?
What is a transition relation?

What's an algorithm?
Yuri Gurevich
https://www.youtube.com/watch?v=FX2J24u92GI

WHAT IS A COMPUTATION ?

It seems that we have no choice but to recognize the dependence of our mathematical knowledge (...) on physics, and that being so, it is time to abandon the classical view of computations as purely logical notion independent of that of computation as a physical process.

David Deutsch, Artur Ekert,and Rossella Lupacchini, Machines, logic and quantum physics. Neural Computation 6 (2000) 265–283, p. 268

WHAT IS A COMPUTATION ?

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, Wiley 1998, (Epilogue: Inference from sparse data, p. 721)

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

SPECIAL ASPECTS OF UNCERTAINTY

The algorithms I discuss in this book are special. Unlike most algorithms, they can be run in environments unknown to the designer, and they learn by **interacting with the environment** how to act effectively in it. After sufficient **interaction** they will have expertise not provided by the designer, but extracted from the environment.

I call these algorithms **ecorithms**.

Leslie Valiant: Probably Approximately Correct. Nature's Algorithms for Learning and Prospering in a Complex World, MIT Press 2013

GRANULES & PERCEPTION

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.

GRANULES

INTERACTIVE GRANULAR COMPUTING (IGrC)

=

GrC +

INTERACTIONS +

REASONING (JUDGMENT)

ASSUMPTION

Physical objects exist in the physical space and are embedded into its parts.

Physical objects are interacting in the physical space, and thus some collections of physical objects may create dynamical systems in the physical space.

PROBLEM

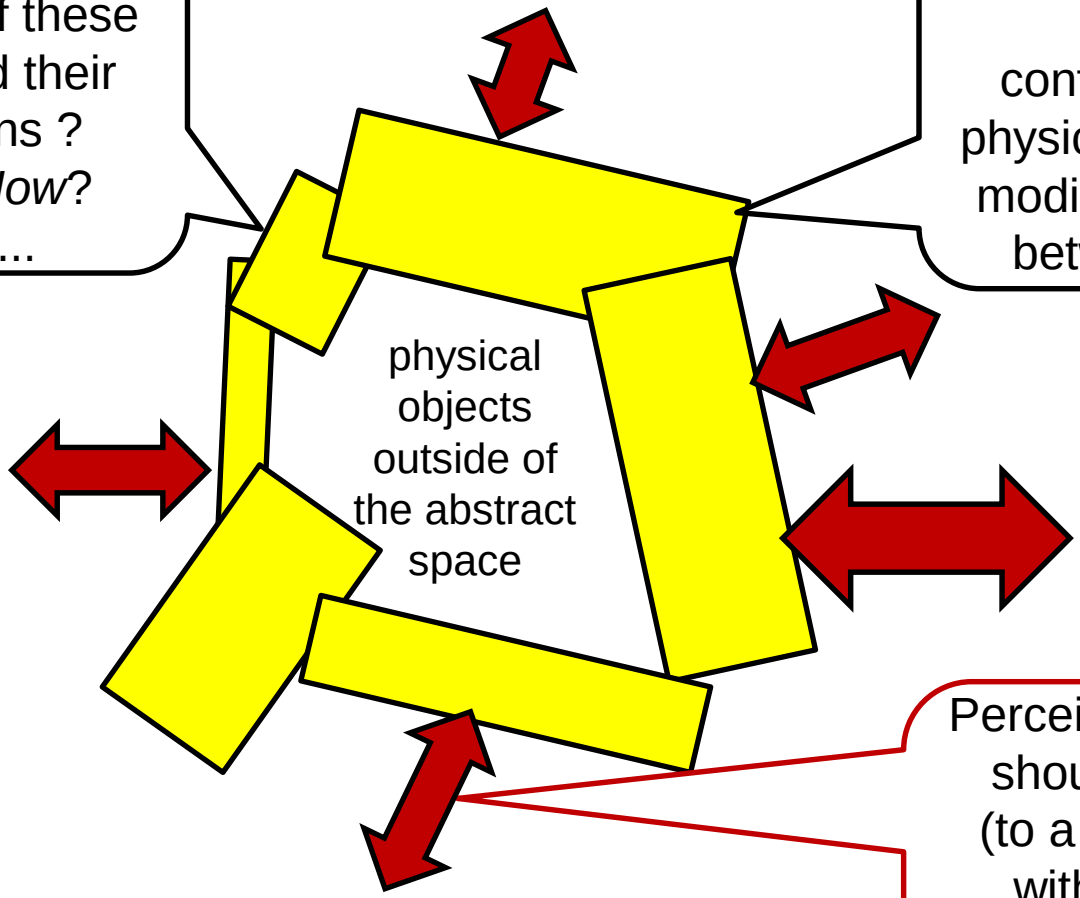
Design of c-granules with the ability of perceiving physical objects and their interactions.

This is realised by the control mechanism of c-granule based on *informational complex granules* (*ic-granules*) and a special kind of reasoning over them, called judgment.

PROBLEMS

How to perceive properties of these objects and their interactions ? *Where*? *How*? *When*?...

How to generate the relevant configurations of physical objects and modify interactions between them?

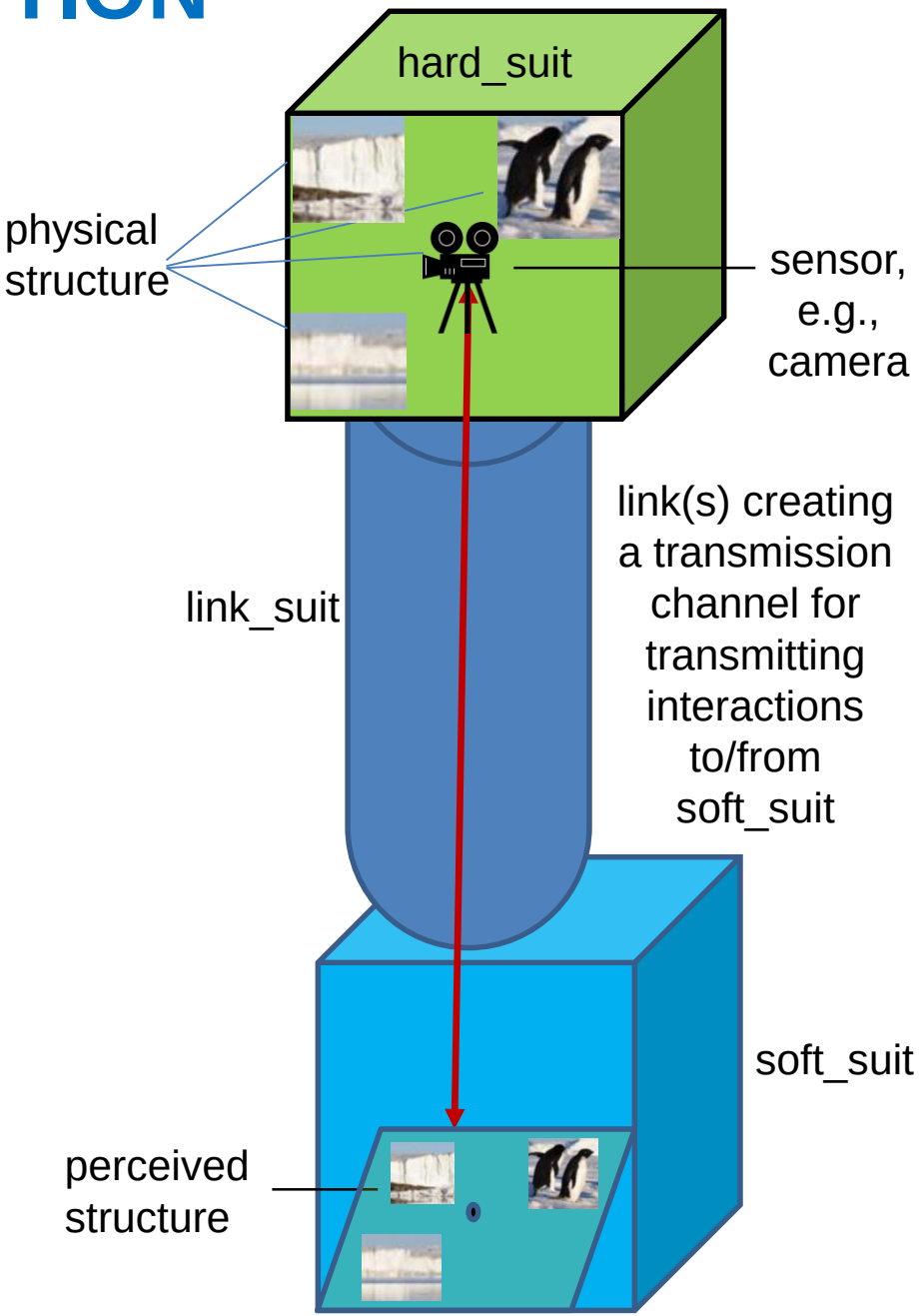


Perceived properties should be robust (to a high degree) with respect to unpredictable interactions from the environment

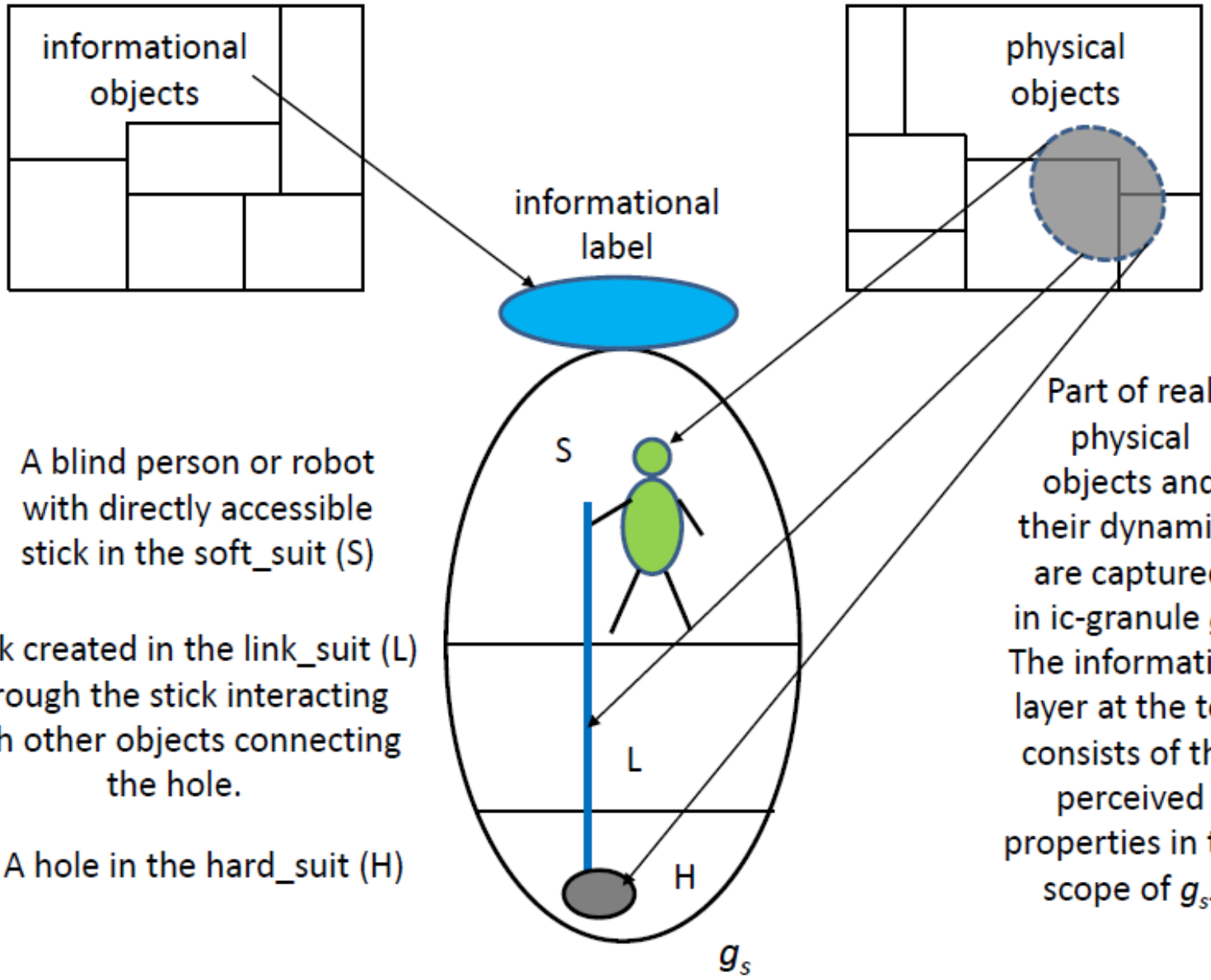
INTERACTIVE GRANULAR COMPUTING (IGrC)

- Complex granules (c-granules)
- Informational c-granules (ic-granules)
- Control of c-granules;
  - Configurations of ic-granules
  - New ic-granule generation
  - Basic control cycle
  - Reasoning (judgment)

C-GRANULE : INTUITION



EXAMPLE



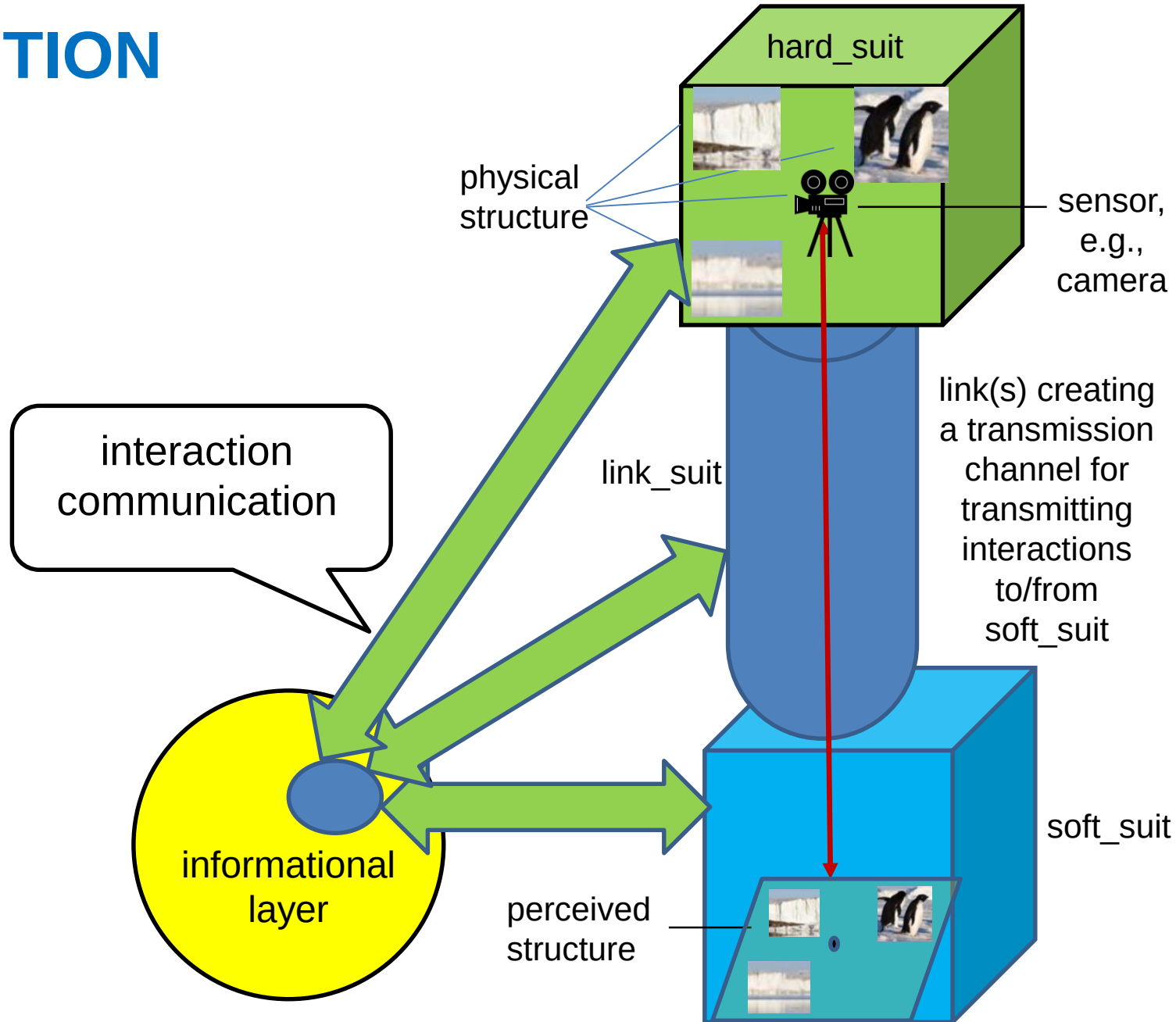
A blind person or robot with directly accessible stick in the soft_suit (S)

A link created in the link_suit (L) through the stick interacting with other objects connecting the hole.

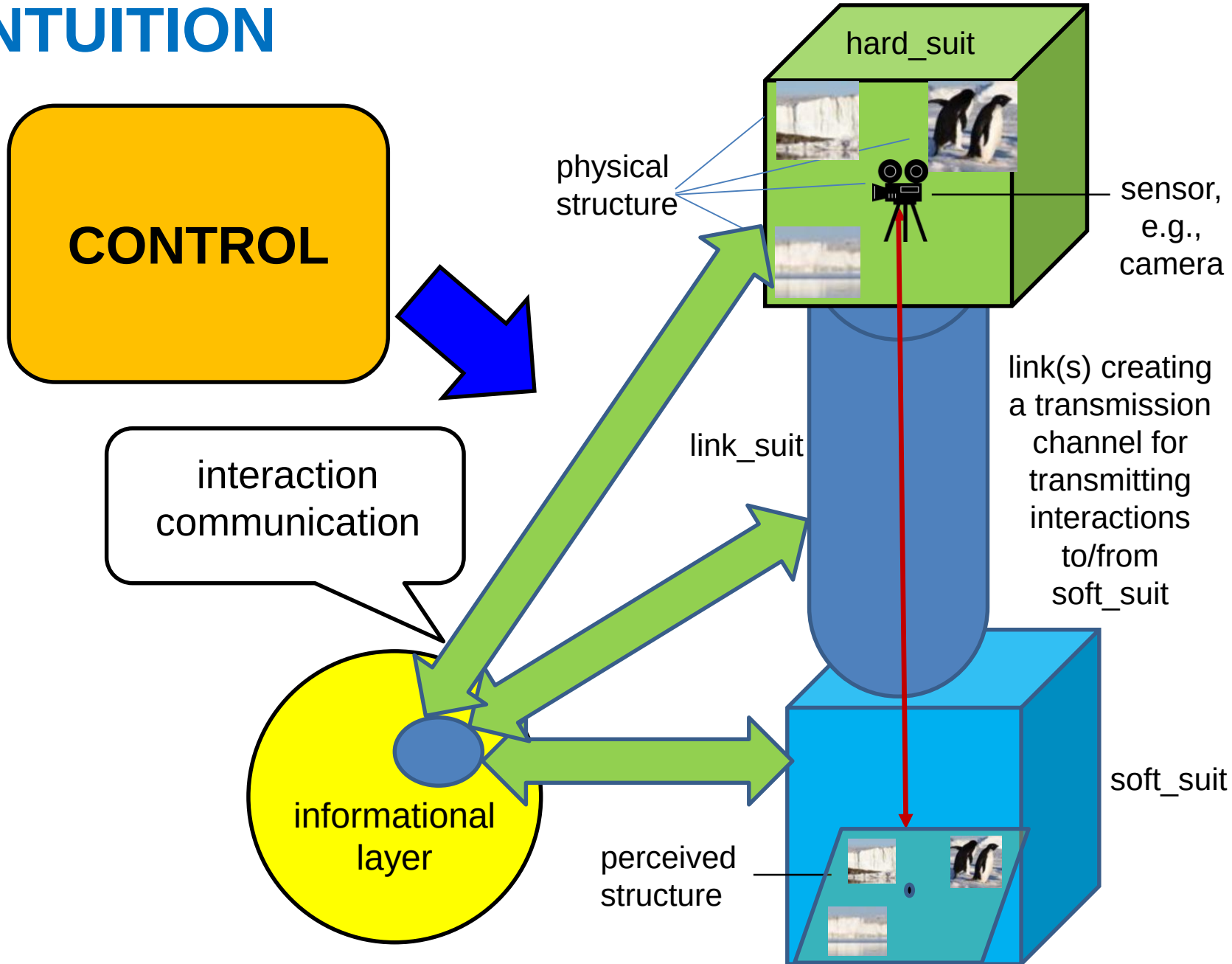
A hole in the hard_suit (H)

Part of real physical objects and their dynamics are captured in ic-granule g_s. The information layer at the top consists of the perceived properties in the scope of g_s.

IC-GRANULE: INTUITION



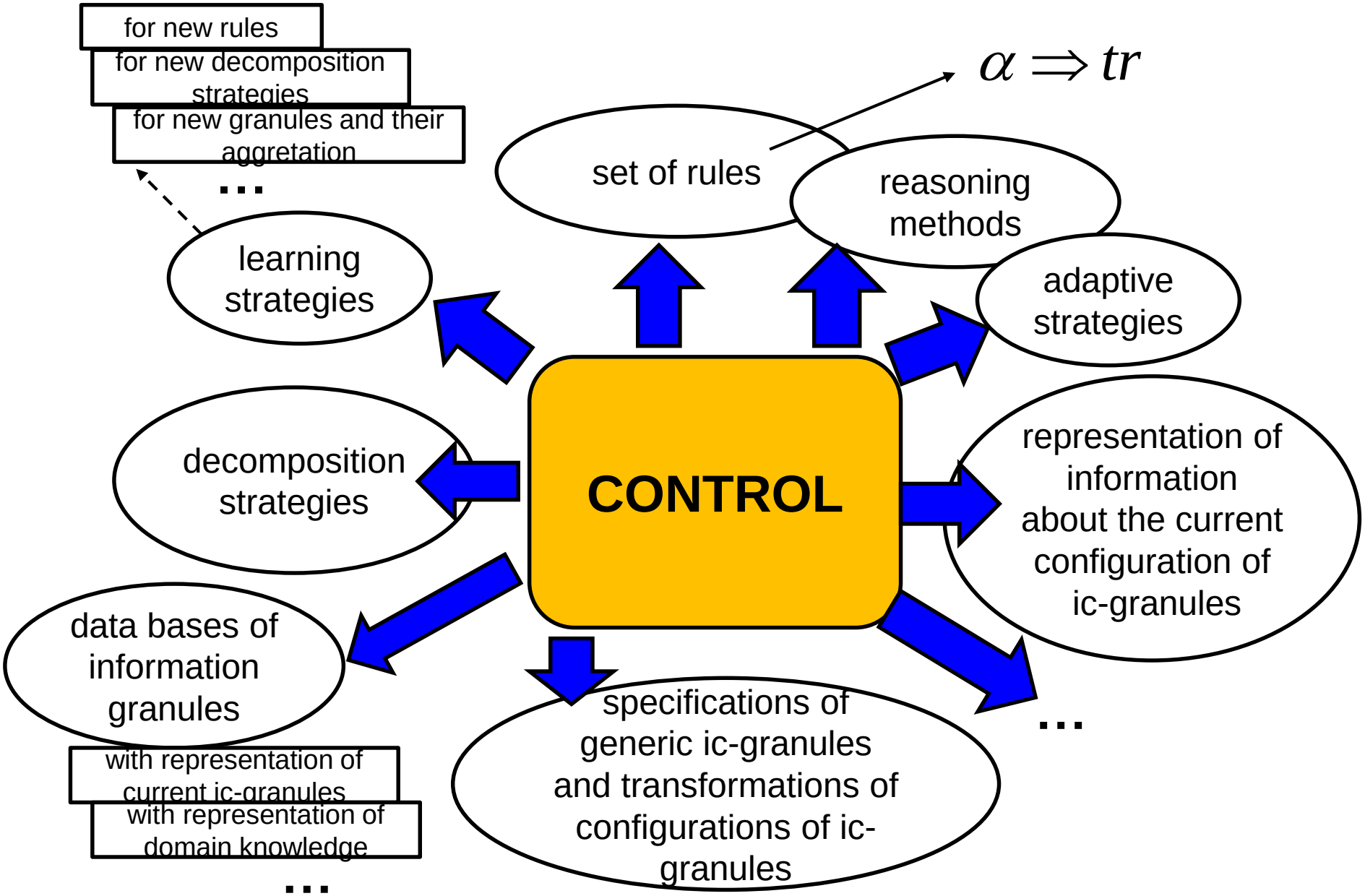
IC-GRANULE: INTUITION



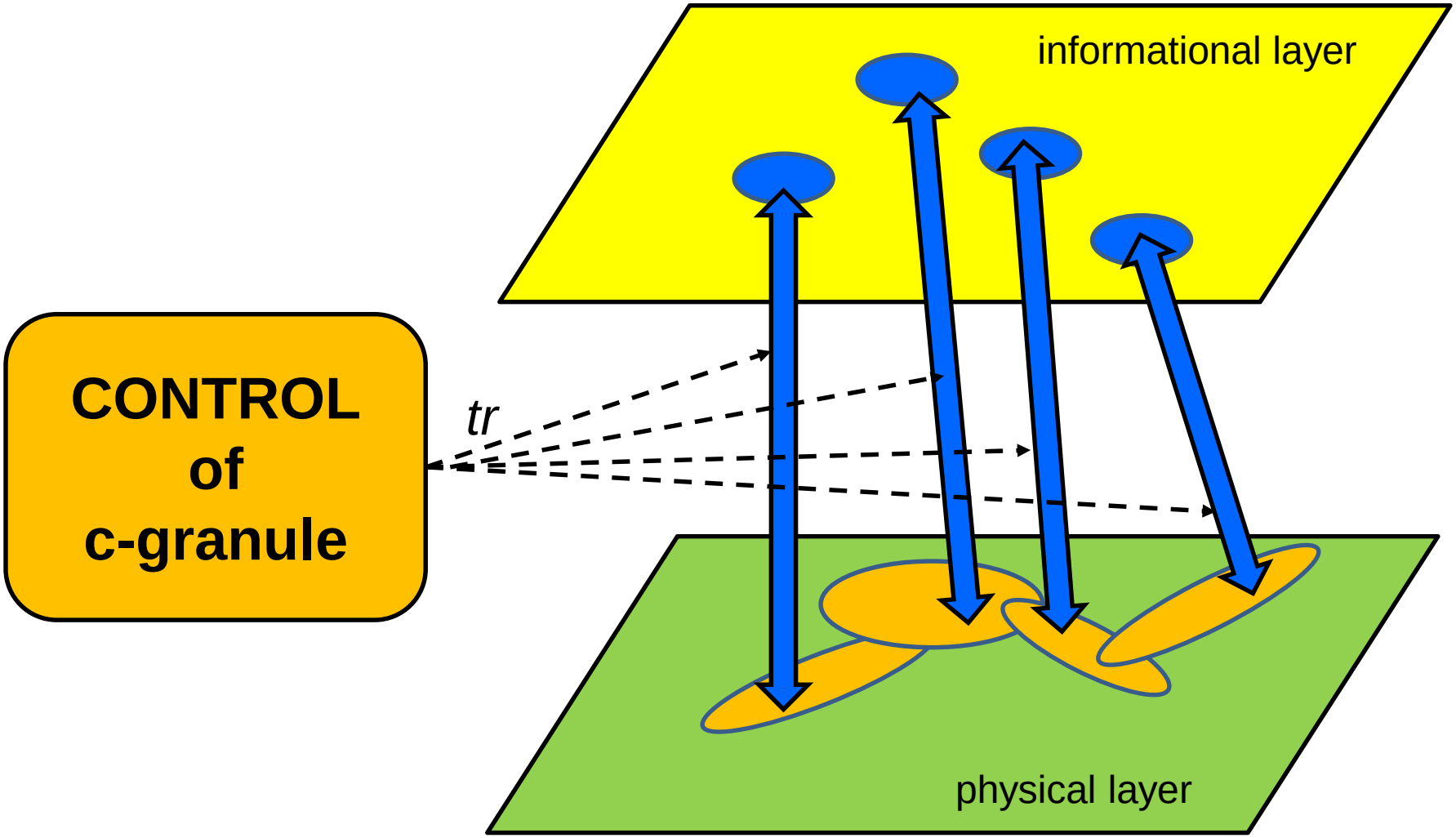
C-GRANULE CONTROL

THE OUTLINE OF THE GENERAL PROCEDURE OF COMPUTATION IN IGRC REALISED BY CONTROL OF C-GRANULE BASED ON SEARCHING FOR RELEVANT TRANSFORMATIONS OF IC-GRANULES AND THEIR IMPLEMENTATION.

CONTROL: INTUITION



CONTROL: INTUITION

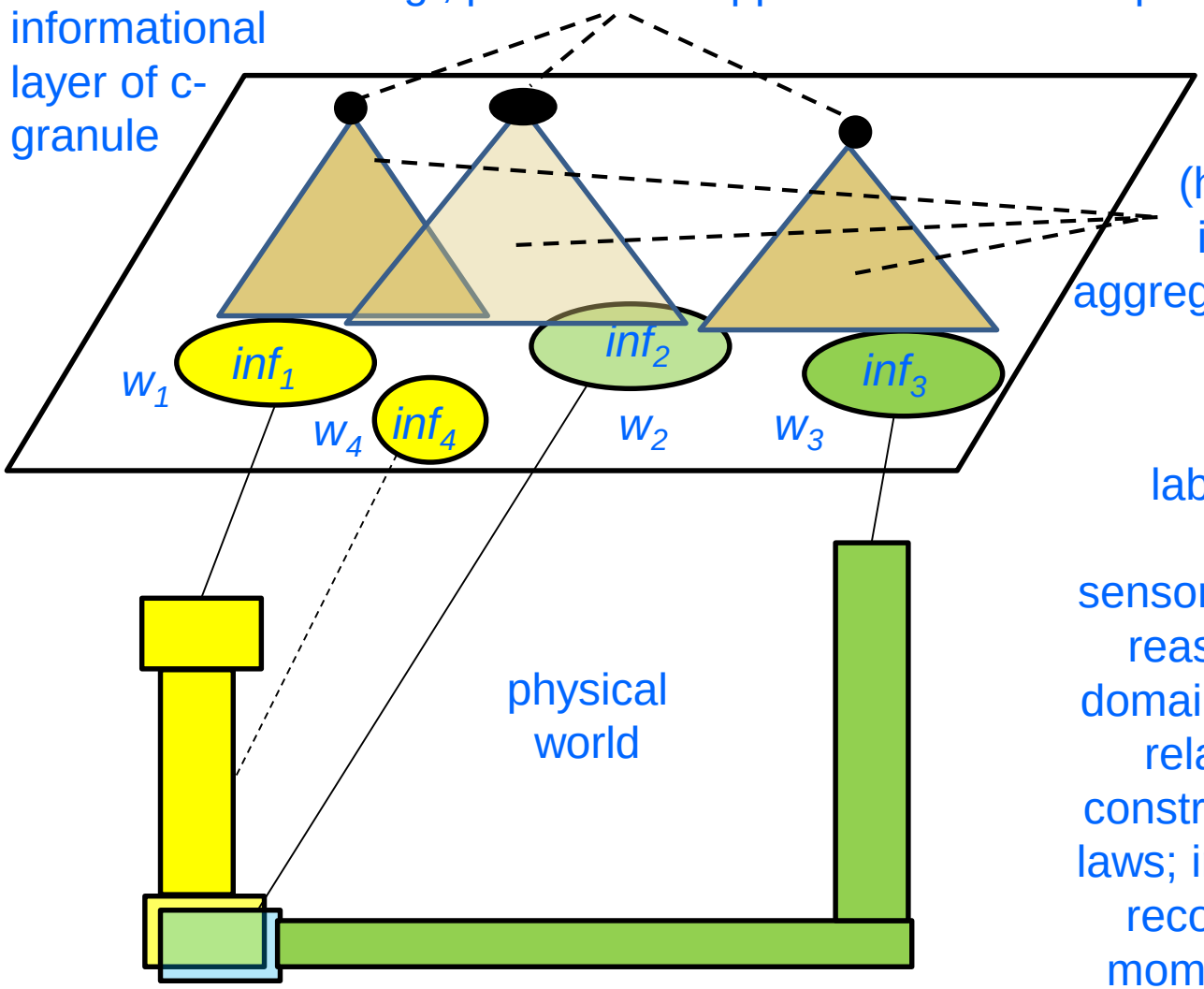


Control is able to initiate communications between the informational layer and physical layer using relevant ic- granules allowing to collect in the informational layers properties of perceived physical objects and their interactions.

SEMANTICS OF CONFIGURATIONS OF IC-GRANULES LINKED TO THE PHYSICAL WORLD

(information) granules (computational building blocks for cognition)
e.g., patterns for approximation of complex vague concepts)

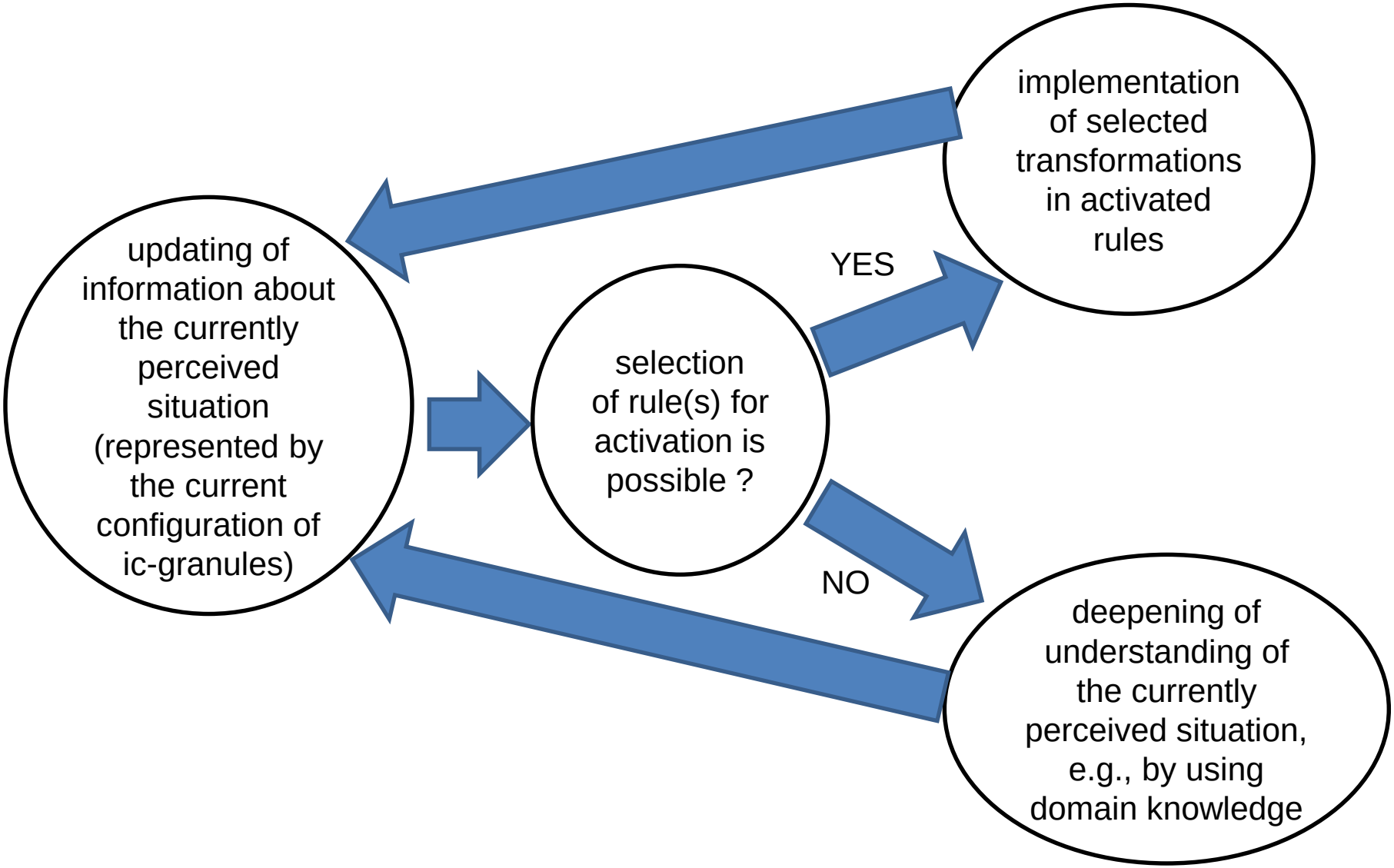
informational layer of c-granule



(hierarchical) information aggregation/granulation

information labelling windows obtained by sensors/actuators and/or reasoning based on domain knowledge (e.g., related to physical construction) or physical laws; information may be recorded in different moments of local time

CONTROL: INTUITION



CONTROL: INTUITION

set of rules of the form

property of the current configuration of ic-granules

$$\alpha \Rightarrow tr$$

formal specification of transformation of the current configuration of ic-granules

FORMAL SPECIFICATION OF CONFIGURATIONS OF IC-GRANULES

- A family of spatio-temporal windows labelled by information

$$N(t)=\{(w_1,inf_1),\ldots,(w_i,inf_i),\ldots,(w_n,inf_n)\}$$

where t is a local time of c-granule and inf_i is information gathered by c-granule (through its ic-granules) up to t about physical objects located in the part(s) of the physical space corresponding to w_i.

- Properties

$$\alpha_1,\ldots,\alpha_i,\ldots,\alpha_m$$

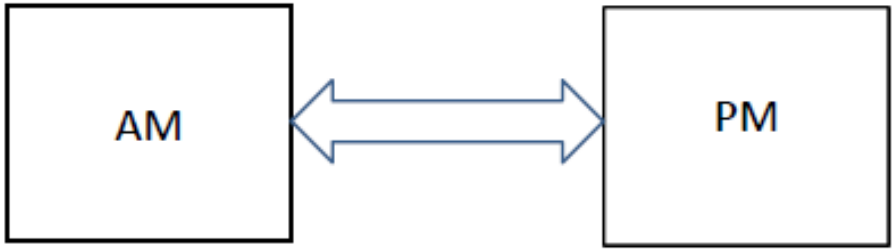
of $N(t)$, e.g., reflecting dependencies of parts of $N(t)$ at t (or over time).

FORMAL SPECIFICATION OF CONFIGURATIONS OF IC-GRANULES : EXAMPLES

- w_i : small spatial neighbourhood around a given point,
- inf_i : a time series (or its aggregation/granulation) with properties labelling points of local time of c-granule up to *t,*
- inf_i : information (decision) systems with objects being fragments (time widows) of time series and attributes describing properties of these windows
- properties:
  - w_i and w_j specify close regions,
  - if object pointed by w_i has property α at t_1 then object pointed by w_j has property β starting from time t_2 , assuming that transmission channel pointed by w_j works correctly,
  - if $N(t_1)$ has property α then $N(t_2)$ has property β *for* $t_2 > t_1$ *and* t_2 close to t_1.

C-GRANULE CONTROL: INTERACTING ABSTRACT AND PHYSICAL MODULES

Interacting abstract (AM) and physical (PM) modules



AM module sends to PM a formal specification of ic-granule transformation. In case when the delivered specification to PM can be directly implemented by PM in the physical world then PM, by creating a network of interacting ic-granules (interacting physical pointers) is aiming to generate perceived by AM information matching the expected properties (expressed formally in AM). Otherwise, PM sends to AM a message about the necessity of the specification decomposition.

How can the representation and algorithm be realized physically?

D. Marr: Vision. MIT Press 2010.

DECOMPOSITION OF TRANSFORMATION SPECIFICATION

Transformation specification *tr* from an ic-granule with property α to an ic-granule with property β available at the planner ic-granule g_0

$$\alpha : g_0 \Rightarrow_{tr} \beta : g$$

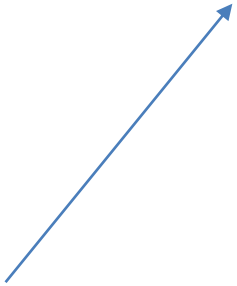
$$\propto: g_o \Rightarrow_{tr_1} \alpha_1: g_1 \quad \alpha_1: g_1 \Rightarrow_{tr_2} \beta: g$$

$$\dots$$

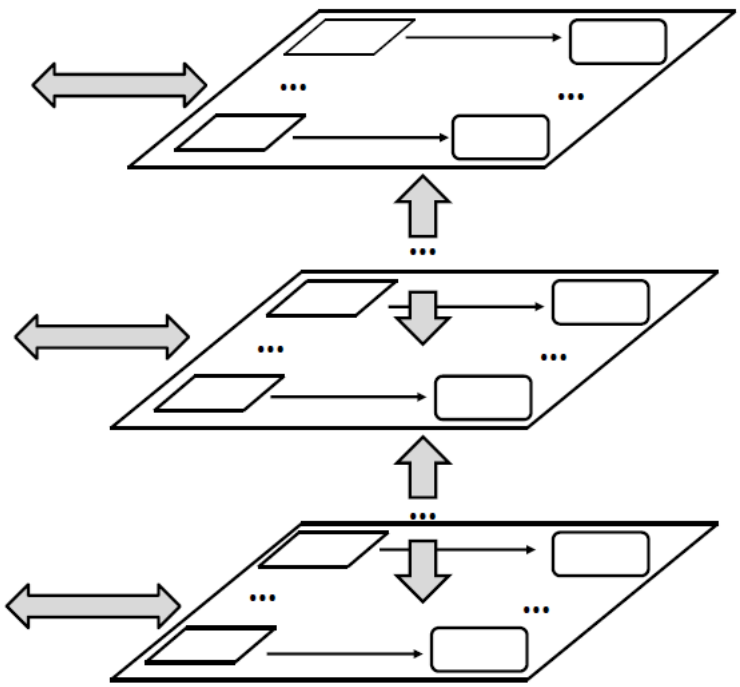
$$\propto: g_o \Rightarrow_{tr_1} \alpha_1: g_1 \quad \dots \quad \alpha_{k-1}: g_{k-1} \Rightarrow_{tr_k} \beta: g$$

REASONING
&
IGrC

REASONING (JUDGMENT) REALISED OVER INTERACTIVE COMPUTATIONS SUPPORTING REALISATION OF PERCEPTION



i.e. understanding the perceived situation to satisfactory degree for making the right decisions



JUDGMENT SUPPORTING -- IN CONTINUOUS INTERACTION WITH THE PHYSICAL WORLD -- DISCOVERY OF RELEVANT STRUCTURES AND COMPUTATIONAL BUILDING BLOCKS (GRANUES) OVER THEM FOR COGNITION

LESLIE VALIANT: TURING AWARD 2010

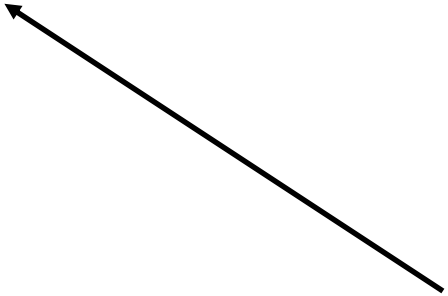
.

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.

power of judging rightly and following the soundest course of action, based on knowledge, experience, understanding, …
Webster's New World College Dictionary



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.

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

JUDGMENT

Reliability of inductive reasoning based on statistical learning theory based on VC-dim.

Harman, S. Kulkarni: Reliable Reasoning: Induction and Statistical Learning Theory. The MIT Press, 2007.

DEDUCTION

INDUCTION

ABDUCTION

…

figures in:
explanation of behavior,
inference,
experience.

Hence the theory of judgment has a place in: psychology, logic, phenomenology.

Wayne M. Martin: Theories of Judgment. Psychology, Logic, Phenomenology. Cambridge Univ. Press (2006).

PRACTICAL JUDGMENT

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

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. Zadeh: 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)

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)

MELANIE MITCHELL

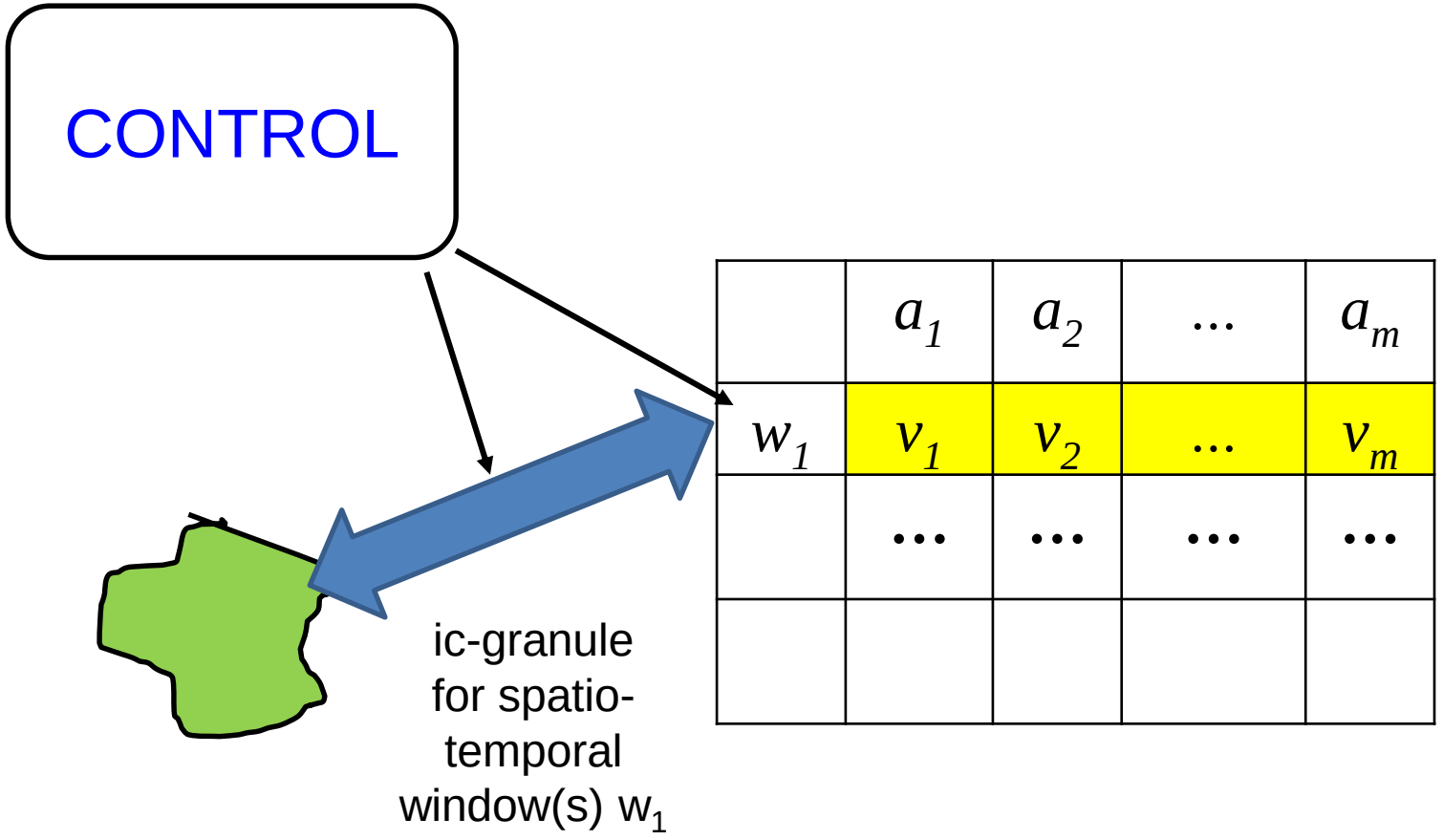
Santa Fe Institute

The quest for machines that can make abstractions and analogies is as old as the AI field itself, but the problem remains almost completely open.

Melanie Mitchell: Abstraction and Analogy-Making in Artificial Intelligence, Annals Reports of the New York Academy of Sciences 1505(1) 79-101 (2021)

IGrC
IN
DIFFERENT DOMAINS

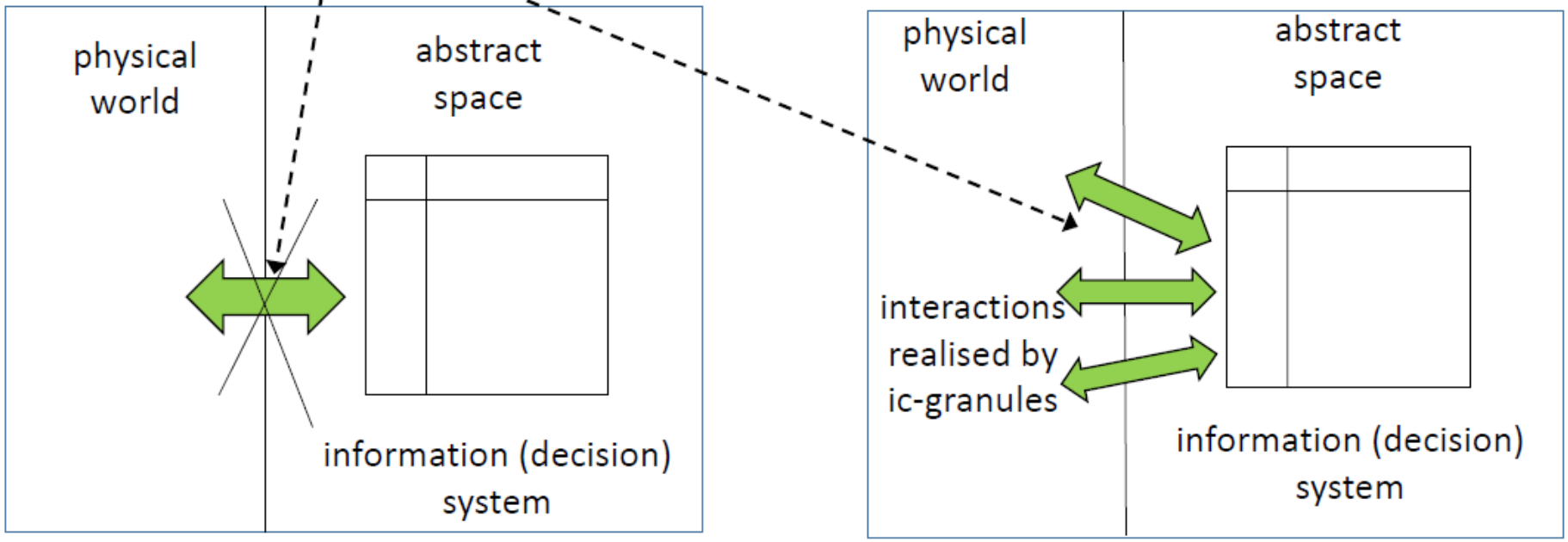
UNCERTAINTY IN OBJECT PERCEPTION INDISCERNIBILITY RELATIONS



	a_1	a_2	…	a_m
w_1	v_1	v_2	…	v_m
	…	…	…	…

ROUGH SETS: PERCEPTUAL APPROACH

Continuous interaction with the real-physical world for perceiving (understanding) the situation on the way to make the right decisions

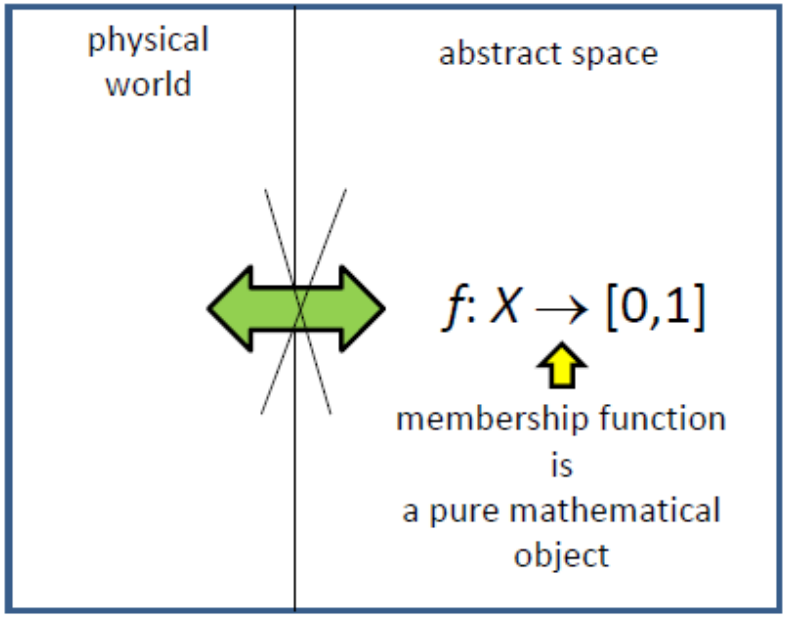


In the existing approach to rough sets interactions with the physical world are eliminated. Attributes are mathematical functions.

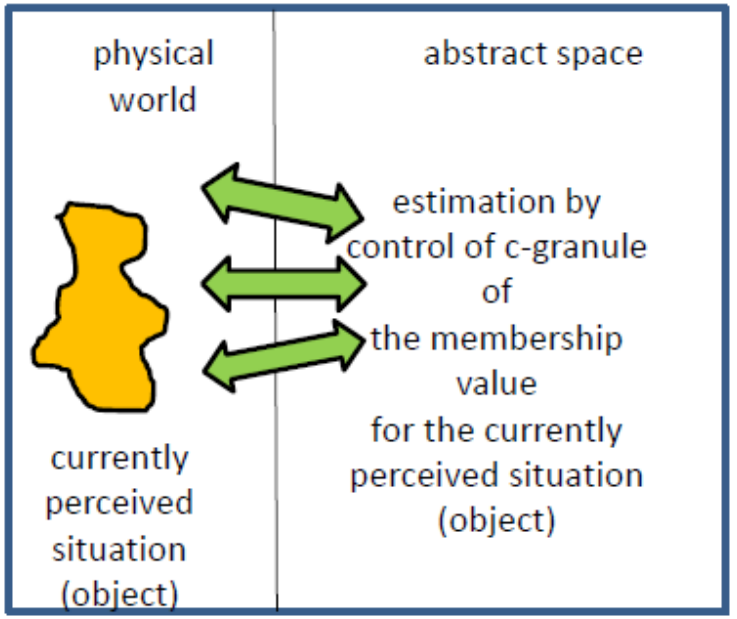
Rough sets in IGrC:

- perceiving values of attributes are based on interactions with the physical world.
- attributes are not pure mathematical functions; they are realised by ic-granules.

FUZZY SETS: PERCEPTUAL APPROACH



Fuzzy membership functions are pure mathematical objects.
According to the cited opinion by Frederick Brooks their models, being often models of vague concepts related to complex phenomena, can't be constructed (induced) using traditional mathematical modeling.
Existing approaches to modelling of fuzzy membership functions should be enriched by mechanisms for continuous interaction with the physical real world for perception of the current situation making it possible to estimate membership values.



Fuzzy sets in IGrC:
fuzzy membership value for the currently perceived situation in the real physical world is estimated on the basis of perceived data by ic-granules dynamically interacting with the real physical world up to the moment when understanding of the perceived situation is satisfactory for making this estimation by control of c-granule.

RS AND COMPLEX PHENOMENA: WHAT NEXT?

REASONING ABOUT CHANGES: ROUGH CALCULUS

Two main problems
of
Computer Science:

What is a state?
What is a transition relation?

What's an algorithm?
Yuri Gurevich
https://www.youtube.com/watch?v=FX2J24u92GI

$$\frac{ds}{dt} \overset{?}{=} G(t, s(t), e(t))$$

$$?$$

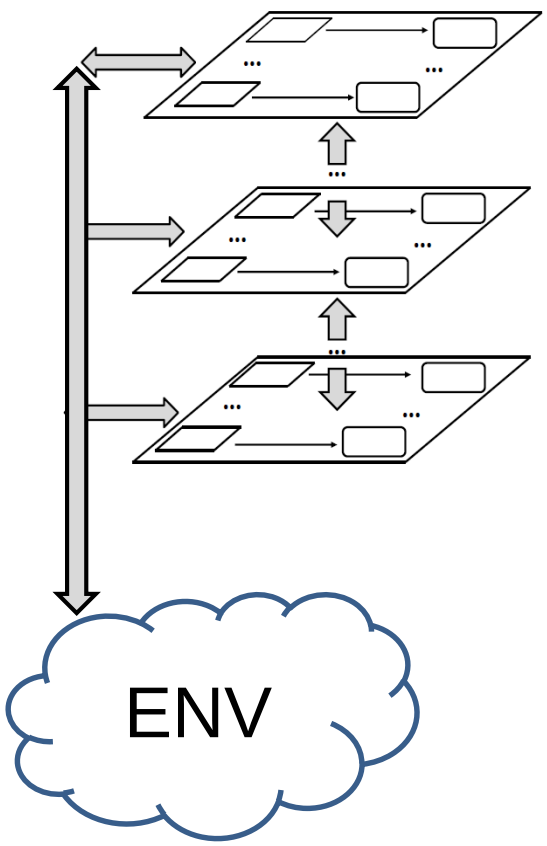
$$\frac{de}{dt} \overset{?}{=} H(t, s(t), e(t))$$

Mathematics and the physical sciences made great strides for three centuries by constructing simplified models of complex phenomena, deriving, properties from the models, and verifying those properties experimentally. This worked because the complexities ignored in the models were not the essential properties of the phenomena. It does not work when the complexities are the essence.

Frederick Brooks: The Mythical Man-Month: Essays on Software Engineering. Addison-Wesley, Boston, 1975. (extended Anniversary Edition in 1995).

RS AND COMPLEX PHENOMENA: WHAT NEXT?

REASONING ABOUT CHANGES: ROUGH CALCULUS



ROUGH SETS
IN INTELIGENT SYSTEMS
DEALING WITH COMPLEX PHENOMNA:

SPACE OF REASONING CONSTRUCTED OVER DYNAMIC STRUCTURES BASED ON INTERACTIVE GRANULAR COMPUTATIONS
(NOT PURELY MATHEMATICAL!)
AS
THE BASIS FOR APPROXIMATE REASONING, IN PARTICULAR FOR CONCEPT (CLASSIFICATION) APPROXIMATION IN INTELLIGENT SYSTEMS

RS:
DYNAMIC SPACE
OF REASONING CONSTRUCTIONS
(NOT PURELY MATHEMATICAL!)
AS
THE BASIS
FOR CONCEPT (CLASSIFICATION)
APPROXIMATION

IGrC creates the basis for dynamically changing reasoning constructions, used for approximation of concepts (classifications) in Interactive Intelligent Systems. The required reasoning methods are far more rich than nowadays used in constructing the rough set-based approximations of concepts.

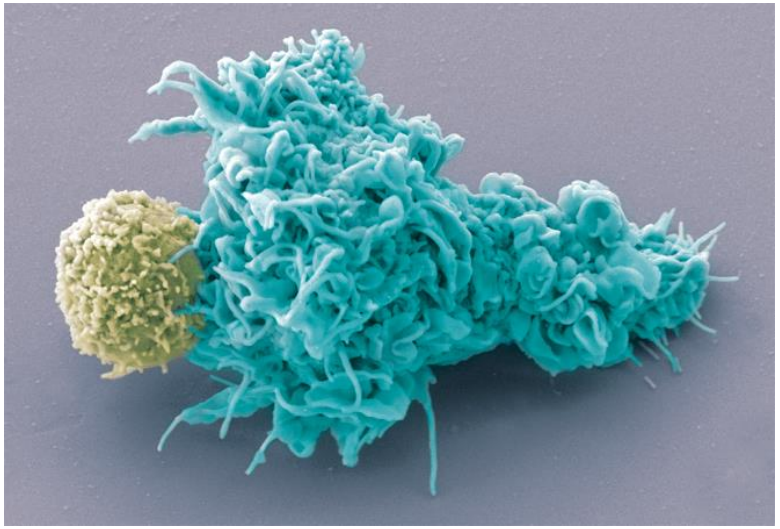
HOW TO CONTROL COMPUTATIONS IN INTERACTIVE INTELLIGENT SYSTEMS (IIS) ?

***

RISK MANAGEMENT IN IIS

MULTISCALING

[…] 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

IGrC
IN
DATA SCIENCE

COLLECTIVE INTELLIGENCE

INTELLIGENCE UNDERSTANDING

...

SUMMARY

We discussed
IGrC model
as the base for design
Decision Support Systems
(Intelligent Systems)
dealing with complex phenomena.

The aim was to explain how the IGrC computing model has the potential to handle the grounding problem by bridging a connection between the abstract mathematical modeling and the real physical semantics.

We discussed some aspects of modelling of reasoning (ADAPTIVE) JUDGMENT on which the behavior of decision support systems dealing with complex phenomena should be based.

We outlined some aspects of the PERCEPTUAL ROUGH SET APPROACH.

https://dblp.uni-trier.de/pers/hd/s/Skowron:Andrzej

THANK YOU!