The 2-nd Interdisciplinary Workshop

What is Information?

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Information?.. It is very simple…

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What is Information? – Everybody knows that!..

But a consensus definition of it does not exist.

(C. Zins in his 2007 paper has documented more than 130 definitions of data, information, and knowledge formulated by 45 distinguished scholars).

It is generally agreed that human intelligence is determined by the brain's ability to process information.

(S. Legg & M. Hutter in their 2007 paper provide more than 70 definitions of intelligence).

This multiplicity of definitions manifests the lack of clarity about what is information and what are the mysteries of information processing.

(That was the reason that forced me to try and to pave my own way into the jungle of indefinable information related issues).

My research was inspired by mid-1960s work of three prominent thinkers: Solomonoff, Kolmogorov, and Chaitin.

What follows from their arguments is:

- If data elements in a given data set are not random they naturally arrange themselves into clusters of data structures.
- These data structures are shaped by the similarity in physical properties of the neighboring data elements.

- For this reason, such data clusters (structures) can be called Primary or Physical data structures.

- In the eyes of an external observer, these primary data structures are further grouped into more large and complex agglomerations. Such agglomerations of primary data structures can be called Secondary data structures.

- While primary data structures are shaped by physical properties of their data elements, secondary structures reflect external observer views on the arrangement of primary data structures.
- External observer views are biased and subjective. Therefore secondary data structures can be called Meaningful or Semantic data structures.

As Kolmogorov's Complexity Theory posits:

- Every data set can be faithfully represented by a consecutive enumeration of its data elements.
- Structured data set can be represented by much shorter descriptions of its composing data structures.
- Each such description can be seen as a program that, when executed, faithfully reconstructs the initial primary data structure.

- Kolmogorov called such descriptions – "Information".
- Chaitin called such descriptions – "Algorithmic Information".

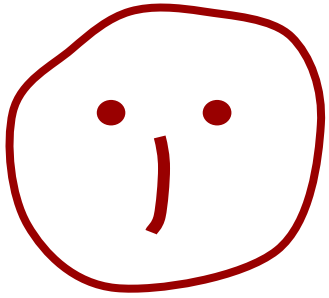
- Following their insights, I propose to call
  descriptions of primary data structures "Physical Information"
  descriptions of secondary data structures "Semantic Information" .

By defining two different types of information my approach opens a new, efficient and effective way of information handling and information processing.

It can also be learned from the Kolmogorov's Complexity Theory that:

-Information is a linguistic description of data structures.
-Information is a hierarchy of different level description details.
-Information hierarchy evolves in a top-down coarse-to-fine manner.
-Information is a composition of two interacting but non-intermixing constituents: physical information and semantic information.

As an example of an information description I would like to quote a kid recite:



"Two dots, a comma, a circular trace,
And here you have a human face."

"Two dots, a comma, a circular trace" – is physical information,
"This is a human face" – is semantic information (a declaration).

Some corollaries can be inferred from what was just said above :

- Information – Physical and Semantic as well – is a linguistic description of a data structure.
- A variety of languages can be used for such purposes. However, physical information is usually described in mathematical languages while semantic information desires special description languages (natural or artificial).
- Only physical information can be derived from a given data. Raw data itself is meaningless. Semantics is assigned to the data by an external observer.
- Physical information interpretation (understanding) comes as a result of physical information association with physical information already retained in the system's knowledge base (the system's previous knowledge).
- Such previous knowledge (semantic information retained in the system) is always provided for the system's disposal from the outside. Therefore, it can not be learned or be created within the system.
- Semantics information is usually a piece of text, a string of words, which can't be processed (as yet) by a conventional computer that is destined (today) only for simple data processing.

Here are some examples of common and widespread misunderstandings

European Commission Document "ICT Work Programme 2009/2010, (C(2009) 5893)" in its "Part 4.2 Challenge 2: Cognitive Systems, Interaction, Robotics" specifies as a problem that Robotic systems have to cope with **"extracting meaning and purpose from bursts of sensor data or strings of computer code…"**

This is a false and a misleading statement

– sensor data does not possess semantics, and therefore meaning and purpose can not be extracted from it.

DARPA's Document "Deep Learning" (RFI SN08-42) states that: **"DARPA is interested in new algorithms for learning from unlabeled data in an unsupervised manner to extract emergent symbolic representations from sensory input…"**

Again, that is a false and a misleading statement

– symbolic representations (semantics) could not be learned from data.

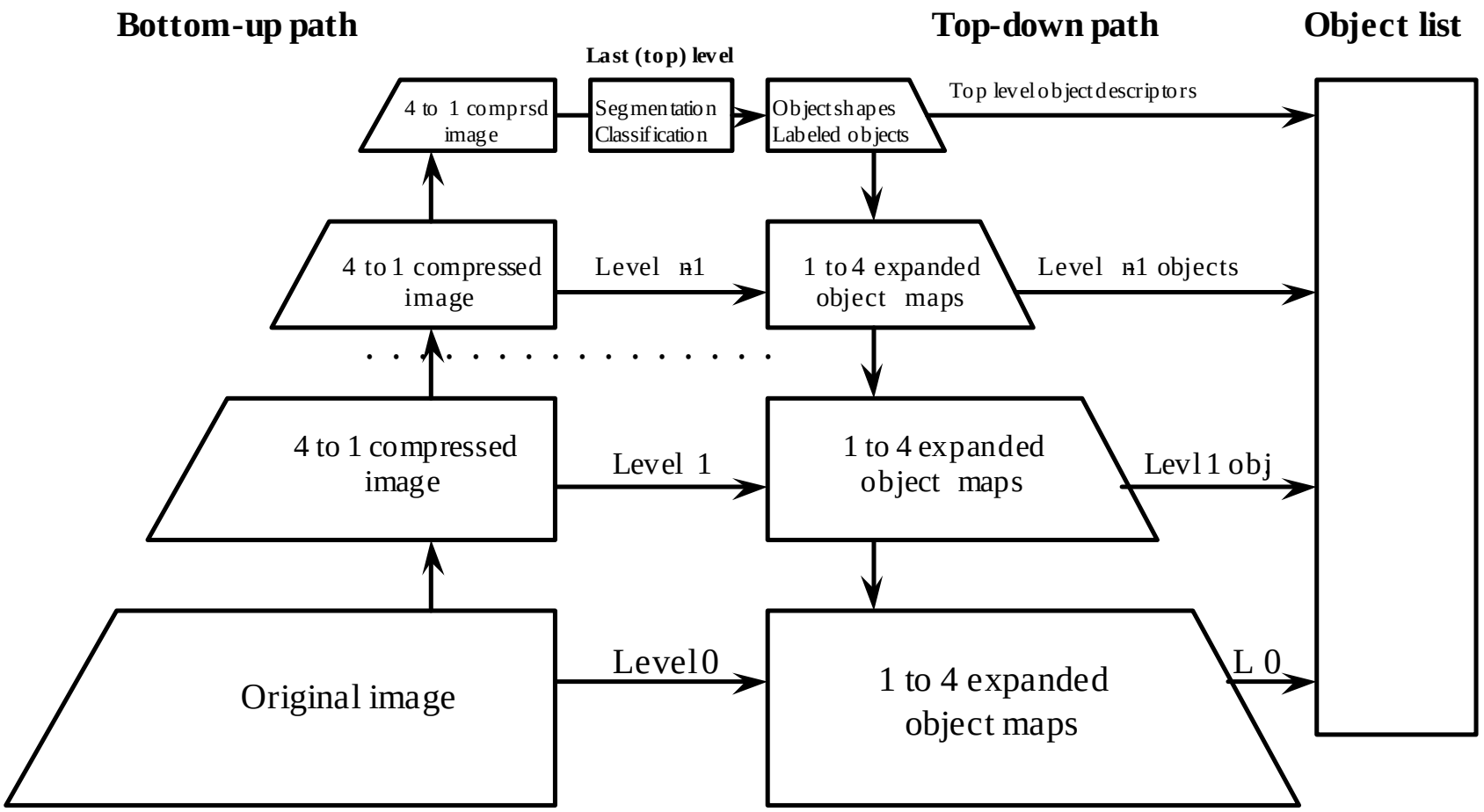
Sorry, but any attempts to reach such goals are doomed to a failure.

Thank you for your patience

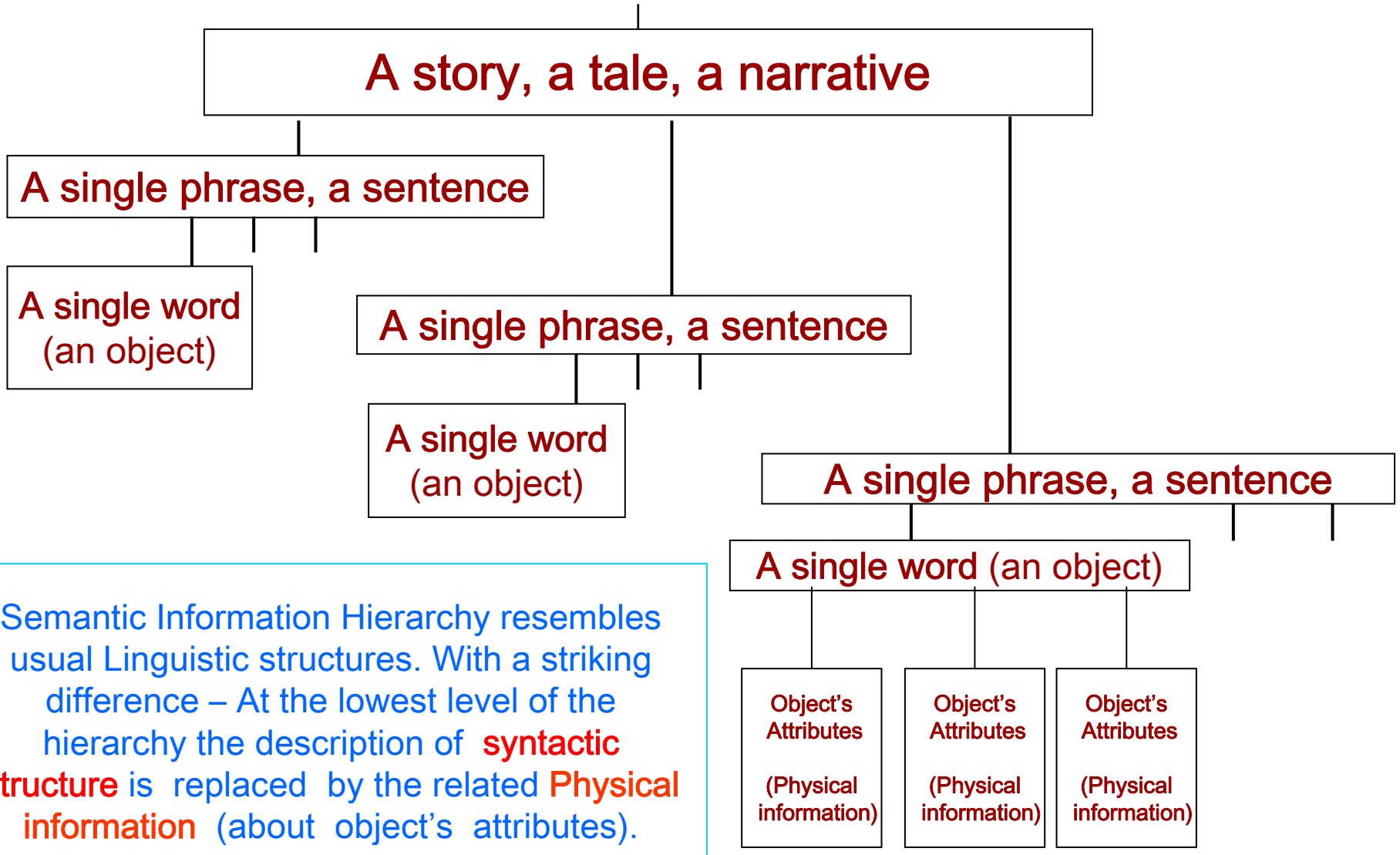
Inspired by Kolmogorov's ideas, I have proposed the following ways of information processing:

Physical Information Hierarchy

(for a visual input data)

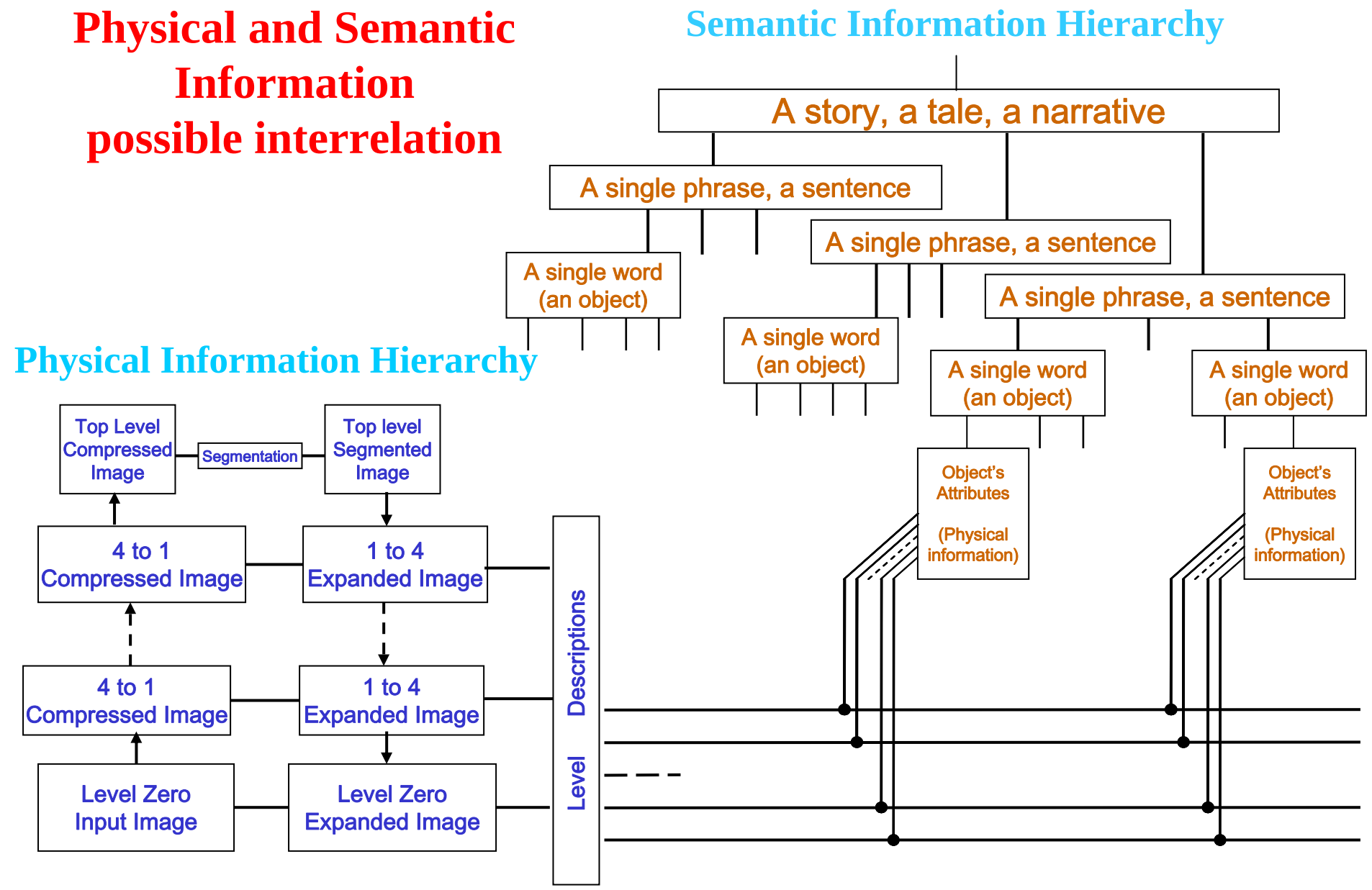


Semantic Information Hierarchy



Semantic Information Hierarchy resembles usual Linguistic structures. With a striking difference – At the lowest level of the hierarchy the description of **syntactic structure** is replaced by the related **Physical information** (about object's attributes).

Physical and Semantic Information possible interrelation



Therefore we are forced to create our own definitions. Here they are:

Data is an **agglomeration of elementary facts**. Some structure is always present in data aggregations. Two types of such structures could be distinguished – primary (or physical) structures, which arise from the similarity between nearby data elements, and secondary (meaningful or semantic) structures, which reflect the relationships between different primary (physical) structures.

Information is the **description of structures in data**. Considering the statements just given above, two types of such descriptions have to be taken into account – Physical Information and Semantic Information.

Knowledge is **memorized semantic information.** Not a higher level of information, not a different kind of information. Simply – semantic information kept in the system's memory.

Intelligence is the **system's ability to process information**. Cognitive capacity (Intelligence) of any system is definitely determined by its ability to process information. This assertion is applicable to all natural (biological, living) creatures and artificial (robotic) systems as well.

What follows
from this new information processing approach?

- Physical information is extracted from the input sensor data (in a top-down fashion).
- Semantic information must be preserved within a system (in a top-down fashion)
- Semantic information is always provided for the system's disposal from the outside. Therefore it can not be learned or be created within the system.
- Semantics is a property of an external observer. Consequently, it is not a property of the data and therefore can not be extracted from it.
- Physical information interpretation (understanding) comes as a result of associating physical information with the system's previous knowledge (with the lowest part of semantic information retained in the system).

Physical information processing implies a **"data processing" paradigm** which can be, and without any difficulty is, implemented on conventional computers.

Semantic information processing (due to the linguistic nature of semantic information) requires a new **"information processing" paradigm** which is completely different from data processing and therefore can not be implemented on a conventional computer (as yet).

What stems from the above conclusions?

- Semantic information is a mutual agreement, a convention, a shared arrangement between members of a specific observer group (Obviously, a robot can be a part of such a group). Therefore, semantic information can't be accessible to any who is not a member of a group. Therefore, semantic information can not be derived from the available data and can not be learned from data in any way or by any means.
- Considering Robotics as a data-processing computational task is a fatal misunderstanding that has derailed its development for more than 50 years.

These are the main flaws that Artificial Intelligence (in general) and Cognitive Robotics (in particular) usually hold as their first design principles. We can only regret that.