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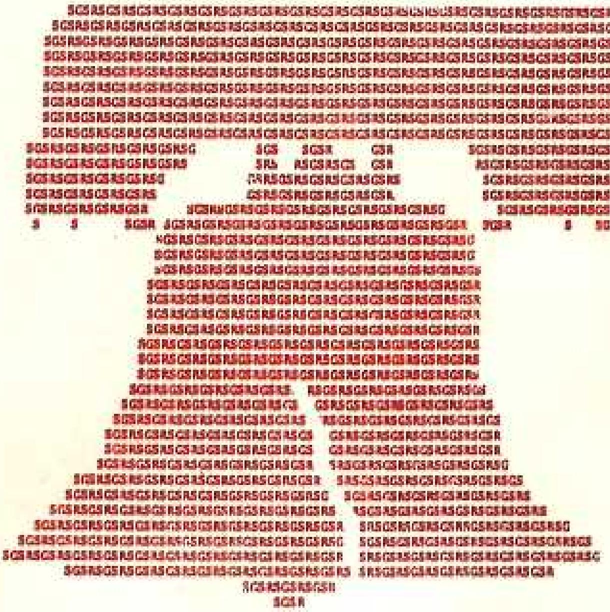
ON

MENTAL IMAGES, VALUES, & REALITY



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NATURAL NUCLEAR COMPUTERS: A CONCEPTUAL MODEL FOR HUMAN INTELLIGENCE

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ABSTRACT

The nucleo-genesis or com-putation of chemical elements from an initial alphabet of nucleons during the evolution of a massive star is compared with the com-putation of words and sentences during the learning process of a human mind. Empirical evidence shows the isomorphic statistical structure of a star in terms of chemical frequencies. We advance the hypothesis of an underlying isomorphic self-organizational core process by which learning and evolutionary processes in general take place.

1. INTRODUCTION

"Things arise in space, as thoughts arise in mind." (Parmenides)

The fundamental question that must be answered by the fifth generation of information technology in the important area of machine intelligence is: "What is the nature of the general human learning process?" (Marcer, 1984).

One of the objectives of General Systems Theory is to bridge the gaps between the disciplines in identifying transdisciplinary concepts or isomorphies, which permit the transfer of models from one discipline to another. As a consequence any GST approach must deanthopomorphize mental images in order to arrive at truly transdisciplinary concepts. "Learning", "Memory", and "Intelligence" are typical examples of anthropomorphic concepts taken from the imagery of everyday language.

We easily accept to transfer these concepts to living entities like mice and rats finding their way through a labyrinth, but somehow we resent to apply the concepts of learning and intelligence to "non-living" systems. (Probably by fear or being accused of non-scientific regression into a primitive animism.) Astrophysicists use several anthropomorphic or biological concepts like "birth", "death", and "life-cycles" of stars, but analogies between stellar evolution and biological evolution have to our knowledge never been seriously taken into consideration (Pecker, 1981). Analogies between astrophysical processes and human intelligence seem even further out and reserved to authors of science fiction (Hoyle, 1983).

2. LINGUISTIC AND ASTROPHYSICAL STRUCTURES

Human language can be considered as the result of a com-putation (latin: putting together) of a finite alphabet of letters or phonems. The com-puted entities are called words. Com-puted words are called phrases; com-puted phrases are called speech or text. Com-puted texts are called journals or books. Com-puted journals and books are called libraries. (The number of levels in the nested hierarchical classification depends on the "resolution" of the conceptual tools describing the linguistic phenomena.)

According to present astrophysical theory the observed phenomena in the universe can be considered as the result of a computation of a finite alphabet of elementary particles. Com-puted nucleons are called atoms or chemical elements. Com-puted atoms are called stars. Com-puted stars are called galaxies. Com-puted galaxies are called clusters and com-puted clusters are called hyper-clusters. (Again the number of levels in the nested hierarchical classification depends on the "resolution" of the tools permitting the observation of astrophysical phenomena.)

So far we have only underlined the common aspect of nested hierarchical structure in the two fields and any analogy still seems farfetched.

A further observation of common characteristics concerns the "sizes" of the com-puted objects in the two fields. Analyzing a given text of human language we can classify its content into words and count the frequency of occurrence of each word-type. Some words occur with an extremely high frequency, while others are extremely rare. The distributions of word-frequencies in all natural human languages show such a behavior of skewed distribution. The quantitative analysis of empirical data comes up with a suprising result: the text of James Joyces "Ulysses", the texts of American Newspapers, German, French, Latin, and Chinese texts covering several thousand years of history and even the bubbling of babies show the same statistical structure, which can be described by the simple Zipf-Pareto law (Zipf., 1948). This isomorphy of statistical structure suggests a common underlying generative or organizational process for the computation of language.

Analyzing an astrophysical system we can classify its content into chemical elements and count the frequency of occurrence of each element-type. Some elements occur with an extremely high frequency, while others are extremely rare. The quantitative analysis of empirical data comes up with a surprising result: the atomic composition of a planet, the sun, or any star show the same statistical structure, which can be described by the simple Zipf-Pareto law (Winiwarter, 1985). This isomorphy of statistical structure suggests a common underlying generative or organizational process for the com-putation of astrophysical objects.

The analogy between astrophysics and human language still seems farfetched, since a similar structure does not necessarily mean similar generative processes.

3. ISOMORPHIC ORGANIZATIONAL CATEGORIES PROPOSITIONAL CALCULUS AND NUCLEAR COM-PUTATIONS

The organizational categories of "logic" human com-putation can be classified according to the symbols of propositional calculus:

1. ∃ existence
2. ~ non/not (negation)
3. ∧ et/and (conjunction)
4. ∨ vel/or (disjunction)
5. → seq/if-then (implication
6. ↔ aeq/if and only if (equivalence)

These organizational operators permit the com-putation of new viable or well-formed formulas on the basis of initial propositions.

If we consider fundamental nuclear com-putations we can identify the following organizational categories:

1. existence of nucleon
2. complementarity of proton and neutron
3. conjunction or linked couple of nucleons (deuteron)
4. disjunction or scattering of nucleons (p,p)
5. sequential linkage or tree structure of nucleons (He3)
6. modular closure of nucleons (He4 = α-particle)

These organizational categories permit the com-putation of viable nuclei based on an initial alphabet of nucleons.

Generalizing we put forward the hypothesis, that any learning process is com-putational and can be analyzed in terms of six general organizational categories:

1. unity
2. complementarity
3. conjunction
4. disjunction
5. sequential branching or tree structure
6. modular closure

The possible transitions between organizational categories during the com-putation process are illustrated by the directed graph of Figure 1.

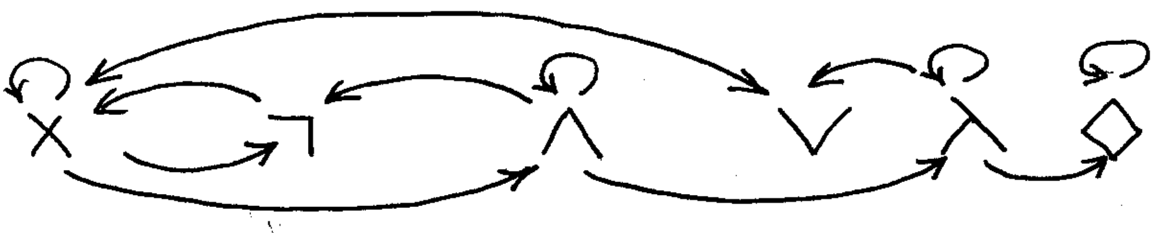


Figure 1. Graph of elementary com-putational process.

In the case of human language the strict application of propositional calculus leads to a sterile construction of a formal system without creation of new "meaning". In order to make truly new "meaningful" com-putations the semantic environment of the propositions has to be taken into account. This link between a purely formal syntactic level and a global semantic level can be considered as the core-problem of human intelligence. In principle we can simulate deductive thought processes, but so far we have no convincing model for the simulation of creative thought processes.

Taking into account the surprising organizational isomorphy between linguistic and astrophysical processes, maybe the analysis of the latter could guide us in formulating a conceptual model for this enigmatic relationship between local syntax and global semantics.

In the following we limit ourselves to the phenomenological description of local nuclear com-putations within the global environment of a massive star. We deliberately oversimplify the current astrophysical theory; the purpose of our analysis was to identify and organize the basic conceptual tools used for the modelling of a "learning process" which comprises both the local aspects of a "syntactic memory" and the global aspects of a "semantic environment".

4.1. Local elements, global field

Transposing the "images" of nucleo-genesis within a massive star to a learning process of an intelligent system, we can describe the evolution of the system in an analogous way. (In the following we use the attribute gnostic for all concepts refering to a general "learning" process of an "intelligent" system.)

The initial gnostic system can be described in terms of an alphabet of local gnostic elements.

A local inhomegeneity in the distribution of gnostic elements creates a gradient within the global gnostic field leading to an attraction of gnostic elements from the periphery of the field and to a concentration of gnostic elements around a central attractor. (See Figure 2.)

Note that the organizing field is not an "external environment", but the collective or cooperative effect of all individual elements. We therefore can speak of a "self-organizational" process (Winiwarter, 1986).

4.2. Threshold for Com-putation
Local modules - global core

Despite frequent encounters the individual gnostic elements do not com-pute temporally stable formulas. A medium range repulsive field surrounding the individual gnostic element prevents them from forming stable links.

The global gnostic field continues to concentrate gnostic elements around the central attractor until a critical threshold density is reached.

The gnostic system can now be described as a global shell, in which no com-putations take place, and a global core in which local gnostic elements are com-puted. The attractive forces of the long-range field exceed the repulsive forces of the medium-range field and permit the action of a short-range attractive field.

The com-puted gnostic formulas can be classified into the six organizational categories of section 3 and the com-putation process follows the directions indicated by the graph of Figure 1 (from unity to complementarity, from complementarity to conjunction and disjunction, from conjunction and disjunction to sequential branching or tree structure, from tree structure to modular closure).

Unity and closed modules can be considered as extremely stable; conjunction and tree structure as metastable; complementarity and disjunction as unstable formulas.

Summarizing this phase of a gnostic process we note the necessary conceptual ingredients for com-putation.

3 different types of fields: long-range attraction,
medium-range repulsion,
short-range attraction

resulting in a global top-down differentiation of the system:
shell or environment
core or memory

and a local bottom-up integration of stable elements:
units of initial alphabet
modules of closed formulas
(computed in the global core)

4.3. Recursive nested hierarchical levels Self-amplification - hypermodules

The com-puted formulas amplify the long-range attractive field within the global core of the system until a critical threshold density of closed modules is reached.

The gnostic system can now be described as a three-level nested hierarchical structure. An outer shell, in which no computations take place, an inner shell in which modules are com-puted from the gnostic alphabet and an innermost core, in which hyper-modules are com-puted.

The com-putation of hyper-modules can be described with the same organizational categories as the com-putation of modules introducing the concept of recursive organizational level transition.

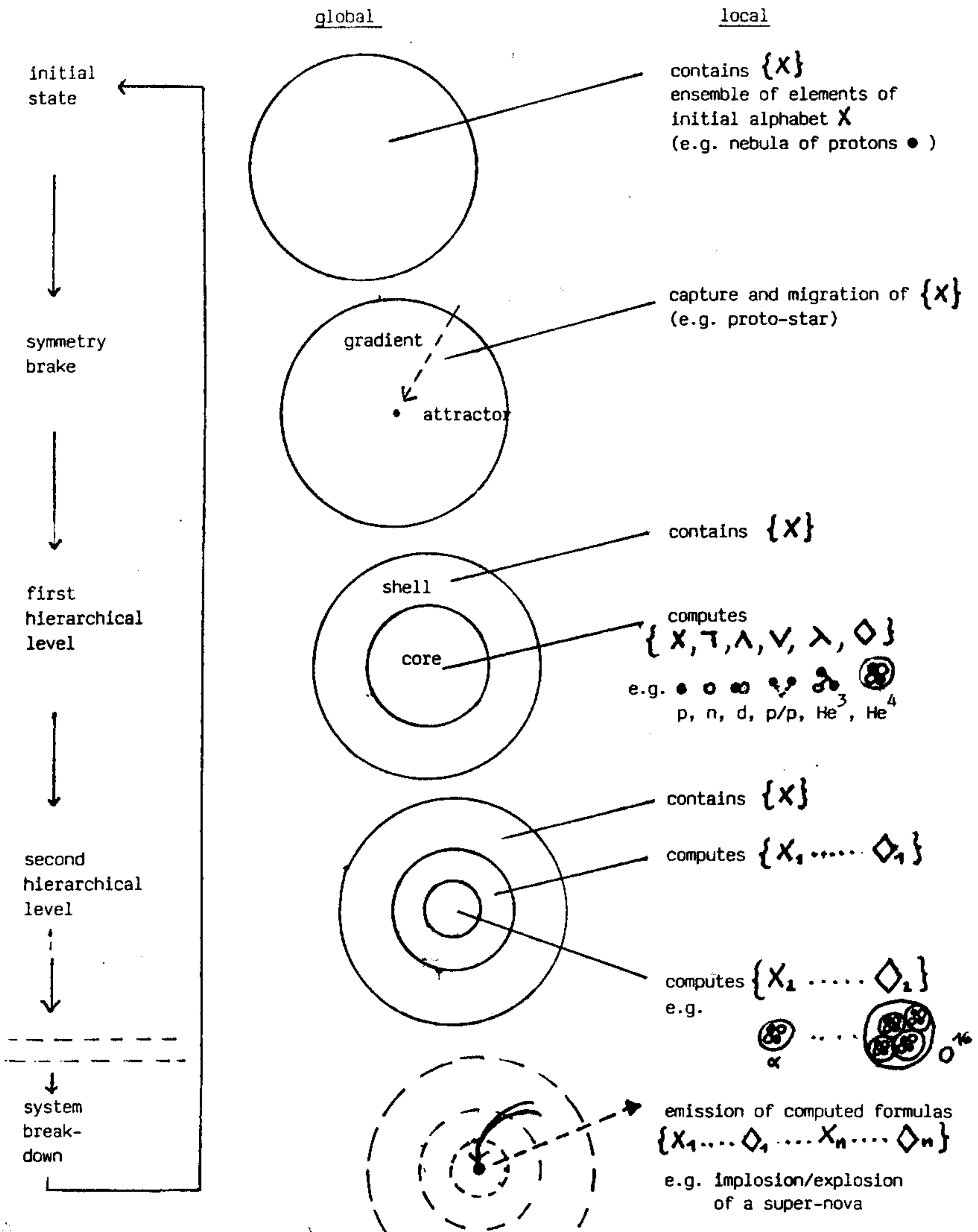
organizational level n:

$$X_n \to \neg_n \to \wedge_n \to \vee_n \to \lambda_n \to \diamond_n$$

organizational level transition

$$X_{n+1} \to \neg_{n+1} \to \wedge_{n+1} \to \vee_{n+1} \to \lambda_{n+1} \to \diamond_{n+1}$$

Figure 2. Co-evolution of global and local nested hierarchies.



After an organizational level transition the closed modules of level n become elementary units of level n+1. This process is recursive and can generate a many-level nested heirarchy. The emergence of an additional higher level of local modules is only possible after the global system has surpassed a certain threshold, which generates an additional nested global core level. Figure 2 illustrates this co-evolution of nested local bottom-up hierarchies and nested global top-down hierarchies.

4.4. System breakdown

Depending on the initial condition of the system (initial alphabet and number of elements) the co-evolution of nested local and global hierarchies continues until the system reaches a maximum value of complexity. At least for nuclear systems a quantitative variable called "complexity" can be defined, which increases in an irreversible manner during stellar evolution (Winiwarter, 1983). This variable C is composed of an informational measure I describing the variety of the com-puted formulas and an energetic measure R describing the relative binding energy or "synergy" permitting the coherence of the system.

Once the maximum complexity of the system is reached, it breaks down. A catastrophic "implosion" destroys local and global hierarchical structures. In some cases - depending on the initial conditions - this "implosion" is accompanied by an "explosion" emitting com-puted local formulas into space. These emitted local formulas can be captured and re-entered into the initial conditions of a future gnostic cycle.

5. TRANSDISCIPLINARY DEFINITIONS OF MEMORY, LEARNING, AND INTELLIGENCE

Physicists will certainly protest against the naive over-simplifications of the above model. Our concern however is not to vulgarize the theory of nucleo-synthesis. We wanted to develop some simple phenomenological concepts describing the essential steps of a "learning" process.

Based on our far-fetched analogy we propose the following transdisciplinary definitions of the concepts memory, learning, and intelligence.

5.1. Memory

Any system capable of mapping global (environmental) phenomena into temporally stable (or meta-stable) local phenomena is called memory system.

If we include the initial environment in the description of our system as we have done in our model, then the memory of a system can be considered as the core or a nested hierarchy of cores, each core being a self-image of the next outer hierarchical level.

5.2. Learning

Any process capable of com-puting local phenomena under the global influence of an "environment" according to organizational categories is called learning process.

We postulate that the organizational categories of all learning processes are isomorph and recursive (from unity to complementarity, from complementarity to conjunction and disjunction, from conjunction and disjunction to sequential branching or tree structure, from tree structure to modular closure, from modular closure to modular recursion).

According to our model, hierarchical bottom-up integration of local memory structures is only possible coupled with hierarchical top-down differentiation of global environmental structures.

Applying these concepts to human language com-putation would suppose that the local hierarchical structure of a phrase emerges within a global hierarchical semantic environment consisting of the combined or cooperative actions of all words within a considered gnostic system. In order to com-pute phrases consisting of 3 hierarchical levels, one would postulate a structured semantic environment containing also 3 nested levels. In short, the number of nested local levels of a linguistic structure equals the number of nested global levels. Thinking, speaking, and learning in general could thus be considered as a hierarchical self-image building process of a gnostic system. (Most traditional models for evolutionary and learning systems omit this hierarchical structuring of the global system by putting all global phenomena into a single level called "environment".)

5.3. Intelligence

Any learning process capable to select in its com-putations local extrema of an objective function according to a Maxwell principle is called intelligence.

The Maxwell principle (some would like to call it Min-well principle) chooses from several accessible minima or wells the deepest one; or from several accessible maxima the highest one.

In the nuclear model, the com-putations are such that the new com-puted formulas "choose" the configurations maximizing nuclear binding energy, or to be exact, nuclear complexity (Winiwarter, 1983).

Applying similar concepts to linguisitc com-putations would imply the difficult task to define a suitable measure for semantic coherence and complexity (corresponding to nuclear binding-energy and nuclear complexity). Intelligent com-putations would then maximize semantic coherence and complexity.

5.4. Self-organizational systems are intelligent

Accepting the above de-anthropomorphized definitions, we admit that stars are memory systems following a learning process and the universe is intelligent. Generalizing we postulate that all self-organizing systems are memory systems following a learning process directed by a global objective function and are therefore intelligent.

6. CONCLUSION

Memory, learning, and intelligence are inherent to all self-organizing phenomena. The learning process can be described as a co-evolution of local and global hierarchies. The organizational categories on each hierarchical level are isomorph following a universal "hierarchy generator" (Voorhees, 1985).

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