ORIGINAL PAPER

METAKNOWLEDGE FOR INTELLIGENT SIMULATION

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Dear God,
Search and research our world,
made by Your Right, and help us complete it
Orthodox Pantocrator

Einstweilen bis den Bau der Welt Philosophie zusammenhält,
erhält sich das Getriebe durch Hunger, Furcht und Liebe
Friedrich Schiller

Das schöne wahre Gute
Johann Wolfgang von Goethe

Abstract. *Intelligence = Consciousness × Adaptability × Intention and Faith = Intuition × Inspiration × Imagination, are the complementary parts of the human mind; the link between is Conscience = Consciousness × Inspiration. Simulation is the relation between function and structure. Conscience simulation demands transcending from computability to simulability, by an intensive effort on extensive research to integrate essential mathematical and physical knowledge guided by philosophical goals. A way to begin is hierarchical simulation. Coexistent interdependent hierarchical types structure the universe of models for complex systems. They belong to different types of hierarchy. Symmetry between simulation and theory can model the conscience.*

Keywords: *Intelligent Simulation, Simulated Intelligence, Hierarchy Types.*

1. INTRODUCTION

Faith and intelligence form the yin-yang of our life: Way, Truth, Life ☯ // frontal view

Human = human (Humanity);

human ∈ Faith × Intelligence → Faith × Intelligence;

Humanity = (Set of humans, eternity / evolution-oriented Structure).

evolution ∈ (Hunger, Fear, Love)×(Technology, Science, Art)→(Technology, Science, Art).

Mathematics ⊂ Art = Human :: beauty-oriented activity (Science, Technology).

Physics = natural Science∪social Science=Human:: truth-oriented activity (Art, Technology).

Technology = Human :: good-oriented activity (Art, Science).

The history of the common measure could be synthesized along the following line:

... ← Philosophy ← ... ← Culture ← specific Knowledge ← Economics ← Force.

Simulation∈Behavior × Structure ⇐ Knowledge // "⇐" stands for "implies"

Knowledge ⇐ Intelligence :: information()// "::" stands for "Class :: method"

Imagination ⇐ |Intuition - Conscience|; Intention ⇐ |Inspiration - Adaptability|

Conscience ⇐ reflexiveAbstraction (Intention);

Adaptability ⇐ simplifyingAbstraction (Imagination)

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2. ARGUMENT

Faith = (Inspiration, Intuition, Imagination) is associated to the right human brain hemisphere. Intuition is the main part of the dark yin, inspiration the dynamical shaped interface to intelligence, whereby the white point, link to the left part, stands for imagination.

Intelligence = (Conscience, Adaptability, Intention) corresponds to the left human brain hemisphere. Adaptability is the main part of the light yang, conscience the variable nuanced interface to faith, whereby the dark point, sent by faith, signifies intention. Conscience is self-awareness of individual faith and intelligence, as well as of the relation to the local context (society) and to the global one (universe). To appear it needs self-knowledge, what could result from community conscience featured by an eternal human structure, e.g., from the past, shepherds, farmers, sailors, Africans, American Indians, Asians, Australians, ... Each individual recognized himself in his cohabitants, being adaptable and having a lot of intuition. The evolution of the common measure is conditioned by the conscient construction of correspondingly intelligent agents to manage the lower stages, as industry enabled the mechanization of agriculture followed by the concentration on economics. Evolution implied a multiple Divide et Impera et Intellige for conscience, associated to generating the components lacking of the mind at start, then assisted by them:

- individual-social-universal conscience → inspiration (subjective-contextual-objective) ↓
- space-time (structure-behavior) → imagination ↓
- discrete-continuous (natural-real) → intention
- beauty-truth-good (art-science-technology) ↓.

1. Mathematics discovers and studies fundamental types of structures: (algebra, topology, order), and fundaments (construction, understanding, orientation). These are rarely separately used, example of correct and complete integration to be followed by science and technology [3].

2. Physics [8] should integrate its fundamental forces theories, but also, as chapters, all others natural sciences and the social sciences, leading them to really apply mathematics. Social sciences study a universe, as complex and nondeterministic as the natural one, so mathematics is at least as important to them as for natural sciences. Science would also be a better inspiration source for mathematics.

3. Engineering has to be closely related to mathematical approach and integration of parts, not only to mathematical techniques; as reality contains the abstract ideas, even if physics could explain everything discretely, the power of continuum can not be forgotten, i.e., analog engineering should not be neglected in modeling and simulation.

The convergence process of evolution demands struggle against time, with structure as ally. Conscience [2] needs, more than discrete recurrence, continuous feedback. Social and individual conscience are mostly divergent nowadays, i.e., we only performed "Divide et Impera", neglecting "et Intellige". It's high time to correct this.

3. SEARCHING FOR CONSCIENCE

Evidently, the anterior relations are oversimplified in order to move towards intelligent simulation. Although we claim they are intuitive and hope they are inspired, to begin, we neglect the essential but too primitive to understand intuition and inspiration, so (see further) formalizing reflexive abstraction by the knowledge hierarchy type and simplifying abstraction mainly by the simulation hierarchy type, it follows that:

Conscience = knowledge (simulation (Conscience)) i.e., a fixed-point relation suggesting that we could model conscience associating to any hierarchical level of the construction process a knowledge level. To solve the fixed-point problem we have to build a metric space where knowledge □ construction is a contraction, i.e., elements implied in the construction should get closer to one another in the formal understanding of the formal construct. If, even in the sketch, we consider general functional relations between the essential parts of the faith-assisted intelligence, it results:

Conscience = knowledge (intention (Inspiration, simulation (imagination (Intuition, Conscience))))

A generic modeling scheme defines the model universe, e.g., a mathematical theory, a programming paradigm. Every entity has behavior (relations to other entities) and structure (internal relations). Behavior can be functional (context-free) or procedural (context-dependent). An algorithm is an entity that can be computer simulated, so it represents computability, bottom-up (construction, design, plan) or top-down (understanding, verification, learning).

The algorithmic approach is equivalent to the formal one: If a sentence of a formal system is true, then an algorithm can confirm it. Reciprocally, for a verification algorithm of the mathematical sentences, a formal system can be defined, that holds for true the sentences in the set closure of the algorithm's results towards the operations of the considered logic.

4. RESEARCHING FOR CONSCIENCE

David Hilbert's formal systems, *Alonzo Church*'s λ-calculus, *Alan Turing*'s machines, *Stephen Cole Kleene*'s recursive functions, *Emil Post*'s combinational machines, *Noam Chomsky*'s grammars, *Aleksandr A. Markov*'s algorithms, are the best-known equivalent formalisms for computation, i.e., algorithm and computability [4]. The alternative ways followed to extend the computability concept can be compared to approaches known from German dramas and novels:

1. Faust (*Johann Wolfgang von Goethe*): heuristics - risking competence for performance, basing on imagination, confined to the mental world.
2. Das Glasperlenspiel (*Hermann Hesse*): unlimited natural parallelism - remaining at countable physical suggestions, so in the Nature.
3. Der Zauberberg (*Thomas Mann*): hierarchical self-referential knowledge - needing to conciliate the discrete structure of hierarchy with the continuous reaction, hoping to open the way to Reality.

They concentrate respectively on the mental world of the good managed by technology, the physical world of the truth researched by science and Plato's world of the beautiful abstractions discovered by art.

Intelligence in evolution is the faculty to:

- synthesize/ analyze/ modify abstract objects, i.e., ideas;
- analyze/ modify natural objects and synthesize/ modify artificial objects in the physical world
- synthesize/ analyze/ modify representations for the mental world [6];

especially hierarchical reflexive: ideas about ideas and how to get to ideas, objects to synthesize/ analyze/ modify objects, representations on representations and how to build/ understand representations.

Evolution is linked to the initial design of mental faculties for surviving of the whole system - not for abstract thinking, but also to the space-time context supposed by communication between intelligent agents. We follow the mathematical paradigm of intelligent simulation by functionally modeling the self-aware adaptable behavior for intelligence simulation. The integration between discrete and analog is needed, for softer adaptability and for conscience simulation as continuous recurrence, i.e., analog reaction.

5. HIERARCHY TYPES

Knowledge and construction hierarchies co-operate to integrate design and verification into simulation; object-oriented concepts are symbolized to handle data and operations formally; structural representation of behavior manages its realization. Hierarchy types open the way to simulate intelligence as adaptable conscience, by integrating the system and the metasystem. Hierarchy is the syntax of abstraction.

As there are more kinds of abstraction, there are also more hierarchy types. Representation is a 1-to-1 mapping from the universe of systems (objects of simulation) to a hierarchical universe of models, so a representation can be inverted. A model must permit knowledge and manipulation, so it has two complementary parts/ views: description and operation. If models correspond to classes, in a formal approach, specifications are instances; for models formalized as languages specifications are expressions.

Hierarchies are leveled structures, which represent different domains. A level is an autonomous mathematical structure, containing abstract/ concrete entities, linked by intralevel relations. Abstraction relates the levels: this induces an interlevel order relation, partial, concerning entities, and total, regarding the levels. Beyond the hierarchical point of view, the system can be formalized as an autonomous domain, structured by metahierarchical relations, building a level in a higher order hierarchical system.

Hierarchical structures exhibit two complementary processing strategies: top-down and bottom-up Coexistent interdependent hierarchies structure the universe of models for complex systems, e.g., hardware/ software ones. They belong to different hierarchy types, defined by abstraction levels, autonomous modules, classes, symbolization and knowledge abstractions.

Abstraction and hierarchy are semantic and syntactical aspects of a unique fundamental concept, the most powerful tool in systematic knowledge; this concept is a particular form of Divide et Impera et Intellige; hierarchy results of formalizing abstraction. Hierarchies of different types correspond to the kind of abstraction they reflect (the abstraction goal):

- Class hierarchy (↑concepts) ↔ virtual framework to represent any kind of hierarchy, based on form-contents, modularity, inheritance, polymorphism.
- Symbolization hierarchy (↑mathematics) ↔ stepwise formalism for all kind of types, in particular also for hierarchy types.
- Structure hierarchy (↑strategies) ↔ stepwise managing of all types on different levels by recursive autonomous block decomposition, closely following the principle Divide et Impera et Intellige.
- Construction hierarchy (↑simulation) ↔ simulation (= design/ verification) framework of autonomous levels for different abstraction grades of description.
- Knowledge hierarchy (↑theories) ↔ reflexive abstraction ("self-referential", "a deeper sense"), aiming that each level has knowledge of its inferior levels, including itself.

The knowledge hierarchy type offers a way to model conscience. The first idea is to consider/ remember that reality is more than nature, as the continuum of IR is more powerful than the discrete universe of IN.

Understanding and construction have correspondent hierarchy types: their syntax relies on classes, the meaning on symbols, and their use on modules (Fig. 1).

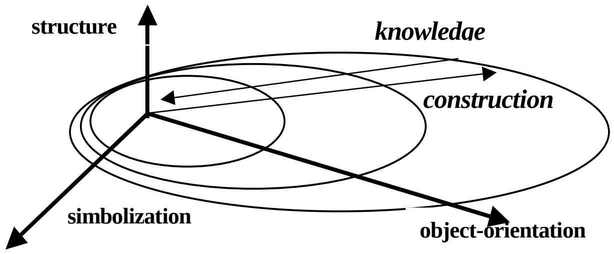

Fig. 1. H – diagram.

The theory of categories offers formalism for hierarchy types. Constructive type theory permits formal specification and formal verification generating an object satisfying the specification.

Example 1:

The classical activities in complex systems simulation, that regard different levels of the construction or knowledge hierarchy, can be expressed symbolically then represented object-oriented and simulated structurally (Fig. 2). Complex simulation needs consistent combination of mathematical domains and an intelligent compromise between consistence and completeness.

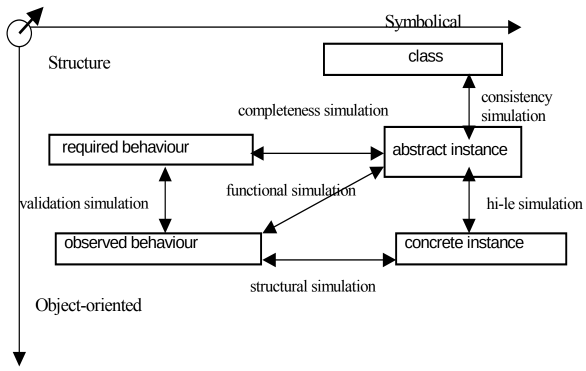

Fig. 2. Hierarchical Simulation Paradigm: representation.

6. METAKNOWLEDGE

Recurrence of structures and operations enables approximate self-knowledge (with improved precision on the higher levels of knowledge hierarchies). Recurrence is confined to discrete worlds, while abstraction is not. This difference suggests searching for understanding based on mathematical structures that order algebra into topology (Fig. 3). A continuous model for hierarchy levels, without loosing the hierarchy attributes, would offer a better model for conscience and intelligence.

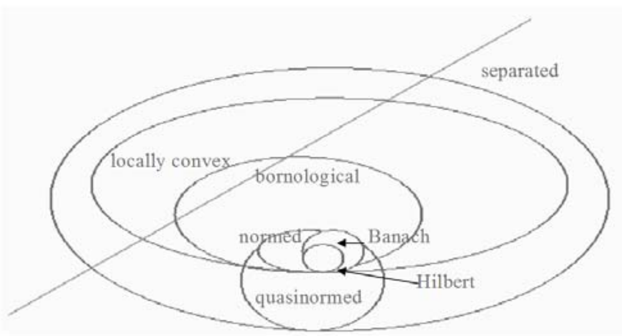

Fig. 3. Topologic vector spaces.

Knowledge is based on morphism mapping the state-space of the object-system onto the internal representation of the simulator. An intelligent simulator learns generating and validating models of the object-system. Therefore: representation for design and verification should be common; the algebraic structures on which the different hierarchy types are based on should be extended to topological structures; the different simulation entities should be symbolic, having attributes as: type, domain, function.

A topology on the space of symbolic objects permits grouping items with common properties in classes [9]. It results a dynamic internal object oriented representation that can be adapted to the different hierarchy types. Topological concepts, as neighborhood, or concepts integrating mathematical structures, as closure, can be applied in verification and optimization, for objects and classes as well.

The hierarchical principle should be applied to the object of knowledge as to the knowledge structure itself: it mediates the action of a paradigm on an environment. The simulation environment prepares a framework for representing entities and relations of the system to be simulated (designed/ verified), as well as general knowledge about the simulated universe.

Knowledge-based architecture bases on separation of representation from reasoning. An intelligent system, i.e., capable of reflexive abstraction, reasons controlled by problem specification and by solving strategies. These are derived from a higher level of knowledge, representing approach principles, which are structured by an even higher level containing abstract types.

An object-oriented simulation framework permits the representation of different knowledge levels, each having a concept hierarchy, possibly abstraction/ structure/ symbolization leveled. Knowledge-based architecture [5], both at environment and simulation component level, ensures flexibility of the framework realization, by defining it precisely only in the neighborhood of solved cases. For representation, this principle offers the advantage of open modeling.

The user describes models, following a general accepted paradigm that ensures syntactic correctness, leaving the meaning to be specified by user-defined semantic functions that control the simulation. For example, a module in an unfinished design can be characterized by constraints regarding its interaction to other modules; the constraints system is a model, open to be interpreted, thus implemented, differently, adapting to criteria in a non-monotonic logic. If one of the imposed properties (design constraints) is considered as not being fulfilled after applying a technique, using a model and suitable methods for measure and improvement, different strategies permit altering one of the technique/ model/ method. The process repeats for the initial behavioral specification or one resulted from prior insufficient improvement. This calls for an intelligent choice of the system that assists/ automates the design. The methods are recursive to handle different components in the behavior specification of the system. The process continuation is controlled by measurement functions, called for each of the improvement functions.

All simplifying hierarchies contribute to the reaction, while knowledge hierarchy stores, analyses, locally integrates, informs the awareness realizing parts and globally integrates. Interlevel relations in a knowledge hierarchy can be interpreted as planning (top-down) and learning (bottom-up). Learning derives a formal structure on the upper level (e.g., a static structure), from experiences on the lower level (procedures executed using resources that are not present at the upper level, e.g., time). It has two complementary aspects: induction - extensive knowledge at the lower level is transformed into intensive knowledge at the upper level, using non-reflexive abstraction, e.g., isolation, equivalence, emphasis, approximation, or idealization; deduction - intralevel concept production, e.g., conditioning, association, stress, imitation.

Planning transforms declarative knowledge (formal, but limited) in partially procedural knowledge (unlimited, but implying a context with resources that are not formalized at the upper level; the main resource is time). Artificial intelligence studies planning as reasoning about actions. Actions are elements of a lower level, generally represented by states (instances of upper level functions in the presence of a context) and operations (determining state transitions). The plan is a non-commutative system of declarative knowledge; extreme cases are: commutative rule set, sequential procedure.

Explanation is a key concept for knowledge-based systems. It can be expressed as proof in a deductive system, whose axioms are the equations constraining component models and input signals, theorems are simulation results, inference rules represent logic and domain-specific calculus. Using constructive logic, e.g., intuitionistic predicate logic, behavior/ structure of the system can be extracted from the proof.

7. REFLEXIVE ABSTRACTION

Mathematics contains structures that suggest to be used for self-referent models. The richest domain in this sense is functional analysis [7]:

- contractions and fixed points in metric spaces
- reflexive normed vector spaces
- inductive limits of locally convex spaces1
- self-adjoint operators of Hilbert spaces
- invertible operators in Banach algebra.

Example 2:

Let $\left(U,\left\{H_j \in S_h\right\}\right)$ be a universe, structured by different hierarchies H_j and S_h the set of hierarchies defined on universe U let be:

- $H = \left(Rel\_eq,\ \left\{\left(Level_j, Structure_j\right) : j \in S_1\right\},\ Rel\_ord,\ \left\{A_j : j \in S_1\right\}\right)$ a generic hierarchy
- S_1 the set of hierarchy levels
- Rel_eq the equivalence relation generating the levels
- $Structure_j$ the structure of level j
- Rel_ord the (total) order relation defined on the set of hierarchy levels

$A_j \in \left\{\left(x,y\right)\ /\ x \in Level_{j-1}, y \in Level_j, j \in S_1\right\}$ the relation of abstraction.

U is a category, e.g., containing Hilbert spaces with almost everywhere-continuous functions as morphisms, enabling different ways to simulate self-awareness. A hierarchical formal system could be defined as:

1. $\left(U,\left\{H_i \in S_h\right\}\right)$, $\mathrm{card}\left(U\right) > \aleph_0$ // hierarchic universe
2. $\Sigma = F \cup L \cup A \cup K$ // functional objects

$F = \left\{ f\ /\ f \in U^* \to U \right\}$ // global functions

$L = \left\{ f\ /\ f \in Level_j^* \to Level_j \right\}$ // level structures

$A = \left\{ f\ /\ f \in Level_j^* \to Level_{j+1} \right\}$ // abstractions

$K = \left\{ f\ /\ f \in Level_j^* \times Level_{j+1} \to Level_{j+1} \right\}$ // knowledge abstractions

3. $I = \Sigma^* \cap R$ // initial functions

4. $R = \{ r / r \in \Sigma^* \times R^* \to \Sigma \times R \}$ // transformation rules.

Considering self-adjoint operators as higher-level objects of the knowledge hierarchy, these levels can approach self-knowledge in the context of knowledge about the inferior levels as of the current one, and having some qualitative knowing about the superior levels. The correspondence problem, i.e., to associate the knowledge hierarchy to the simulation hierarchy, is managed by natural transformations over the various functors of the different hierarchies regarding the simulated system. To complete the simulation of the intelligence's components, intention is first determined by human-system dialogue. Further than modeling conscience to simulate intelligence there will be searching to comprehend inspiration, may be using: Lebesgue measure on differentiable manifolds on non-separable Hilbert spaces. Perhaps even mathematics will have to develop more philosophy-oriented to approach intuition.

8. CONCLUSIONS

Conscience simulation demands transcending the present limits of computability, by an intensive effort on extensive research to integrate essential physical and mathematical knowledge guided by philosophical goals. A way to begin is hierarchical analog-digital simulation. Applying DII to hierarchy types, using the formalism of categories, reveals their comprehensive constructive importance based on structural approach, symbolic meaning, object-oriented representation. Formalizing hierarchical descriptions, we create a theoretical kernel that can be used for self-organizing systems. Simulability is computability using the power of continuum. There are enough positive signs for this from analog electronics, control systems, mechatronics. Real progress towards this way of computation needs unrestricted mathematics, integrated physics and thinking by analogies. Evolution needs separation of faith and intelligence, understanding and using consciously more of faith's domain, integrating them to human wisdom, to be divided further to get more human. Metaphorically phrased, our problem is that: Uncountable are God's ways.

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