THE EIS KNOWLEDGE STANDARDS

STANDARD ONTOLOGY FOR MACHINES AND PEOPLE

OR

HOW TO BUILD A VIRTUAL ARISTOTLE

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standard ontology for machines and people

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ABSTRACT.
The book is a systematic deep quest for the nature and meaning of reality, its constitution and classification, its basic contents, kinds and levels, giving a systematic analysis and formal representation of its structure, properties and states, dynamics and behavior, and all possible relationships. The whole idea is to work out a standard world schema in order to organize human knowledge, to create encyclopedic reasoning systems and to secure communication interoperability between two species of intelligences, existing human beings and emerging knowledge systems and reasoning applications

To this effect, there is constructed an all-embracing dynamic framework as a unified theory of entities and relationships made to function as the common language for computers and persons. The integral combination of the global schema and fundamental mathematics resulted in a standard model of the universe of things involving substances and objects; states and properties; changes, actions, processes, and events; relationships, connections, and associations. The general framework provided a system of knowledge standards (as elements and primitives) underlying the key concepts of scientific knowledge, the basic constructs of minds, the major categories of languages, as well as the entity data types and reasoning rules of knowledge systems and so constituting a representational and inferential framework for a new class of intelligent applications. It is shown that the standard formal ontology makes the single foundation upon which knowledge domains of physical, mental, or cultural worlds as well as natural language constructions are raised. As a consequence, the natural language is proved to be the most general knowledge and reasoning language not only for persons but also for computing machines, which to become truly intelligent systems should be able to process and communicate semantic information about the world and its domains in NL forms. This, as shown, opens up the possibility of natural language applications of encyclopedic (Web) intelligence such as a Virtual or Digital Aristotle and global knowledge resources as the Onto-Semantic Web.

To meet the challenging undertakings, the all-inclusive world model was developed as underpinning computational upper ontologies, the ER extended data models, data integration systems, and Web ontology languages. Representing reality to formal reason of humans and to programming machines enables an effective way to ontology-based knowledge technologies and encyclopedic intelligent systems:

(Reality or the World) → Knowledge of the World {(Universal Ontology + Mathematics + Semantics + Science) + Logic of Things} → Natural Language → Informatics and Computer Science → NL Engineering and AI Technology → NL Knowledge and Reasoning Machines (systems, applications, agents, robots, software programs, tools) → Encyclopedic Intelligences (Virtual or Digital Aristotle) → Onto-Semantic World Wide Web → Global Intelligent Cyberspace.

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INTRODUCTION: a Standard for Science, Upper Ontologies, and Web Ontology Languages

Of all sorts of intellectual pursuits, nothing appears of greater import than to give a formal account of the world understandable both by humans and computing machines. Art, religion, science, and technology by their specific ways seek to model, explain, or represent reality, but only one human activity is thoroughly and systematically committed to the grand cause of technical inquiry into the world as a whole, its cardinal classes, properties, and relations. Being the hardest, most exacting but mostly awarding and winning, such an ambitious search for the whole world knowledge is defined as the mother science of ontology, the heart and soul of all human learning, wisdom and reasoning, unveiling the common nature, mechanisms and meanings of things and their relationships diversified into the key levels and kinds of reality, natural, mental, social, cultural, or informational. For the source science of all knowledge bases and domain theories develops the most general theories about reality and thus being fully concentrated and devoted to the profound accounting of beings, things, or entities. All kinds of science, basic or applied, hard or soft, theoretical or empirical, fundamental or descriptive, natural or humanitarian, to some degree partake in the general theory of entities and relationships as domain specific ontologies. Again, all types of knowledge, theoretical, formal, experimental or practical, presuppose essential, ontological knowledge of things. Implicitly or explicitly, ontological principles can be found among mostly general theories, mostly universal axioms and laws, and in mostly interesting scientific problems. As ideas, ontological concepts, notions, and terms lead the list of great ideas making the very substance of the grand elemental conceptions. For they are the abstractions by which thought knows the world and minds think things, the terms in which we formulate major principles and facts of reality, the notions in which we make definitions, put fundamental questions, and solve decisive problems. Ontological ideas constitute the very framework of mental contents and cognitive processes as the heart of mental life. With that, they reside in language as mind in body, as pungency in pepper; our human language is pervaded with ontological categories, for the syntactic, grammatical categories and semantic classes are tied to world things, eventually describing and explaining constituents and properties of being, thereby predicting the behavior of the real world. Wherefore, all great human actions and intellectual achievements, all our rational practice and moral conduct intrinsically guided by ontological rules and principles, the basic truths of reality. Still this is not all the outstanding accomplishments of the science of reality. Unprecedented and profound impacts on human life and culture as well as on the dominancy of human beings as the only creatures of sapience are expected with the beginning of the third millennium.

Nowadays, computers grounded to electronic measuring devices, transducers, and telemetric systems are increasingly transforming into worldwide integrated information processing networks. And ontology science and engineering is getting a long-waiting and fully deserving recognition of a critical factor in the 21st century information and communication technology, particularly, in building knowledge-driven intellectual technologies, meaningful machines and reasoning systems, the engine and driving force of the Global Knowledge Society [Novik and Abdoullaev, 1991].

As computing is concerned with computable structures and processes and ontology reveals general structures and patterns of relationships in the world, the latter permeates the key branches of computer science: knowledge engineering in AI, conceptual modeling in information systems and databases, and type systems and domain modeling in programming languages design. It can be said that the action, the most important and breakthrough technological works, is no longer in artificial intelligence but rather in ontology research, design, engineering and large intelligent applications constructing thereof [Abdoullaev, 1989, 1992].

Today particular domain theories and models (or specific ontologies) are actively used in all basic fields of computer science and technology: artificial intelligence, computing networks, informatics, software engineering, programming languages, and computational linguistics. It is increasingly realized that computing knowledge products ought to be founded on comprehensive world models represented in precise (formal) language of things with clear syntax and strict semantics.

The close examples of such understanding are far going research projects initiated within the AI and Web communities and aimed to construct domain-independent ontologies and ontology languages for developing extensive knowledge and reasoning applications. So, under the auspices of the Institute of Electrical and Electronic Engineers (IEEE), there has been started the ambitious project of 'a standard upper ontology of high-level concepts, definitions and relationships processable by computers' [IEEE SUO, 2004; SUMO, 2004; CYC, 2003; SUO IFF, 2004]. As the starting candidates the IEEE SUO initially included the IFF (Information Flow Framework) foundation meta-ontology based on a mathematical category theory [SUO IFF, 2004] and the SUMO (suggested upper merged ontology) targeted to sort out more than 20k common notions of objects and processes. These both were joined with the CYC ontology which commonsense knowledge base is boasting more than 100k terms, 10k predicates, and 1M assertions [CYC, 2003]. Later, the number of candidates was increased with the Shell's data model of things as a sample of 4D ontology, named Lifecycle Integration Schema, and the multi-source ontology (MSO) aimed to unite some of these taxonomies. However, to its fatal end, the SUO project has been performed under the precarious belief that the standard model can be built as a library of distinct modules by mapping, merging, and integration of broad vocabularies and nomenclatures and domain terminological sources [IEEE SUO].

Another similar outstanding undertaking has been performed under the World Wide Web Consortium (W3C) Semantic Web Activity [W3C, 2004], where the all-important role in the cause of transforming the Syntactic Web into the Semantic Web is again assigned to ontology [Berners-Lee and Fischetti, 1999; Berners-Lee, Hendler, Lassila, 2001]. The new generation of OntoWeb is planned to develop radically novel features with respect to the traditional Web. Such computer network is generally defined as *a worldwide information space of resources and services and web agents interrelated by hypertext links, and which architecture is based on three principles: identification of resources by global identifiers; representation of resources states, or data formats; and interaction protocols* [Berners-Lee, 2004].

Whereas, the upcoming Onto-Semantic Web is distinguished as *a worldwide knowledge space of intelligent contents and resources (programs, databases, Web pages, models, and sensors) and services communicating by reasoning agents via the standard ontology language encompassing the Internet markup languages, schemas, and logics*.

In sum, the key technologies of the Semantic Web are structured as a seven-tier cake of specifications: the URI naming scheme, the Extensible Markup Language (XML) syntax [XML web site, 2004], the RDF (Resource Description Framework) object-oriented language [RDF web site, 2004], the Web Ontology Language (OWL) vocabulary [OWL web site, 2004], Description logic, Proof, and Trust [Hendler, 2001]. Such prominent undertaking is distributed among many kin topics: Web ontology formalisms and languages; Web-based intelligent software agents with semantic markup languages and tools; Ontology-based semantic portals; reasoning and knowledge representation on the Web; Intelligent Web services and products; Semantic integration of information resources on the Web. Again, the essential component of the whole undertaking is an ontology language (built atop of URIs, XML namespaces, and the RDF vocabulary) much trusted to advance interoperable technologies, web search and retrieval, knowledge management, software intelligent agents, and reasoning applications through providing machine-understandable processing of the Web content. Unlike the SUO, the OWL, formulated as a formal language describing classes and their relations embodied in Web documents and applications programs, had better fate of being recommended as a standard semantic markup language for Web ontologies [OWL Web Ontology Language web site 2004].

Additionally, in the realm of Semantic Web, the European Union initiated large R&D projects in Information Society Technologies, known as the European 6th Commission Framework Programme, in order to achieve a novel strategic goal, 'the most competitive and dynamic knowledge-based economy in the world' [Lisbon European Council, 2000]. Within the FP6 Programme, all the web-based knowledge technology projects are largely concerned with ontology research, design, learning, and management. So, Knowledge Web 'network of excellence' engaged to transfer ontology technology from universities to industry; Data Information and Process Integration (DIP) group is contracted to contribute to the infrastructure of semantic web services; SEmantic Knowledge Technologies (SEKT) network is signed to produce ontological software and tools for semantic web services (Sdk, 2005). Again, all the integrated research activities are performed under the costly collective delusion that ontology-based semantic web and services technologies can be constructed without having an *integrated knowledge framework*. The cost of an academic head game of missing an all-data and information skeleton may be a total budget of the integrated project coming over €36M, what repeats the typical CYC's error of confusing public aid spending with ontology technology creation.

As an illustrative example from the classical AI paradigm may well serve the Vulcan project Halo [Project Halo, 2004]. It was targeted to build a Digital Aristotle, a large knowledge representation and reasoning system, projected as 'a computer system containing extensive knowledge about the world, expressed as computer-processable rules, and an inference engine for reasoning with those rules' [Friedland, Allen, and Witbrock, 2004]. A venture to create a question-answering knowledge application driven by upper level descriptive taxonomies and logic-based knowledge representation and reasoning technologies [Friedland, 2004] was doomed to failure. First of all, it is again because of the critical deficiency of the unified representation of the world consistently and uniformly organizing the classes of things and their associations, both in human understandable and machine readable forms. For just the global schema can permit a deep analysis of the nature, meaning and structure of so-called WH-questions, whereby giving a basis for an educational dialogue system with broad scientific knowledge and deep causal reasoning, as the Digital Aristotle is to be.

Nevertheless, it is symptomatic that any advanced computing projects purposing either building a foundation ontology standard, or constructing an ontology-based Web, or creating the Digital Aristotle, all try to postulate some sort of extensive world models expressed in formalized but meaningful ontology languages. So, implicitly or explicitly, the general classification schemes and conceptual models are involved in all the tasks performing the most ambitious and challenging computing projects. At the first place, among them can be included: i) the IEEE SUO aimed to establish a single domain-independent description of general entities; ii) the Semantic Web mainly established on the Web Ontology Language presented as outperforming the extant data languages in the capacity to represent machine processable content on the Web; or iii) the Digital Aristotle project intended to establish and demonstrate the validity of ontological models in creating an encyclopedic knowledge and reasoning system.

Thus, the search for a computing representation of things covering all the possible entities and their relationships, either as a common upper ontology, a common ontology language, or in the form of universal knowledge application, is currently establishing as an urgent activity of great engineering import with many candidates aspiring after the Holy Grail and Soul of intelligent knowledge technologies.

All the prospects would seem bright and promising unless one annoying and persisting obstacle. For the time being, the Web and AI communities are marked by deep division with respect to the fundamental issue of the whole field: whether it is possible and how it is possible to build a standard upper ontology of comprehensive coverage and a standard language with a machine processable syntax and unambiguous semantics. At the first place, this discord occurs on account of a widely spread ambiguity of the very definition of ontology, the meanings of ontology knowledge, ontology design and engineering.

There is today an explicit general consensus that the world models turn out to be an unavoidable and decisive part of any large-scale knowledge applications. But, at the same time, there is also widely implicit consent not to explore the nature of fundamental ontology, as if its emerging computing descendant were an illegitimate offspring without one of the richest knowledge pedigree among the modern sciences. As a consequence of such disregard of the knowledge line of descent, the term ontology is subject to many interpretations, readings, versions, and renditions.

In information sciences and engineering, an ontology (instead of Ontology) is claimed to be ‘an explicit specification of conceptualization’, ‘a theory of content’, ‘a theory (a system) of concepts/vocabulary used as building blocks of information processing systems’, ‘a set of agreements about a set of concepts’, or ‘the representation of the semantics of terms and their relationships’. Alternatively, it is interpreted as ‘the class hierarchy in object-oriented paradigm’, ‘a complete schema of the domain concepts’, ‘an entity-relationship schema with subsumption relations between concepts’.

Sometimes, one can meet such definitions as ‘conceptual patterns’, ‘concept heterarchies or hierarchies’, ‘a body of conceptualizations’, ‘schemata’, or ‘metadata scheme’, ‘a common set of terms’, ‘a controlled vocabulary of terms’, ‘a representation vocabulary’, or ‘a body of knowledge’. At best, in the context of computer science, information and communication technologies, the science of entities is reckoned to be:

- a set of generic or philosophical concepts, axioms, and relationships for domain ontologies [IEEE SUO];
- a taxonomy of world terms/categories comprising definitions, hierarchical relations, and formal axioms [Mizoguchi, 1998];
- a set of definitions of classes and their relations, as well as individuals and their properties [OWL Web Ontology Language Web site, 2004];
- a catalog of the types of things (representing the predicates, word senses, concept and relation types of some formal language) organized by the class-subclass taxonomical relation [Sowa 2000];
- metadata schemas with machine processable semantics [Horrocks, 2003];
- content theories about the kinds of objects, their properties and relationships possible in a certain knowledge field [Chandrasekaran, Josephson, and Benjamins, 1999];
- the total of a taxonomy and a set of inference rules or a document (or file) formally defining the relations among terms [Berners-Lee, Hendler and Lassila, 2001]

It appears that in artificial intelligence, the semantic web, and software engineering, the science of things and relationships in general is commonly regarded as an extension or an external layer of logical calculi and formal languages. As a result, such a formal logical ontology is trivially specified as consisting of the following logical elements: concepts (classes, objects, or categories) with their characteristics (attributes, slots, functions, roles, or properties) and relations (generalization and specialization, functions), plus logical axioms (assertions) and instances of classes and properties [Gomez-Perez and Corcho, 2002].

Apart other things, such confused state of affairs may be partly attributed to the long-standing disagreements, disputes, conflicts, polemics, and arguments over the scope and nature of the subject area even among its greatest students. For, when taken as pure and abstract knowledge, the general study of entity in all levels and kinds of reality is formulated as different as:

- the science (account) of entity (or being) in general;
- the knowledge of the most general structures of reality;
- the theory of the kinds and structures of things in every domain of reality;
- the study of entity types and relations;
- the most general theory concerning reality, being, or existence;
- a collection of absolute assumptions;
- the study of change;
- the science of all possible worlds and everything conceivable;
- the study of semantic values of natural and formal languages and ontological commitments about the world

Such total ambiguity or rather equivocation causes the researcher to decide: is the whole activity about the inquiry of entity, its forms and properties, or just about some general concepts with their formal logical relations? Or, are we supposed to deal with 'the nominal' ontology of terms and their semantic relationships instead of 'the world' ontology of entity types and their external relationships? Now, one can freely choose three perspectives: either the world ontology (realistic and veridical), or the concept ontology (conceptual and notional), or the word ontology (linguistic and nominal). As human history witnesses once and again, big troubles in our world stem from the erroneous views and corrupt world models. It appears the upcoming intelligent systems are not going to make any exception; for just as wrong ontologies are fatal to the human race's way of life, so they are destructive of the knowledge artifacts built to represent and operate the information about the world.

It emerges that, apart from the technical and instrumental issues of growing pains of computing ontology, here lies a hindrance virtually insurmountable without taking more profound and fundamental approach to the issue. As like as the traditional engineering, the ontology engineering is generally expected to follow the same stages: research, development, design, construction, production, operation, and management. The most challenging, science-intensive and crucial stage is the first one, the research phase, which involves disclosing a set of well-defined fundamentals for an applied or engineering ontology. It is crystal clear that such fundamental principles and rules can come from nowhere but theoretical (pure or abstract) ontology consisting in a systematic inquiry of reality and its properties with the help of conceptual tools of science, mathematics, and logic. Evidently, this research should commence from the clear identification of the scope and range of the subject, its major principles and methods of inquiry, enhanced with the analysis of their validity, and only then the issues of goals, roles, practical uses, and engineering applications may come to the surface.

Our inquiry is all about constructing a general framework as a unifying theoretical system and universal language by compounding the classical models and theories about the nature and pattern of reality within a single standard account. For, without proper respect of the great works, their most productive insights and finds, we are doomed to be complementary, confusing, misleading, or conceptually trivial. In other words, a universal reference frame has to embrace the ontological categories making a firm grounding for the great ideas. For it must be clear that pursuing the final cause of so-called template ontology, we always risk falling into a fundamental fault by leaving out the standard resources of the standard authors. Particularly this is those resources systematically collected in the Great Books of the Western World and digested in the two-volume subject-matter index [the Syntopicon, 1990]. Topped by the universal classes of Being or Thing or Entity, these great ideas are enumerated as follows: Angel, Animal, Aristocracy, Art, Astronomy and Cosmology, Beauty, Cause, Chance, Change, Citizen, Constitution, Courage, Custom and Convention, Definition, Democracy, Desire, Dialectic, Duty, Education, Element, Emotion, Eternity, Evolution, Experience, Family, Fate, Form, God, Good and Evil, Government, Habit, Happiness, History, Honor, Hypothesis, Idea, Immortality, Induction, Infinity, Judgment, Justice, Knowledge, Labor, Language, Law, Liberty, Life and Death, Logic, Love, Man, Mathematics, Matter, Mechanics, Medicine, Memory and Imagination, Metaphysics, Mind, Monarchy, Nature, Necessity and Contingency, Oligarchy, One and Many, Opinion, Opposition, Philosophy, Physics, Pleasure and Pain, Poetry, Principle, Progress, Prophecy, Prudence, Punishment, Quality, Quantity, Reasoning, Relation, Religion, Revolution, Rhetoric, Same and Other, Science, Sense, Sign and Symbol, Sin, Slavery, Soul, Space, State, Temperance, Theology, Time, Truth, Tyranny and Despotism, Universal and Particular, Virtue and Vice, War and Peace, Wealth, Will, Wisdom, World.

So, to achieve the lofty target of all-entity representation system of knowledge standards, we surely can't ignore the conceptions systematically arranged as the Great Ideas. Besides, it is crucial for the common reference system to be validated with the essentials of human learning as represented in the Outline of Knowledge [Propaedia, 1994] and Knowledge in Depth [Macropaedia, 1994], to be supported with the thesaurus of Webster's Comprehensive Dictionary [the New International] and large lexical online resources [WordNet web site, WordNet 2.0, 2004]. For, to have an open dynamic reference ontology valid to science and engineering, we must be able to import and integrate in a single unifying scheme such complex entities as matter, energy, life, human, body, mind, society, culture, art, technology, religion, altogether with their key partitions, divisions, and subdivisions.

In pursuit of such a task demanding profound scholarly learning, intellectual dedication and consecration to fundamental study, we hold to several well-established and self-evident working principles. Traditionality, no one large classification scheme will have application prospects without being grounded on the classical ontological writings and works. Aristotle's standard books in the first place [Aristotle, Logic, Physical Treatises, Metaphysics], to which all the great minds seeking for a broad scheme of things tried to conform for many ages. Fundamentality, until the fundamental ontological categories will not be cleared up and specified as the general type system, all attempts of erecting an ontology standard will be impracticable with inherent flaws insuring their failure in future applications. Mathematicism and scientism, the knowledge standard should be constructed as a universal system of classes, definitions, axioms, and rules consistent with the sciences and mathematics to render the completeness of analysis, consistency of meaning, and correctness of inference. Hierarchy and systematism, there are three types of ontology: universal, upper-level, and regional or domain-specific ontologies; the union of which forms a complete, unifying system. Universality, the common standard is a theory and a language at the same time. Since it can be employed as a language by the specific theory, like theoretical sciences (relativity) are using mathematical language (topology), and all of them – a general ontological language. *Last but not least*, professionalism, any computing professional, an AI expert or Web researcher, however brilliant, can not do here better than a professional ontology scientist.

Adhering to the methodological rules, we research the nature and meaning of reality, its classification or constitution, its basic contents, kinds and levels, by giving a systematic analysis and formal representation of the world’s composition and structure, properties, states, dynamics and behavior, and all possible relationships. All this is done with a view to work out a standard world schema for programming knowledge and reasoning systems and human beings, so that to secure semantic interoperability between and among the members of these seemingly unlike species of intelligences, existing and emerging.

The subject matter or the object of study of the work can be specified as the largest existing environment, that is, the world or reality or the universe or existence. The keynote, burden, and motif of the book is the practical possibility of a unifying representation and reasoning (K&R) system determining the basic classes of things in the world (or its special domain) and authorizing the major classes of reasoning processes (thinking, intellection, strategies, procedures, cognition, computation) about the world. As a result, such an integrated K&R mechanism will be capable the following:

- ✓ to organize all substantial information about the world;
- ✓ to assign semantics or meanings to representational languages, natural or artificial;
- ✓ to acquire and learn new facts (data and information) and rules and principles about changing surroundings;
- ✓ to prescribe architectural schemes of reasoning systems and knowledge agents;
- ✓ to make and perform knowing decisions and intelligent actions

Crucially, the work formulates the integrated account (of classes of entities or things or beings or resources) proven to be fundamental to construction of knowledge and reasoning application not only as a descriptive account but also as an explanatory and predictive scheme. Explaining and describing the central generic entities in terms of mathematical and natural languages, the book uncovers the way to deliver an intellectual artifact as intricate as the Virtual Aristotle, which can be synonymously defined as the know-all language machine or the encyclopedic AI or the all-purpose semantic machine or the ontology-based knowledge system. This required developing the Master Ontology capable to incorporate the content of traditional theories of the world, lexical taxonomies, (upper) ontologies, and data languages for Web ontologies like as OWL. As a result, we could propose a collection of template classes together with their principal relationships to be used as the fundamental knowledge standards (elements or units) in developing the core knowledge structures for ontological machines defined as versatile knowledge and reasoning systems with the inbuilt all-embracing schema.

To grasp the general meaning of the whole work as well as to see its main points, it may be of use to refer to the unified data model well known and widely practiced in information engineering, which is the entity-relationship (ER) model [Chen, 1976]. Since some basic assumptions of the ontology reference can be also comprehended in terms of the ER schema, an original source of the whole new class of ontological languages and technologies in computing applications, like XML and RDF, and the Semantic Web ontology. Such success of the ER model is mostly explained by that the real world was presented as the totality of entities and relationships and their properties, and that distinct entities and relations were generalized as an entity set and a relationship set, respectively. This permitted to employ the conceptual power of mathematical set theory and relation theory. As a result, all individual things were ordered by entity classes E_i or relationship classes R_i. Accordingly, a property (attribute) was represented as a function f mapping from an entity (relationship) set into a value set (or a cross product of value sets). So in the ER scheme the formula for the world (or a domain of interest) W can be written as the mathematical structure $W = < E_i, R_i, f>$. This ontological approach has been taken as a paradigm by many subsequent data modeling languages, including the Semantic Web ontology, where the task of the (concept) ontology is also defined as the descriptions of general things (classes), their relationships, and the properties (or attributes) which they may possess [OWL, WC3 Recommendation, 2004].

It appears the ontology standard can be constructed as the extended ER semantic model dealing with the whole world or reality as the single universe of discourse composed of entity classes and relationship classes and instantiated by the entity (relationship) species and individuals. A comprehensive formal theory of entity and relationship is then something indispensable, something that is required before building any general ontology languages or data models of reality.

But, unlike the insights of the ER model, the extant computational entity typologies are implicitly shaped by the old-fashioned philosophical traditions, where reality is separated into two or three disjoint divisions of the same rank and status. These broad categories are either concrete individuals (contingent things as physical objects and events) and universals (necessary things, or abstractions as classes, states, qualities, and relations), or the concrete and the abstract (conceptual, conceptional, ideal, theoretical entities, or universals) intermediated with collections (or classes or sets) of concrete things (concrete universals) Written in abbreviated forms, the above may be presented as the CC (concrete and conceivable) schema or the CCC (concrete, collective, and conceivable) perspective of reality; what is commonly expressed in the natural languages as concrete names (individuals), collective names (collections), and abstract names (classes or masses). Then most existent general and upper ontologies, like the Semantic Web and SUO, can be assigned to the CC or CCC taxonomies limited by Nothing or Nonentity at the bottom and the concept of (individual) Thing or Entity at the top.

It appears that the main theoretical obstacle to the standard reference framework lies in the uncritical acceptance of the dichotomous classification of entities into realities and abstractions, like as tangible (objects), intangible (processes), or theoretical entities (representations). When individuals (the concrete) together with sets (abstract representations or collections of individuals) are viewed equipotent with ontological structures (universals), the researchers are doomed to create redundant entities and relationships while trying to construct a formal general ontology language [Degen, Heller, Herre, and Smith, 2001; Heller, Herre, Burek, Loebe, Michalek, 2004].

In effect, we need to consider the things in the right order of their existence and presentation, neither as an equal-order absolute separation into abstract and concrete nor in the inverse order, from the concrete objects, properties, events, and specific relations to the abstract ontological classes of substance, state, change, and relation. The order of things here makes all the difference. As the sociologists observed, a young woman personality may be quite different depending on the order of occurrences of her life experiences: becoming a mother, a college graduation, and becoming a wife.

In the proposed research we lift up entity or thing as the topmost class of all classes complemented with the concept of nothing (the null class as part of everything). The ultimate class of thing or entity now denotes a single, unitary ontological category having as its parts the entity classes and the relationship classes with their instances and occurrences. We thus attached to the scientific way of considering reality as the whole class of entity consisting of entity classes and relationship classes, all together constituting the nature and essence of an infinite multitude of individual things in the real world. So our approach is rather the C/C/C top-bottom descending model of the world, where sets (set-theoretical structures) and individuals are only instantiations or representations of the entity-universal (ontological structures), that is, they are considered of much lower rank in the ontological status. But, however important the issue of ontological status may be, it is not so decisive in comparison with what we mean as the basic kinds of entity and relationship, their nature and content. In fact, revealing the content and meaning of entity is the be-all and end-all of the general science of reality and this can not be discovered by means of any extended entity-relationship data models [Thalheim, 2000].

Pursuing the goal declared, we are about to demonstrate that the entire universe consists of things divided into four key classifications and parts, mutually dependent, overlapping and inclusive, namely, substances, states, changes, and relations. Analogically, like all the trillions of human cells are grouped just into four basic classes of cells, the entire plurality of particular things can be arranged by four basic classes of substance, state, change, and relationship. This is formally represented as mathematical entity sets and relationship sets, instantiated as the corresponding individuals and objects; conditions, situations, and properties; events, happenings, doings, and activities; specific associations, links, ties, and bonds. Such a unified and consistent model of things provides opportunity for an integrative account of causality, the live-or-death relationship, thereby enabling an explanatory and predictive scheme of the world.

Briefly, we intend to show that beyond the domain of time and space there are general ontological structures (patterns) of things manifesting to human experience in their specific and individual realizations or embodiments and projecting to the mind as mental constructs. And there are also mathematical or symbolic (linguistic) structures representing the ontological entities.

Thus, the world representation schema proposed in book is based on the central thesis: the entire reality, the universe, the world as the whole entity, which parts and domains are aimed to be represented by science and data models, is to be split up into four prime entity kinds (or entity variables):

- **Substance, stuff, or substrate (objects, material or nonmaterial, spatial or nonspatial) O;**
- **State (properties, quantities, qualities, and attributes) S;**
- **Change (actions, activities, events, or behaviors) C;**
- **Relation (links, associations, connections, and bonds) R.**

And all the kinds, types and instances are comprised between the null class of Nothing or Nonentity, ⊥, and the universal class of Thing or Entity, **T**. We can now return again to the ER model of reality but essentially enriched with the entity theory founded on the world-formula, $\{\mathbf{W}, W_I\} = <\mathbf{T}, \{\mathbf{O}, O_j\}, \{ \mathbf{S}, S_k\},\{\mathbf{C}, C_l,\}\{\mathbf{R}, R_m\}, \{\mathbf{f}, f\}, \bot >$, formulated in terms of real classes expressed by real variables, which specific values correspond to individual objects, instances, examples, cases, happenings, etc. In other words, the basic classes (or universals and types) are instantiated by concrete instances (particulars, tokens, individuals, objects, events) in the realm of causality, time and space, all symbolically expressed either by linguistic items or by mathematical values of variable quantities.

A main line of reasoning about the world as the totality of substances **O** can then be conducted the following way. At any moment of time, the world is in a condition named a state defining its innumerable properties, substantial and relative, which values are determined by instrumental measurements and recordings as data points, readings, and statistics. This means that the current world's state is amount to all the values of all the properties (attributes, dimensions, or variables) recorded as the outcomes of all possible measurements or observations, and formally described by a set of distribution probabilities or weighting factors. Then the set of all possible states allowable for the world determines its state space **S**, which size can be defined by the quantity of distinct spaces as its difference, distinction, heterogeneity, diversity, variety, uncertainty, or information. A process of change of the world state or its dynamics is a transformation of its state space, one-to-one, one-to-many, many-to-one, or many-to-many, represented by the process variable **C** and formally described by a matrix of transition probabilities. In the course of change the values of properties (or entity variables) are liable to constraints and limitations imposed by the laws of reality, which is the reflection of relationships between universal entities in reality (or entity variables) **R**. As in the scientific description of natural and social phenomena and systems resting on the concepts of a system of entities, state of a system, the changes of state, the interactions of changes, and the laws of phenomena, the modeling of reality is also similarly on the classes of objects, states of objects, changes of states, and relationships of objects, states, or changes.

Thus, considered apart from the concrete embodiments and circumstances, the Great Four Categories establish the top classes of entity diversified by a multitude of particular objects, qualities, events, and links making an infinite plurality of instances, cases, occurrences, and exemplifications. Crucially, our object of study is the modeling of the whole world as the largest system and the unbounded dynamic environment at the same time. This generalizes presenting the universe as a large collection of systems where each system is bounded by the environment (context, background, surroundings) and distinguished by its properties, dimensions, attributes, states, variety, dynamics, and constraining relationships (control, complexity, or information), as it is practiced in cybernetic modeling [Heylighen and Joslyn, 2001].

Modeling the total of entities in reality, Frame Ontology starts with the largest thing in existence, the world or reality **W**, by mapping onto the global knowledge and reasoning representation system its contents, state space **W** = $\{W_I\}$, dynamics ($W \rightarrow W$), real relationships ($W \times W \ldots \times W$) and its key kinds, domains and levels. The backbone modeling system is marked by a self-consistent representation of the world's dynamics as the total continuum of circular processes (**F**: **W**→**W**), when the state space is mapped into itself by a world transformation function or operation **F**. The mapping describes all sorts of real circularities and nonlinearities, the key features of complex nonlinear systems as physical systems, organisms, intelligent systems, organizations, economies, and social systems, studied in cybernetics, mathematical dynamic systems, systems science, nonlinear physics, life sciences, and social sciences. A crucial importance is commissioned to causal circularities as the network of mutually related causal processes encompassing various feedback cycles or loops, positive and negative, and thus driving all complex phenomena in the natural domain, conceptual universe, cultural region of social reality, or virtual world of computing machines. As a consequence, the dynamic nonlinear world is modeled as the entire networks (web) of interacting causal changes (processes, agents, factors, elements, or variables) reciprocally and reversibly convertible with each other [Abdoullaev, 2000]. Besides, the book reveals that the universal dynamic structure is applied not only to the whole entity but also to any specific field, realm, region, or part of the world, to any domain of interest ranging from set theory to physical devices domain, viewed either as a set of components or a set of specific physical processes.

The **standard ontology** then should be constructed as a formal theory of world entities existing as natural, psychological, cultural, or computational (virtual) realities. Evolving the definition, we display that the type of ontology acting as a coherent and consistent knowledge supporting structure is the one allowing the top-level entity class and its four basic kinds to embrace all things, things of every type and level: the material realm of natural realities, the conceptual realm of mental entities, the social reality of cultural forms and processes, or the computational level of informational entities. And all this is subsumed by several primitive classes each of which is assigned to all things but of a certain kind, along with the family tree of contingent particulars, objects, properties, and occurrences.

In such a general but deep consideration, whatever exists and happens (or conceived as existing and occurring) can be named an entity, a thing, or a being, so that all beings, things, or entities are organized into a great hierarchy of kinds, types, subtypes, and individuals. That is, a few fundamental kinds of entity compose the principal kinds of things in the universe (of discourse), which are substances and objects (spatial and non-spatial or abstract), states (attributes, properties, qualities, or quantities), changes (actions and processes), and relations (entity-to-entity). So, following the underlying principles, we can work out a universal formal account of reality having all the necessary resources to incorporate conceptual models, lexical taxonomies, general ontologies, and formal ontology languages into a single, consistent, and comprehensive scheme.

Passing to sketching the outline of the book content, the author will be allowed to note that the whole research is the effort of more than fifteen years investigations on the subject of the dynamic nonlinear world, its uniform modeling and common representations by machines and human beings [Abdoullaev, 1989, 1992, 1997, 1999, 2000; Novik and Abdoullaev, 1991; Standard Ontology Internet site, 2005; Encyclopedic Web Intelligence Internet site, 2005].

To see the fundamental meanings of the art of ontology engineering and computing applications, first of all, we need to find the well-founded answers to the all-important ontology issues: What are the most general kinds of entity in reality? How are these things related? How the entities and relations could be truly modeled, represented, and expressed? And how should be constructed a standard world specification language for a global representation and reasoning system such as the ontological semantic web?

In the Part I we pursue the fundamental inquiry of a theory of generic entities following the above indicated methodological guidelines. It is revealed that the type of ontology relevant to the standard case is the one modeling the universe as the totality of entities organized under few primitive classes and embodied as a multitude of contingent particulars, objects, properties, occurrences, and associations. In such a global model whatever is and happens can be named an entity or a thing or a being, where all beings, things, or entities are arranged into a comprehensive hierarchy of entity types: the prime classes, their subordinate kinds and innumerable individuals. It is also uncovered that the few fundamental kinds of entity, namely, substances, states, changes, and relations, make the principal ontological classes of things in the total reality as well as in its particular domains, realms, regions, and levels. Considered apart from the concrete embodiments and circumstances, the Great Four Fundamentals determine the top classes of entity, while all sorts and manner of particular objects, qualities, events, and links make up their instances, cases, and exemplifications. Such an integrating theoretical account provides the highest classes of ontological predicates as the conceptual templates under which all other constructs, notions, terms, and predicates can be ordered and distributed whereby unifying a multitude of domain specific ontologies. This postulates that any entity data framework should first appeal to a formal account of reality, to a consistent and exhaustive classification reflecting the real structure of the world and the ordering of its entities. Using the system of symbols and techniques of mathematical foundational theories, vocabulary of higher algebra, lattice theory, set theory, and category theory, we developed the World Representation Knowledge Framework as a standard model involving the world-formula in onto-mathematical terms of entity variables. It is crucially important that the Part I also formulates the principles of **Causal Mathematics** of reality as the means whereby we can achieve the dynamic formal theory of complex real structures and causal systems.

In the Part II, we present reasons and arguments for that the entire gamut of knowledge about the world can be expressed in a single ontology language common to scientific knowledge, extant upper ontologies, and web ontology languages. We give a formal description of the primary entity types, objects, states, and changes, as the template classes of the universe of discourse. It is proved that to have a well-developed ontology of computable classes, to construct a high quality Web ontology language, we first need to formulate the universal entity framework supporting all the major classes in the world hierarchy of entities. To design such a machine-centric type system requires a formal inquiry into the world's objects, states, and changes, as the classes of ontological predicates specifying the structure of any realms of thing or any knowledge domains and bases. Having in view the close perspective of practical application of the entity type system as the unified modeling language, this part also examines and formulates the distinguishing features of objects, states, and changes, their definitions, axioms, properties, classification, and rules, so that to identify the common rules of reasoning about them.

The Part III reveals the core of the general ontology language: an axiomatic model of underlying relations of reality supported with a formal description based on algebraic relation theory. A consistent system of ontological axioms is given as displaying the inherent properties of relational entities, which are as follows:

- ✓ holding between or among things (as components);
- ✓ being endued with order or direction;
- ✓ being able to reverse the order;
- ✓ being capable to be realized (instantiated, exemplified, or embodied);
- ✓ being comparable as identical, like or unlike

In the simplest case of entity-to-entity relationships, all the possible relative orderings are systematically arranged in the Entity-Entity Relationship Matrix (EERM) structure:

O : O	**O : S**	**O : C**	**O : R**
S : O	**S : S**	**S : C**	**S : R**
C : O	**C : S**	**C : C**	**C : R**
R : O	**R : S**	**R : C**	**R : R**

Given the nature of correlatives, the relational matrix formula allows for (and generate) a full extent of specific relation types, as in:

- object-to-object relations for spatial (material) substances and non-spatial (abstract) objects;
- state-to-state relations for attributes or properties, qualities and quantities;
- change-to-change relations for natural, mental and social events;

- relation-to-relation meta-relations as analogies and proportions of various sorts

The common taxonomy of relational classes, existing actually or conceptually, comprises the OWL mathematical (logical) relations between sets (classes) making only a small part of an enormous universe of relations. As well, it covers the rich listing of the WordNet relation types running from the part-whole relations to causality to spatial relations to temporal relations to social, human and business relationships to magnitude relations to semantic, linguistic and formal relations. The Part III also demonstrates that classifying the relationships should be performed both by their real properties and formal attributes. Thus, widely practiced in data modeling methodologies the classification of relationships by degree (number of entities connected), connectivity and cardinality (the number of connected occurrences for each of the related entity types), direction (the parent entity and the child entity), mode of existence (contingent, or optional and necessary, or mandatory), or reflexivity (symmetry or transitivity) is proved to be only a part of the whole matter.

In the Part IV, it is emphasized that of all sorts of relationships the relation of causes and effects comes to be the most substantial connection in reality (hence in the universe of discourse), the formal analysis of which, of its nature, structure, and meaning can be given within the general framework of relations in reality. It is established that whatever is predicated of the relation is also affirmed of causality as its distinguished species. First and foremost, all the ontological axioms revealing the inherent properties of relational entity apply to causal relations, namely:

- holding between two and more change types;
- endowing with ordering or direction of actions;
- reversing the causal order of actions or effects;
- instantiating in concrete facts and particular events

While resting on the common theory of relations, there appears the possibility to give a unified account of causality and causation covering the various causal models and perspectives: functional, instrumental, counterfactual, probabilistic, factual, etc.

As the relations are among the prime constituents of the universe of discourse, the knowledge of relations, particularly the ontological relation of causality, constitutes the basic core of world knowledge and the fundament of reasoning about the world. It is shown that any consistent reasoning upon the world, its particular classes, parts and features, is to be founded on the ontological relationships of substances, states, changes, and relations, as well as on the meta-relations of parthood (part to whole/whole to part relations specified as classificatory relations like subordination, membership and instantiation) and comparison (contrast, identity, resemblance, difference, and analogy). It turned out that the species of reasoning are ultimately determined by the kinds of relationships. As a result, the whole new ideas opened up, that of ontological reasoning (inference), realistic inference rules and veridical inference system (an organized system of ontological axioms and inference rules) as a pattern and road map for enabling a new class of intelligent artifacts such as ontological reasoning applications and ontology-based search engines.

The Part V is largely about building the human natural language as a common knowledge representation and reasoning language for advanced information systems, AI software, and global meaning-based knowledge technologies and applications such as the upcoming semantic web and reasoning services. This part uncovers how the entity and relationship classes may serve as the ultimate semantic values to the word classes and expressions and sentence constructions. It is thus devoted to a formal ontological analysis of natural language, to the role the world knowledge plays in adjusting natural language for meaningful processing by knowledge machines through establishing the semantic relationships between the entity types and the language units. As the world knowledge resides in the natural language as intelligence (mental powers) in the human brain, so any rich natural language can be well regarded as a linguistic extension of ontology defining its verbal classification of things.

The natural human language is approached from many sides: physical, physiological, biological, psychological, linguistic, logical, mathematical, and semantic. However we show that the only one approach brings out the underlying structure of linguistic knowledge, the fundamental nature and meaning of its parts and lexical units (combining forms, morphemes, words, terms, phrases, expressions, sentences, or utterances). It is that which is based on ontological knowledge and real world semantics. We prove that the number, meanings and relations of word classes (both content words and function words) are tied to the classes of things, to the relationships of their meanings. Or, the syntactic, semantic, and logical structure of language, along with the meaning of its major elements, is ultimately determined by the typology and relationships of the top world things, the referential objects of linguistic signs.

It is shown that the language as a collection of expressions can be classified with respect to the principal classes of things: substances, objects, or agents; states, properties, qualities and quantities; changes, actions, activities, events and occurrences; or relations, dependencies, and connections. An onto-semantic analysis of the parts of speech and basic sorts of sentences is performed on the assumption that there are virtually several sorts of words and expressions:

- entity referring terms;
- substance naming words;
- state expressing words;
- change indicating words;
- relation signifying words

As there are four distinct name types of things like the names of substances, states, actions, and relations, so there are four kinds of adjectives, substantive, stative, active, and relational, and four types of verbs indicating being or existence (to ‘be’ or to ‘exist’), states, changes, or relations. As a result, it is confirmed that any linguistic statement asserting that something exists (or does not exist) signifies, at the first place, either substance, stuff, and identity or state, attribute, property, quality, and quantity or action, change, process, and behavior or relationship, association, connection, and link; while, at the second place, there come the derivative features like temporality, spatiality, conditionality, or modality.

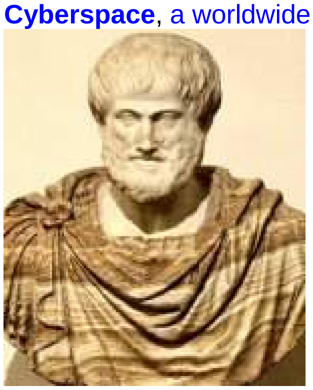
The Part VI discusses a great practical import of the ontology standard language in the project of Virtual Aristotle Machine (VAM), a universal ontology semantic machine generating and understanding the natural human language according to formalized grammatical and onto-semantic rules. The principal component of such a Natural Language Ontology Machine is a question-answering system possessing the world knowledge and large lexicon enabling it to deep causal reasoning in any open domain in terms of human language. Unlike the demised Halo project of Digital Aristotle because of using the traditional KR&R formal logical technologies for modeling, inference, query encoding, answer justification, the VAM is to be designed by applying onto-semantic techniques involving real world modeling, entity (or content)-based reasoning, NL query, and causal explanation and prediction.

Unlike the DA held isolated from the Semantic Web project, the VAM is expected to critically contribute into transforming the Syntactic HTML Web into the Semantic Ontology Web as the next generation of the Internet's World Wide Web. To elucidate the distinctions of the conception of the Virtual Aristotle from the Digital Aristotle, as well as from traditional KR&R systems, we focused the study on the attributes of the VAM as a know-all natural language machine. Among them there are the following decisive issues:

- how the basic kinds of things determine a full set of question classes (and answer types) to meet human inquiry in any knowledge domain;
- the semantic properties of world representation and reasoning formalism;
- how should be structured the whole world knowledge base content;
- interpretation of the VAM in terms of automata theory as a universal Q&A intelligent transducer, or a general-purpose knowledge automaton subsuming the extant logical models of intelligent agents

The main thrust of the ending chapter is that in order to develop the Virtual or Digital Aristotle capable to intelligently extract and process the meanings of symbolic representations, we need to move away from the historical knowledge engineering tools and technologies too much banking on formal logical languages.

To sum up, the whole content proposed is opening up the way of constructing the standard ontology as a unified (descriptive and formal) account of reality producing the world knowledge standards meeting the requirements of machine intelligences and human minds. It provides the entity type system with descriptive, explanatory, and predictive features capable to incorporate the relevant constructs from existent upper ontologies, classification schemes, conceptual data modeling languages, and the web ontology languages into a comprehensive ontology library of things used a single consistent frame for all sorts of computing reasoning applications. Having the standard ontology of semantic primitives admits of natural language as the most general knowledge representation and reasoning language. As a result, the formal natural language theory (algorithm) enables us to lay down the principles and rules for designing and developing encyclopedic knowledge and reasoning machines as a new class of intelligent information systems understanding human natural language. Equipped to learn, acquire, process, accumulate and communicate the world knowledge in NL forms, the encyclopedic reasoning application (or the Virtual Aristotle) will constitute the most vital part of coming **Global Intelligent Cyberspace**, a worldwide computer networks of intelligent NL machines and human beings.



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