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EVOLUTION BY CHOICE IN ONTOLOGIES

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Abstract: Blindly copying and mimicking evolutionary processes in animated nature along with well developed mathematical models for them looses its base, the inevitable evolution looses its meaning. Instead the evolution by choice more and more establishes itself and it has much greater perspectives to spread. The experiments of evolution by choice is in an abstract mathematical domain where the models include numerous number of elements, i.e. much too bigger in number than the biological evolutionary models. The paper introduces the idea of evolving-by-choice ontologies, a juxtaposition of evolving ontologies with an evolution by choice algorithm. A principle scheme of evolving-by-choice ontology is introduced and the starting options of the model are presented. In total the fundamental problem for biologically inevitable evolution – prove that the solution space exists – in the case of evolving-by-choice ontologies is replaced by the problem to find the shortest path to the solution space.

Keywords: inevitable evolution, evolution by choice, evolving ontologies, evolving-ontologies state-of-the-art, evolving-by-choice ontologies.

ACM Classification Keywords: C.0 Computer Systems Organization – System architectures, C.4 Performance of Systems – Modeling techniques & Performance attributes, D.2.4 Software/Program Verification - Validation, D.2.8 Metrics – Complexity measures & Performance measures, D.2.9 Management - Life cycle & Productivity, D.2.10 Design – Methodologies, D.4.8 Performance – Modeling and prediction, F.2.2 Nonnumerical Algorithms and Problems – Complexity of proof procedures, G.4 Mathematical Software – Efficiency

Introduction. Necessity of Evolution by Choice in Ontologies

At present “ontology evolution is barely study” [1]. The undeveloped state of the theory may be treated in two major aspects: (i) shortage and even absence of a general and comprehensive theory due to (ii) blind copying the biological evolution [2] formalized as applying mainly statistical methods from mathematics for phenomena in biology as reproduction, mutation, crossover, etc. [3, 4, 5].

At a closer look the following classification approaches are valid for ontologies: (i) abstract-theoretic fixed at the philosophical concept of ontology with all its typical features and characteristics which include the lowest level of application for a specific domain (the so called formal ontology [6]), (ii) theoretic-applied developing in *principal* implementations in economics (Web services and e-learning [7]); knowledge management and design of information systems [8]; process control systems [9, 10, 11]; (iii) applied for a specific domain: software platforms [12], standards, programming languages and software technologies for e-learning, programming and logical languages, formats and standards for ontologies in management systems.

Dynamics in ontologies is predetermined by the environmental dynamics. It is linked with the temporal properties of the system “object-environment” and it is formalized via temporal dependencies imposing temporal and other limitations. Basic tools to formalize dynamics are the ones of mathematics and of logic, but statistics (statistical analysis systems, statistical packages for social sciences) is excluded.

Recently the research of evolutionary-type changes in ontologies are reduced to establishing inherent concepts and also to their organization in a definite and logically-consistent system. For example some of the basic terms and concepts for the working group in the Karlsruhe University during the last years are: (i) type of evolutionary operations in ontologies [13]; (ii) requirements for ontology evolution [14]; (iii) ontology evolution phases [15]; (iv) types of relations in evolving ontologies [16]; (v) ontology mapping via axioms [17]; (vi) discovery-driven ontology evolution [14]; (vii) evolving ontology evolution [15]; (viii) incremental ontology evolution [16]; (ix) classification of changes in ontologies [15]; (x) revision of ontologies as beliefs' revision [18]; (xi) collaborative engineering of evolving ontologies [19].

Obviously the last more general concepts are directly related to the previous more particular ones. Besides one and the same authors develop and specify both categories of concepts for evolving ontologies. At this stage from the point of view of formalism about evolving ontologies the essence of logical rules (limitations, axioms) undergoes a rapid growth and it removes typical mathematical techniques (inherent to taxonomical and in fact unified approach to processes in a given domain). In this natural way blindly copying and mimicking evolutionary processes in animated nature along with well developed mathematical models for them looses its base, the inevitable evolution looses its meaning [2]. Instead the evolution by choice more and more establishes itself and it has much greater perspectives to spread [2].

Arguments for the latter can be found for example in [15]. The authors introduce the following taxonomy of changes: (i) definition of ontology change (OC); (ii) ontology change subfields (in fact this taxonomy list); (iii) ontology evolution; (iv) ontology versioning; (v) heterogeneity resolution to enhance ontology ensemble operation; (vi) ontology integration; (vii) ontology merging. On the other hand the application of the typical mechanism of evolution for living creatures [20] confronts with invincible contradictions concerning the concepts in this taxonomy except for the concepts of ontology evolution (iii) and its versioning (iv).

In [2] it is postulated that the evolution by choice was an object for experiments in an abstract mathematical domain where the models include numerous number of elements, i.e. much too bigger in number than the biological evolutionary models. The basic advantages of the evolution by choice which are also its identification marks are: (i) the goal formulation does not indicate a respective fitness function; (ii) intermediate solutions and estimates are also an object of the evolution; (iii) processing includes variable reference points rather than probabilistic expertise; (iv) the final result is more reliable compared to the traditional evolutionary approaches. In fact the possible heuristics in the evolution by choice is introduced only by the user; it is replaced by exact knowledge (models or inference schemes); exact knowledge originates during the mathematical proof thus reducing the role of the heuristic information. In contrast to this type of evolution the finalizing procedure of the inevitable evolution is unclear or weak and heuristics is decisive to reduce the solution complexity, etc.

A special matter of interest about the evolving-by-choice ontologies are the concepts for the direction of evolution and for the restrictions of evolution. The directions here may be general and temporal and they may be logically united. The limitations may be static and dynamical. In the case of dynamical limitations the dynamical-restriction weights are much bigger than the weights of static restrictions.

In total the fundamental problem for biologically inevitable evolution – prove that the solution space exists – in the case of evolution by choice is replaced by the problem to find the shortest path to the solution space.

Possible Realization of the Evolution by Choice in Ontologies

The main peculiarity in the case of applying the method of evolution by choice for evolving dynamical ontologies is the following consideration.

The computer component of the human-machine system processes only the syntax of knowledge and the human (the user) is responsible for the semantics and pragmatics of knowledge [2].

The resented below scheme and algorithm of operation in evolving ontologies is based on the presented in [21] (for the ontology scheme) and [22] (for the ontology algorithm) ontology schemes and also to the proposed in [2] algorithm fro evolution by choice.

The Typical Scheme of Evolving Ontologies. Ontology Changes and Ontology Evolution

The basic part in a typical scheme of evolving ontologies is the ontology analyzer [21]. It must fix the change in the object ontology via its comparison with the already accumulated archive about the already fixed ontology changes.

Besides the fixation of the new change and its logging in the library the following new actions are performed: (i) deletion of the already unnecessary class(es); (ii) pooling of some classes, (iii) addition of a new class; (iv) the Universal-Knowledge-Identifier (UKI) Modifier changes the respective UKIs; (v) the ontology version is updated.

Obviously in the most minimal (but *fundamental*) version the ontology evolution is reduced to a fixation and reacting by the human-machine system to the changes in the ontologies and also to the adaptation to them; the *forecast* of the system behavior in the future is *null* and the reconstruction is reduced to reconfiguring the classes *post factum* instead. There is no action concerning *dynamic* parameters (besides the UKIs, classes and the ontology version) and especially the *continuous* dynamics. The changes of UKIs, classes and the ontology version are always triggered by user requests instead of following some law of temporal behavior. The operation in the *temporal* dimension is not possible yet. This means that either the basic evolving-ontology model is *temporally incomplete* or it must be *upgraded towards its temporal dimension*. Therefore the relation between the *system*, the evolving ontology *model* and the application *domain* is vague and also that the environmental *properties* are not reported.

The up-to-date upgrades in the direction of temporal behavior concern just concrete *aspects* of the overall system behavior for the concrete *domain*; the concrete ontologies are also tied to the concrete problem. *This explains the absence of a generalized but unified model of evolving dynamic ontologies*.

In total, the evolution of the *quasi-dynamic quasi-evolving ontology* is *not by choice*. It is even *not inevitable*, it is *unpredictable* instead (except for the user intentions). Such type of evolution resembles to a great extent the evolution of living nature thus obeying the typical for it *uncontrollability* and *unavoidability*.

Evolution-by-Choice. Important Considerations

Following [2] we may split the algorithm of evolution by choice in two big successive parts: pre-evolutionary part and a part most tightly connected to the system evolution.

Pre-evolutionary Part. It corresponds to the formalization of the problem including the goal formulation and the determination of the environmental properties.

These properties are determined via the constraints and/or axioms that are imposed over the system. The environmental properties are available on the basis of the input data. The user inputs a *set of models* with their *priorities*. The input data set is tested for inconsistencies with the *accumulated knowledge*.

The field of the application domain is expanded on the basis of the mathematical induction.

Evolution-by-Choice Part. It adapts the data and/or the knowledge to the available knowledge thus making the model valid also for other possible models.

The mainstay for corrections and changes in the current solutions comprises the process of modeling, fixing and solving contradictions. Therefore the evolutionary process most often changes or it picks up strength along with the system operation.

The most often used techniques include juxtaposition, comparison, grouping and analysis of relations between the data, the knowledge or of their sets.

The *fitness function* is implicit. It is formed and changed.

Initially there is an infinite number of *possible solutions*.

Estimation criteria of the solution are unknown a priori. They are based on the application of “assumption-conclusion” relations of different types which can be within a broad range from completely informal up to Horn rules.

The *best solution* is determined based on the solutions with the highest priorities.

In the algorithm proposed in [2] the *time coordinate* (the temporal dimension) is logically based which in its turn depends on the logical inference. In addition it strongly depends on the *learning* process during the evolution cycle because most of the dynamic changes are unknown a priori.

The power of the algorithm is based on:

- expansion or correction of the accepted *model*,
- expansion or correction of the *space of relations between the input data*,
- reduction of *inconsistencies between the data interrelations and the stored knowledge*,
- ability to *learn from dynamical constraints*.

The last feature is the cherry on the pie for applying the evolution-by-choice mechanism for dynamical ontologies' evolution. In contrast the learning process in living creatures is inconsistent, chaotic and random while the evolution itself is accidental rather than law-governed.

Comparative Analysis of the Two Introduced Models. Their Unification in Evolution by Choice in Ontologies

In total the basic model from item "The Typical Scheme of Evolving Ontologies" reacts event not right to the evolution stimulating factor itself but rather to the *single changes* in the environment. Consequently such model(s) is (are) contextually a model of a dynamic (or variable) ontology; and formally, from the software point of view – a model of a quasi-evolving quasi-dynamic ontology which responds to the environmental changes.

On the contrary, the model from item "Evolution-by-Choice" is not just an evolutionary model; it is rather a model of a *goal-driven evolution* or of an evolution by choice.

The basis for unifying (and mutual supplement) of those both models may be the presented in [22] scheme of the ontology life cycle. Just like the presented in the "Evolution-by-Choice" item algorithm this scheme may also be divided in two big clusters which are handled one after another: (i) system initialization with data and knowledge which do not depend on the user requirements, and (ii) processes which follow from these requirements.

Entity (i). It comprises the knowledge about the domain, the procedural knowledge, the conceptualization with its explicit specification, the metric characteristics of similarity and the estimates based on them.

Entity (ii). It comprises the factorization of the ontology to shared and private, the contextualization, the ontology development (which includes refinement, generalization, redundancy, similarity), the simplification of the ontology and the creation of a Truth Maintenance System (this block may be considered identical or at least analogous to the mechanism of resolving inconsistencies in the model from item "Evolution-by-Choice").

In addition the state of the ontology can possess several dimensions (temporal, spatial, a degree of similarity and fuzziness as a functional of the affiliation set). It can be determined at least in three possible ways: as a cumulutative network of possible combinations of the formal ontological model and also as a general state – a vector of the partial ontologies. At that each state of every partial ontology is a vector of the components of the formal ontological model.

It is evident that the part closest to satisfying the requirements for an evolution-by-choice algorithm is the one which is responsible for the ontology development with its four basic entries (refinement, generalization, redundancy, similarity). At the same time the formalism describing the ontology state must be supported. The system constraints may be formulated via the tools of logic as axioms and rules of one or several types of logic (descriptive, temporal, etc.).

Principal Scheme of an Evolution-by-Choice Ontology

The scheme of an evolutionary-by-choice ontology is shown in fig. 1.

It can be partitioned briefly in two big parts, before and after the test for changes in the data and in the environment. In its turn the part before the test is subdivided in two smaller parts, before and after the ontology-user-requirements input.

In fact before the test for changes about the ontology there are two *parallel* branches that perform coherently.

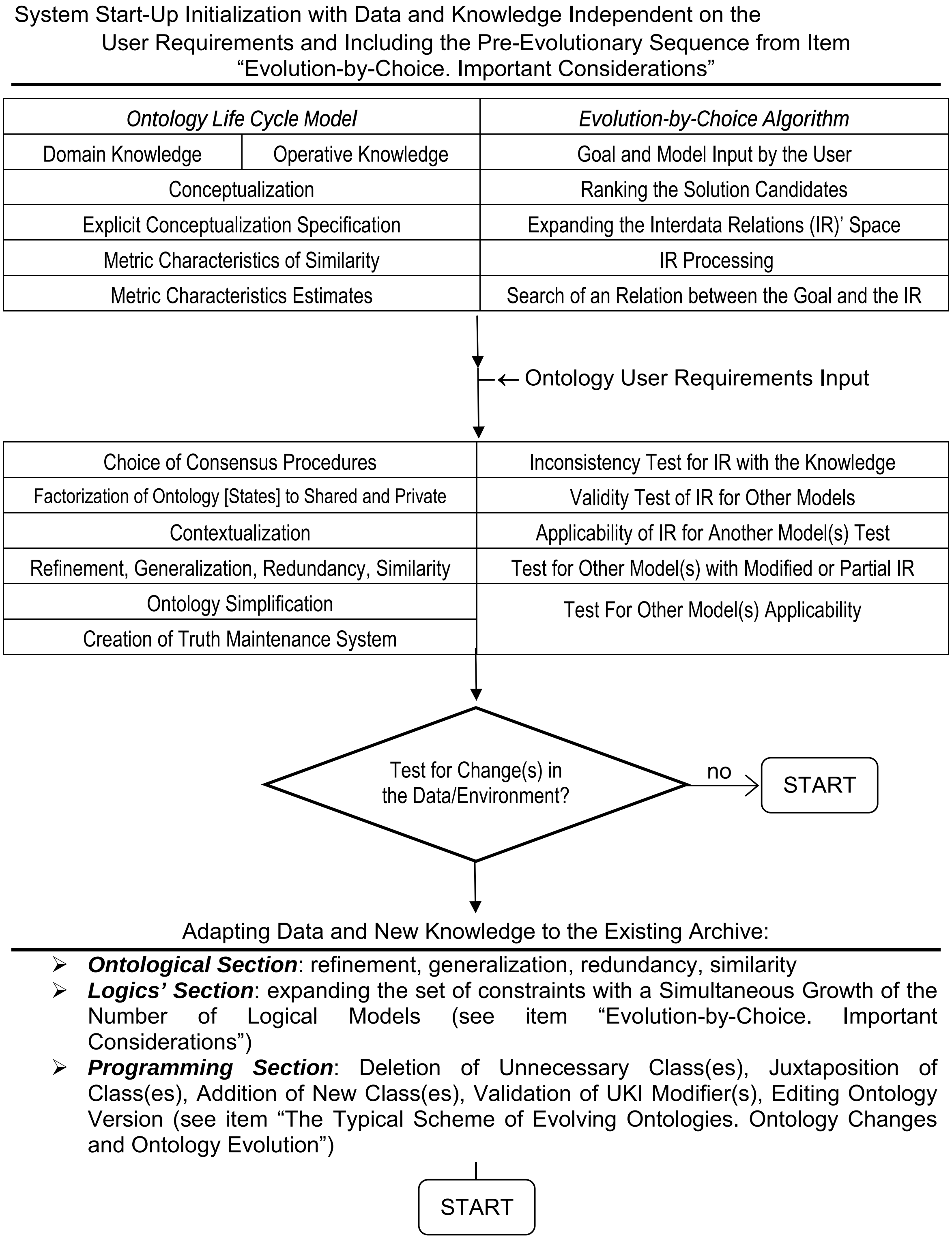

Fig. 1. Principal Scheme of an Evolution-by-Choice Ontology

Before the ontology user requirements input the first branch (it is denoted in the left half of the scheme) is responsible for the basic types of initialization of the ontology at first or for the iteration (domain and operative knowledge, conceptualization, explicit conceptualization specification, metric characteristics of similarity and metric characteristics estimates). Simultaneously with it the second branch (in the right half of the scheme) is responsible for the startup initialization of the logic tools (input of the goal and the model by the user, ranking the solution candidates, expanding the interdata relations (IRs) space, IR processing, search of a relation between the goal and the IR).

After the input of the user requirements for the ontology on the left side the processing continues with the choice of a consensus procedure, followed by the factorization of ontology [states] to shared and private ones, contextualization, refinement, generalization, redundancy and similarity, ontology simplification, and the creation of a truth maintenance system. The logical tools proceed with an inconsistency test for the interdata relations (IRs) with the accumulated knowledge, followed by a validity test of IRs with other models, with an applicability check of IRs for another model(s), with a test for other model(s) with modified or partial IRs, and with a test for applicability of other model(s).

The adaptation process of the ontology to the changes in the environment and/or in the model are mainly grouped to three main phases: (i) for the left half of the scheme, a development of the ontology (refinement, generalization, redundancy and similarity), (ii) for the right half of the scheme, expanding the set of constraints with a simultaneous growth of the number of logical models (see item 2.2) and (iii) deletion, juxtaposition and addition of new class(es), validation of the UKI Modifier(s), and editing the ontology version (see item 2.1). It is evident that (i), the first phase, concerns the evolution of the ontology itself or the *ontological evolution*, that (ii), the second phase, is directly connected with the *logical evolution* of the system and that the third phase, (iii), is connected with the *algorithmic-programming evolution* of the system. So we may conclude that the system evolution is deployed to three successive [branches of] evolutions (ontological, logical and algorithmic-programming).

In fact this partitioning of the overall algorithm to three successive evolutions is rather conceptual than crisp, it marks three substantially different kinds of processing from which the first two concern the internal system mechanism (or modes of operation) on a *semantic* level and the third one – on a *formal* level (the ontological and logical evolutions are formalized via programming constructions).

The mutual coordination between the two semantic aspects of the system evolution by choice is substantial for the good performance of the system as a whole. Kinds of preferable types of logic are the descriptive and temporal logic, the paraconsistent logic and so on.

Due to the extreme novelty of the proposed method the system *starting version* is the minimal possible on. It shall be upgraded in the course of time developing towards its gradual sophistication.

The following options have been accepted for the starting version of the system:

- implementation only of a subset of temporal logics including the relations ‘preceding’/’before’ and ‘succeeding’/’after’;
- system of priorities for achieving the goal ranging from ‘low’ through ‘middle’ up to ‘high’. This system of priorities resembles to a great extent the apparatus of fuzzy logic (though it is *not* a true fuzzy logic at the beginning; subsequently the authors have the intention to apply a simple type of fuzzy logic);
- Prolog-like syntax for inference of new constraints corresponding to the new changes for system operation.

Conclusion

Blindly copying and mimicking evolutionary processes in animated nature along with well developed mathematical models for them looses its base, the inevitable evolution looses its meaning. Instead the evolution by choice more and more establishes itself and it has much greater perspectives to spread. The experiments for evolution by choice is in an abstract mathematical domain where the models include numerous number of elements, i.e. much too bigger in number than the biological evolutionary models. The basic advantages of the evolution by choice which are also its identification marks are: (i) the goal formulation does not indicate a respective fitness function; (ii) intermediate solutions and estimates are also an object of the evolution; (iii) processing includes variable reference points rather than probabilistic expertise; (iv) the final result is more reliable compared to the traditional evolutionary approaches. The paper introduces the idea of evolving-by-choice ontologies, a juxtaposition of evolving ontologies with an evolution by choice algorithm. A principle scheme of evolving-by-choice ontology is introduced and the starting options of the model are presented. In total the fundamental problem for biologically inevitable evolution – prove that the solution space exists – in the case of evolving-by-choice ontologies is replaced by the problem to find the shortest path to the solution space.

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