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Triune Continuum Paradigm

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INTRODUCTION

This article reviews the Triune Continuum Paradigm—a logically rigorous theoretical base for organization of conceptual frameworks that are used for system modeling in different contexts (e.g., in software development, in enterprise architecture, in the architecture of financial services, in jurisprudence, etc.). This paradigm is an important contribution to the system modeling domain, because currently none of the prevailing system modeling frameworks has a satisfactory formal theoretical foundation.

The absence of a theoretical foundation for modeling frameworks leads to the practical application experiences where modelers are constrained to be guided by chance and not by a founded reason. This often leads to the inadequate choices of modeling frameworks, that is, to the situations where a chosen modeling framework is not designed to deal with the targeted modeling problems. Possible consequences of such choices include incorrect (e.g., inadequate with regard to the requirements) information systems specifications, contradictory data architectures, incomplete service specifications, and so forth—all of these being the decisive contributions to failures of many projects. The paradigm, which we review in this article, fixes this problem providing missing theoretical foundations for frameworks positioned in the domain of general system modeling.

Many of the existing system modeling frameworks appeared as an integration of the best modeling practices. The reviewed paradigm does not repudiate the practical experience that was gathered by these different frameworks, but fixes its inconsistencies and complements it supporting with logically rigorous theoretical foundations. Therefore the paradigm brings a significant constructive potential to the evolution of modern system modeling frameworks. This potential could be realized if people responsible for the design of modeling frameworks and tools would heed the proposed paradigm.

BACKGROUND

The Cambridge Dictionary of Philosophy (Audi, 1999, p. 641) provides the following definition of the term "paradigm": "Paradigm, as used by Thomas Kuhn (The Structure of Scientific Revolutions, 1962), a set of scientific and metaphysical beliefs that make up a theoretical framework within which scientific theories can be tested, evaluated and if necessary revised."

In practice, a paradigm is usually defined for a collection of sciences. In this context a paradigm introduces and justifies a set of basic assumptions and principles on which any of sciences from the collection can rely as on their foundations. Then, starting from the principles provided by a paradigm, different sciences build their specific frameworks of knowledge. And if some sciences share the same paradigm, then they can bind and synchronize their specific frameworks of knowledge. By doing so they can mutually enrich each other with the knowledge obtained from the different (but consistent with regard to the basic principles) points of view.

The Triune Continuum Paradigm (Naumenko, 2002) is a paradigm for general system modeling. Thus the Triune Continuum Paradigm serves the sciences that have diverse interests in system modeling. As any paradigm, it introduces and justifies a set of principles that provide the sciences with the necessary starting points for building their diverse conceptual frameworks of scientific knowledge, in our case the principles that are necessary for building modeling frameworks.

THREE PRINCIPLES OF THE TRIUNE CONTINUUM PARADIGM

The Triune Continuum Paradigm is composed of three principles.

The first principle is the result of application of Tarski's Theory of Truth (Tarski, 1956) for the case of general system modeling. This application allows defining coherent semantics for the concepts of a modeling framework. This is done by constructing formal descriptions for the relations between the subjects that are interesting to be modeled on one side, and the concepts that have to represent these subjects in the models on the other side. This principle is necessary to assure the *coherency* and *unambiguity* within modeling interpretations performed using a single system modeling framework.

An application of the first principle provided by the Triune Continuum Paradigm results in a system modeling framework that features modeling terms with a coherently defined semantics in the form of Tarski's declarative semantics. The justifications of importance of this principle for the information systems modeling were presented and analyzed in details (Naumenko, Wegmann, & Atkinson, 2003). In particular, it was demonstrated that Tarski's declarative semantics are:

- formally *sufficient* for the definition of the application scope of a modeling language;
- formally *sufficient* for unambiguity in coherency of interpretations within modeling representations; and
- formally *necessary and sufficient* for unambiguity in adequateness of modeling representations.

The second principle of the Triune Continuum Paradigm is the result of application of Russell's theory of types (Russell, 1908) for the case of general system modeling. This application defines the way to categorize concepts of a modeling framework so that in applications of this framework the concepts make up *internally consistent* structures of propositions. Thus this principle is necessary to assure the consistency of descriptions and specifications, which are constructed with the aid of the modeling frameworks.

The importance of this principle is justified by the fact that Russell's theory of types was formulated to resolve Russell's paradox, "the most famous of the logical or set-theoretical paradoxes" (Irvine, 2003). Thus with an application of the second principle of the Triune Continuum Paradigm, the resulting modeling framework in its own applications will produce internally consistent system specifications (i.e., system specifications that are devoid of self-contradictions).

The name of Triune Continuum Paradigm originates from the third theory that was employed for the paradigm definition, from the Theory of Triune Continuum. This theory was defined by Naumenko (2002). This theory allows for the introduction of the abstract ontologies that are formally *necessary and sufficient* to cover the modeling scope of different modeling contexts on the most abstract level.

In particular, the Theory of Triune Continuum was applied in the context of general system modeling (Naumenko, 2002), and this application contributed to the definition of the Triune Continuum Paradigm. The application is the third paradigm principle that allowed introducing and justifying a minimal set of modeling concepts that are necessary and sufficient to cover the representation scope of the general system modeling domain on the most abstract level. This principle is necessary for different system modeling frameworks to justify the existence of their basic modeling concepts.

The Theory of Triune Continuum introduces three continuums that represent in models the scope of general system modeling. The first two continuums are:

- **Spatiotemporal Continuum:** Where subjective space-time metrics are defined to be used in the subjective representations.
- **Constitution Continuum:** Where subjective constitutional metrics are defined to be used in the subjective representations, for example, objects defined in relation with their environments.

These two continuums are introduced in relation with each other as complements within the universal general system modeling scope. In other words, everything in the scope that is not space-time is constitution; and everything in the scope that is not constitution is space-time.

The third continuum is:

- **Information Continuum:** Which emerges from the mutual relations of the first two continuums and contains the corresponding information about these relations, for example, information about objects and their environments being related to the spatiotemporal intervals or to the points in space-time).

Thus the three continuums are *triune*: none of them exist without the others; either the three exist altogether, or they do not exist at all. Indeed, as soon as the first (spatiotemporal) continuum is introduced, everything in the universal scope that does not belong to the first continuum immediately shapes the second (constitution) continuum; and the third (information) continuum immediately emerges as the information about the mutual relations of the first two continuums (e.g., as spatiotemporal information about the constitution).

The third principle of Triune Continuum Paradigm is important for various system modeling frameworks, which are used in diversified domains of human activity (e.g., the frameworks used to analyze, design, and develop coherent structures providing useful functionalities in domains spread from jurisprudence and health care to software engineering and machine-building industries). Using the notion of Triune Continuum it is possible to introduce and justify minimal sets of modeling concepts that are necessary and sufficient for those diversified frameworks to cover their respective representation scopes.

APPLICATIONS OF THE TRIUNE CONTINUUM PARADIGM

The Triune Continuum Paradigm can be applied in practice either to improve an existing system modeling framework or to design a new system modeling framework for a given purpose. Let us mention here three of the existing applications of the paradigm:

- case of the Unified Modeling Language (UML);
- case of the reference model of open distributed processing (RM-ODP); and
- case of the systemic enterprise architecture methodology (SEAM).

The first two of the three cases illustrate the paradigm applications targeting improvements of the existing system modeling frameworks. The third case illustrates the paradigm application contributing to the design of a new system modeling framework.

Case 1: Triune Continuum Paradigm Application for UML

"The Unified Modeling Language (UML) is a language for specifying, visualizing, constructing, and documenting the artifacts of software systems, as well as for business modeling and other non-software systems" (OMG, 2003, section 1.1). UML is a proposition of the Object Management Group (OMG) that emerged from the integration of different industrial practical experiences and became an influential phenomenon in the system modeling. As a matter of fact, due to the multiple efforts of different interested parties, UML has gained a relative domination over the other modeling techniques in the current industrial practices. This is why it was interesting to apply the Triune Continuum Paradigm for the case of UML conceptual framework. Results of this application were presented to the UML research community (Naumenko & Wegmann, 2002). With the aid of the Triune Continuum Paradigm it was shown that the metamodel of UML features a number of undesirable properties, in particular:

- absence of an explicit structural organization defined for the UML metamodel;
- absence of Tarski's declarative semantics in the UML metamodel; and
- absence of theoretical justifications for the UML metamodel to represent the modeling scope that is targeted by UML.

The paradigm-based solutions were presented for each of the three identified problems (Naumenko & Wegmann, 2002) providing designers of UML with the benefits of the paradigm's logical rigor, of its formal presentation, and of its solid theoretical foundations.

Case 2: Triune Continuum Paradigm Application for RM-ODP

The RM-ODP is an ISO and ITU standard for system modeling, designed to model ODP-systems (ISO & ITU, 1998). The result of Triune Continuum Paradigm application for the RM-ODP case is especially interesting because it allowed accomplishing a single consistent formalization of the RM-ODP conceptual framework, providing the denotational semantics for the basic modeling and specification concepts of RM-ODP. Such formalization was officially declared as a goal of the ISO and ITU activities in the scope of RM-ODP standardization (ISO & ITU, 1998). But this goal was not achieved by the standard; and so far the paradigm-based formalization remains the only solution achieving the defined objective.

The formalization was expressed in a computer interpretable form using Alloy formal description technique (Jackson, 2002). Alloy was chosen because of the public availability of the corresponding software tool, "Alloy Constraint Analyzer," that allows simulating the instances of conceptual structures formalized with Alloy and representing these instances in a graphical form. However, due to the nature of denotational semantics (Naumenko et al., 2003), any choice of the formal description technique does not change semantic interrelations within the formalization. So, another formal description technique could also be used to express the paradigm-based formalization of the RM-ODP conceptual framework in a computer interpretable form.

The paradigm-based formalization of RM-ODP presents a concrete example of formal ontology for general system modeling. Thanks to the Triune Continuum Paradigm, the metamodel that is realized by the formal ontology is internally consistent, introduces logical coherency of interpretation of a subject of modeling, defines formal semantics for the modeling concepts, and its models are verifiable with the aid of computer tools. These results were presented to the RM-ODP research community (Naumenko & Wegmann, 2001, 2005; Naumenko, Wegmann, Genilloud, & Frank, 2001), and they attracted interest of the ISO/ITU committee that is responsible for the RM-ODP standardization. This provides the Triune Continuum Paradigm with a chance to influence future evolution of the ISO/ITU standard.

Case 3: Triune Continuum Paradigm Application for SEAM

The systemic enterprise architecture methodology (SEAM) is a methodology proposed by LAMS-EPFL (Wegmann, 2003) for system modeling in the domain of enterprise architecture, which is the domain that considers integration of IT systems and business systems in the context of an enterprise.

Applying the Triune Continuum Paradigm, a logically rigorous framework of concepts covering the representation scope of SEAM was designed and implemented as a specialization of the RM-ODP standard conceptual framework (ISO & ITU, 1998). Thus in this case the paradigm application provided a formal ontology for SEAM. The corresponding research results were reported to the Enterprise Architecture community (Wegmann & Naumenko, 2001) and provided the necessary basis for ongoing evolution of SEAM.

FUTURE TRENDS

The Triune Continuum Paradigm provides a set of theoretical foundations for different frameworks of knowledge belonging to the general system modeling domain. In most of the cases currently existing industrial and academic frameworks for system modeling do not feature such theoretical foundations, because these frameworks are developed using the so-called "best practices" approach (when results of different practical experiences of system modeling within a given domain are integrated to build a modeling framework for the domain). And if the "best practices" approach is not accompanied by theoretical foundations, then it is impossible to justify a number of important properties for the resulting system modeling frameworks (e.g., to guarantee the necessity and sufficiency of a framework for its domain representation, to assure internal consistency within different pieces of practical experience integrated in a single framework, etc.).

So, the Triune Continuum Paradigm provides an indispensable contribution to the general system modeling. And the future trends should assure practical realization of the significant constructive potential that the paradigm features for those numerous system modeling frameworks that currently do not have satisfactory theoretical foundations. This potential will be realized through the paradigm applications to these concrete system modeling frameworks. Some of the examples of such applications were presented in this article.

CONCLUSION

The Triune Continuum Paradigm provides system modelers (in particular, IS modelers) with a set of principles that are essential to build adequate system modeling frameworks. These principles are based on the solid theoretical foundations discovered in the last century: Tarski's Theory of Truth was presented in 1935, while Russell's Theory of Types was formulated in 1908. The authors of these two theories, Alfred Tarski and Bertrand Russell, are recognized to be among the greatest logicians throughout the history of humankind. Thus the Triune Continuum Paradigm, through its applications used in the computer-aided environment, promotes the use of fundamental logical theories to the practices of regular modelers, information system designers, and architects. The paradigm-based theoretically founded approaches to the information systems development make a constructive difference in the IS development projects where the usual "best practices methodologies" do not perform well enough due to a number of reasons (e.g., lack of flexibility, lack of representation possibilities, lack of internal consistency, etc.).

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KEY TERMS

Reference Model of Open Distributed Processing (RM-ODP): An ISO and ITU standard for system modeling designed to model open distributed systems.

Russell's Theory of Types: A theory proposed by British logician Bertrand Russell to resolve Russell's paradox, which appears when the set of all sets that are not members of themselves is considered in naive set theory. The paradox is that such a set appears to be a member of itself if and only if it is not a member of itself.

Systemic Enterprise Architecture Methodology (SEAM): A methodology proposed by LAMS-EPFL for system modeling in the domain of enterprise architecture (the domain that considers integration of IT systems and business systems in the context of an enterprise).

Tarski's Theory of Truth: A theory proposed by Polish logician Alfred Tarski. The theory defines the criteria for a formal definition of a true sentence; the theory allows deriving the notion of Tarski's declarative semantics for a modeling language where the modeling language terms are put in the unambiguous correspondence with the subjects of modeling interest that they represent in applications of the language.

Theory of Triune Continuum: A modeling theory proposed by Andrey Naumenko. The theory introduces three continuums (spatiotemporal, constitution, and information continuums) to justify a minimal set of modeling concepts that are formally necessary and sufficient to cover the representation scope of different modeling contexts on the most abstract level.

Triune Continuum Paradigm: A paradigm for general system modeling. The paradigm introduces and justifies a set of principles that provide designers and architects of system modeling methodologies with the necessary theoretical support for building their modeling frameworks. The principles are derived from the Tarski's Theory of Truth, from the Russell's theory of types, and from the Theory of Triune Continuum.

Unified Modeling Language (UML): Proposed by the Object Management Group (OMG) for system modeling in the domains of software systems, of business systems, and others.