A report on the Triune Continuum Paradigm and on its foundational theory of Triune Continuum

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Abstract. This paper familiarizes the audience with the Triune Continuum Paradigm, a paradigm that provides philosophically supported theoretical foundations for system modeling in general and in particular for Information Systems engineering. The paper presents theoretical foundations of the paradigm; in particular it presents some of the key features of the theory of Triune Continuum, one of the three theories that contribute to the definition of the paradigm.

1 Introduction

The Cambridge Dictionary of Philosophy [1] provides the following definition of the term “paradigm”: "*Paradigm, as used by Thomas Kuhn [5], 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 was originally defined in [7] and later presented in [6][1]. It 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.

The principles of Triune Continuum Paradigm allow for building system modeling frameworks that:

[1] [7] contains all of the technical details related to the paradigm definition; and [6] presents a brief introduction to the Triune Continuum Paradigm.

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- are coherent and unambiguous in their interpretations of different subjects of modeling interest;
- being applied, produce internally consistent applications (in other words: being applied, produce concrete system specifications that are devoid of self-contradictions);
- have the terminologies that are adequate for their modeling scopes (in other words: have their respective terminologies that are formally necessary and sufficient for representations of their respective modeling scopes).

The Triune Continuum Paradigm is the only existing paradigm that features such set of principles.

The Triune Continuum Paradigm is a complete in its scope of purposes and formally presented theoretical base that can be used for building or for improvement of modern modeling frameworks that are employed for system modeling in different contexts, in particular in software development and in the engineering of enterprise information systems.

The paradigm can be considered as an important contribution to the system modeling domain. As it was demonstrated for instance in [7], [8] and [9], the currently prevailing system modeling frameworks do not have a satisfactory formal theoretical foundation. The absence of theoretical foundation favors introductions of ambiguous semantics for the terms of modeling frameworks, encourages inconsistent system specifications in the applications of modeling frameworks and impedes adequacy of modeling frameworks for their representation purposes. The Triune Continuum Paradigm provides the necessary means for elimination of these problems.

This paper is organized as follows. Section 2 introduces the Triune Continuum Paradigm by describing the applications of three theories that contributed to the paradigm's definition. Section 3 presents the key features of one of these three theories: of the theory of Triune Continuum. Section 4 describes several examples of applications of the paradigm. And finally, Conclusions summarize the paper.

2 Three principles of the Triune Continuum Paradigm

The Triune Continuum Paradigm is constructed as a synthesis of three principles that are, in their essence, applications of the following three theories: of Tarski's Theory of Truth, of Russell's Theory of Types and of the Triune Continuum Theory.

In practical applications of the paradigm these three principles serve as fundamental theoretical foundations for the definitions of system modeling frameworks. Let us introduce each of the three principles of the paradigm.

2.1 Application of Tarski's Theory of Truth

The first of the aforementioned theories is Tarski's Theory of Truth, proposed by Alfred Tarski in 1935 [14]. To define the Triune Continuum Paradigm, [7] performs an application of this theory in the context of general system modeling. This application is the first principle of the Triune Continuum Paradigm. And this principle, being applied in its turn to a modeling framework, allows to define coherent semantics for the concepts of the 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 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 paradigm's principle 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 modeling of Information Systems were presented and analyzed in details in [10].

2.2 Application of Russell's Theory of Types

The second among the aforementioned theories is Russell's Theory of Types, defined by Bertrand Russell in 1908 [13]. To define the Triune Continuum Paradigm, [7] applies this theory in the context 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 that are constructed with the aid of 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*" [2]. 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). In other words, if a modeling framework is supported by the paradigm, then thanks to the second paradigm's principle, the metamodeling structure of the framework will ensure internal consistency in the framework applications.

2.3 Application of the Triune Continuum Theory

The name of Triune Continuum Paradigm originates from the third theory that was employed for the paradigm definition, the theory of Triune Continuum. This theory was defined in [7]. 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.

To define the Triune Continuum Paradigm in [7] the Triune Continuum Theory was applied in the context of general system modeling (the same context as for the two other theories). This application, being the third paradigm's principle, allowed to introduce and to justify 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.

3 Key features of the Triune Continuum Theory

The previous section mentions three theories that contribute to the Triune Continuum Paradigm: Tarski's Theory of Truth, Russell's Theory of Types and the theory of Triune Continuum. The first two theories are well known; they were formulated by two famous logicians of the XX-th century. The last of the three theories was formulated recently, in 2002. Let us clarify here several key features of this theory.

3.1 Why "Continuum"?

As we have mentioned in the introduction, the Triune Continuum Paradigm is a paradigm for general system modeling. As we explained in Section 2, to define the paradigm in [7], the three paradigm's foundational theories were all applied in the context of general system modeling. So, before defining the paradigm in [7] it was important to define the domain of general system modeling.

To define the domain of general system modeling, [7] explores the foundations of conceptual modeling and finds that the notion of continuum is particularly important for explanation of the nature of conceptual modeling. [7] formulates two definitions; the first of them introduces Tarski's declarative semantics for the term of *continuum* and the second introduces denotational semantics[2] for the term of *concept*:

Def. ([7] p.14): *Continuum* (in the model) is an extent representing a subject of modeling.
Def. ([7] p.36): *Concept* is a discrete interval within a *continuum*.

When introducing the definition of *concept*, [7] explains that this definition is possible due to the nature of categorization. [7] sees the nature of categorization in the duality of two essences: continuum and discontinuity. In particular [7] explains (see p. 36): "*Continuum as soon as it is introduced, automatically allows for discontinuity to appear*", - indeed, any discontinuity exists only in the scope of a continuum and can be defined as soon as its corresponding continuum appears. "*Discontinuity allows to define limiting points within a continuum, which consequently allows defining the interval between limiting points and the space outside the interval within the continuum. Thus we were able to define a concept as a discrete interval within a continuous conceptual dimension*". Here, by defining an interval within a conceptual dimension and relating it to the conceptual space outside the interval, [7] makes it possible to understand **what the concept** that corresponds to the interval **is** and **what it is not**. In this way a concept is differentiated from its conceptual environment and consequently an identity can be assigned to the concept.

Further [7] explains that the continuum/discontinuity vision allowing a differentiation of things in a given domain (e.g. in time, in space, in some non-spatiotemporal conceptual domain) is not universal, but that it by itself is a modeling approach. And even if this modeling approach provides foundations for all the conventional science,

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[2] For an explanation of the differences between Tarski's declarative semantics, denotational semantics and operational semantics the readers can refer to [10].

nevertheless it was successfully challenged by Zeno, a pre-socratic Greek philosopher (490-425 BC), who formulated a set of paradoxes (see [1] on "Zeno's paradoxes", p. 987) proving that the continuum/discontinuity model is contradictory by its internal nature and hence cannot be an adequate model for a subject of modeling.

In support of Zeno's claim, [7] reports on difficulties to define Tarski's declarative semantics for the terms representing discontinuity in models. Thus, taking into account Zeno's paradoxes and problems with the definition of Tarski's declarative semantics for the terminology of discontinuity, [7] considers the continuum/discontinuity approach (that allows differentiating things in a given domain) as a fair approximation, whose fairness is justified by practical reasons, namely by the fact that all the conventional modeling results are achieved neglecting Zeno's paradoxes. Referring to the paradoxes, the alternative to continuum/discontinuity approach is formulated in [1] (p. 988) as following: "*if you allow that reality can be successively divided into parts, you find yourself with the insupportable paradoxes; so you must think of reality as a single indivisible One*".

Between the two alternatives [7] decides to stick to the continuum/discontinuity approach that gave the possibility to define the term of concept and to have concepts grouped in the categories of concepts for a representation of a subject of modeling.

3.2 Why "Triune Continuum"?

The Triune Continuum Theory 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 (e.g. 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, which is not space-time, is constitution; and everything in the scope, which 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 (e.g. 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).

3.3 How the theory of Triune Continuum is applied?

[7] formulates several essential features of conceptual modeling and defines *general system modeling* as a kind of *conceptual modeling* that adopts for modeling the framework of *natural science* under the condition that the framework of natural science is adapted to support these essential features of conceptual modeling.

To perform this adaptation of the framework of natural science to the needs of general system modeling, [7] proposes to use the theory of Triune Continuum. The application of the theory of Triune Continuum allows to generalize the framework of natural science. In particular, the theory of Triune Continuum provides to modelers a special observer-relational frame of reference:

- in classical (Newtonian) mechanics, observer-relational reference frames exhibit the relational nature in space, whereas time and material objects remain invariant for different observers;
- in relativistic mechanics observer-relational reference frames exhibit the relational nature in space and in time, whereas material objects remain invariant for different observers;
- in the Triune Continuum Theory, an observer-relational reference frame exhibits the relational nature in space, in time and in the constitution of models that represents different subjects of modeling (including material objects) in the models. So, representations of material objects are observer-relational here.

As we have explained in Section 3.2, in the Triune Continuum Theory the *constitution continuum* is defined as the complement to the *spatiotemporal continuum* in the universal modeling scope. And the third, *information continuum* emerges describing the mutual relations of the first two continuums. These three continuums form the aforementioned frame of reference. Thus all the three continuums are observer-relational (i.e. their contents defined subjectively for every modeler).

3.4 What is useful in the application of Triune Continuum Theory?

With the aid of the aforementioned application of Triune Continuum Theory, [7] justified the introduction of basic object-oriented modeling terms. It showed that a concrete limited amount of terms is formally *necessary and sufficient* for the representation of general system modeling scope on the most abstract level. An example for the separately considered space and time dimensions is shown on Figure 1.

On this example we see that to cover the modeling scope in the case of separately considered space and time dimensions we need to have the following concepts:

For the spatiotemporal continuum:

- (1) ***space interval***, (2) ***space outside the space interval*** and (3) ***point in space*** as the boundary between the first two spatial concepts;
- (4) ***time interval***, (5) ***time outside the time interval*** and (6) ***point in time*** as the boundary between the first two temporal concepts.

For the constitution continuum:

- (7) constitutional interval, usually called ***object***;
- (8) constitutional space outside the constitutional interval, usually called ***environment*** of an object;

- (9) boundary between the first two constitutional concepts, usually called ***interface*** of an object to the environment.

For the information continuum:

- (10) information about constitution related to a point in time, that is a static information element usually called ***state***;
- (11) information about constitution related to an interval in time, that is a dynamic information element usually called ***action***;
- (12) information about constitution related to a point in space, can be called ***spatial state***;
- (13) information about constitution related to an interval in space, can be called ***spatial trace***.

These 13 concepts are necessary and sufficient to cover the general system modeling scope on the abstract level in the case of separately considered space and time dimensions. In the more general case of a single spatiotemporal dimension we will have 8 concepts.

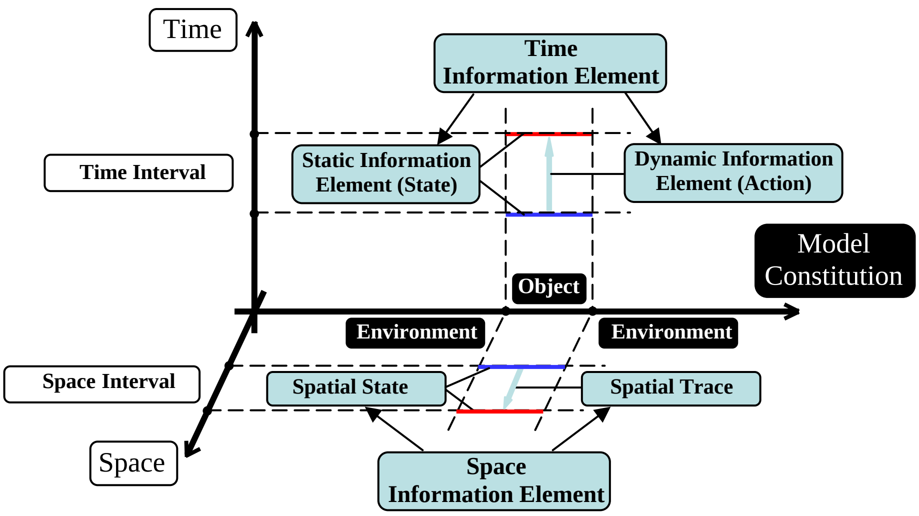

Fig. 1. An example of reference frame of the Triune Continuum Theory.

3.5 Tao Te Ching and the theory of Triune Continuum

Let us conclude the review of the Triune Continuum Theory by making a relation to one of the famous paragraphs of "Tao Te Ching" [15] written by Lao Tzu in the six century B.C. Here we refer to the paragraph 42, where we find:

The Tao begot one.
One begot two.
Two begot three.
And three begot the ten thousand things.

The style of “Tao Te Ching” is considered to be in general “*lapidary to the point of obscurity*” (see [1] on “Lao Tsu”, p. 482). The theory of Triune Continuum provides a comprehensible interpretation of the aforementioned paragraph in the context of general system modeling:

- “*The Tao begot one.*” – a *universe* allows for *modeling* (or a *modeler* intends to *model*). Any choice between the passive or the active perspective doesn’t influence the meaning that is the appearance of a *model,* the correspondence to “*one*”;
- “*One begot two.*” – a *model* intrinsically assumes two essences: spatiotemporal (*space-time* in the model) and non-spatiotemporal (*constitution* in the model).
- “*Two begot three.*” – from *space-time* and model *constitution* necessarily emerges *information* about their mutual relation;
- “*And three begot the ten thousand things.*” – *information* about mutually related space-time and model constitution is *unlimitedly rich*.

In the last line we see the appearance of unlimited richness of the information continuum. The representation of unlimited richness of the information continuum is assured by the Triune Continuum Paradigm with the aid of the application of Russell’s Theory of Types that allowed for an infinite (in the general case) hierarchy of propositions defining the specification concepts that represent the information continuum in models. The application of Russell’s Theory of Types was very briefly introduced in the section 2.2 of this paper. For more details the readers can refer to [7].

4 Use of the 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 several of the existing applications of the paradigm, in particular the applications:

- for the Unified Modeling Language (UML);
- for the Reference Model of Open Distributed Processing (RM-ODP);
- for the Systemic Enterprise Architecture Methodology (SEAM).

The first two of the three paradigm’s applications illustrate improvements of the existing system modeling frameworks. The third application illustrates the paradigm’s contribution to the design of a new system modeling framework.

4.1 Triune Continuum Paradigm application for UML

UML, a proposition of the Object Management Group (OMG), “*a language for specifying, visualizing, constructing, and documenting the artifacts of software systems, as well as for business modeling and other non-software systems*” (see [12], Section 1.1), is probably the most popular among the modern modeling languages. 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 (e.g. see [8] and [9]). With the aid of the Triune Continuum Paradigm it was shown that in its current state 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;
- 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 [8] providing designers of UML with the benefits of the paradigm's logical rigor, of its formal presentation and of its solid theoretical foundations.

4.2 Triune Continuum Paradigm application for RM-ODP

The Reference Model of Open Distributed Processing (RM-ODP) is an ISO and ITU standard for system modeling, designed to model ODP-systems [3]. 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 modelling 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 [3]. 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 [4]. 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 [11], and attracted the 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.

4.3 Triune Continuum Paradigm application for SEAM

The Systemic Enterprise Architecture Methodology (SEAM) is a methodology proposed by LAMS-EPFL [16] 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 [3]. Thus in this case the paradigm application provided a formal ontology for SEAM. The corresponding research results were reported to the Enterprise Architecture community [17] and provided the necessary basis for ongoing evolution of SEAM.

5 Conclusions

This paper presented the Triune Continuum Paradigm, its main features and several of its applications. This paradigm provides system modelers (in particular, IS engineers and designers of IS modeling frameworks) with a set of principles that are essential to build adequate system modeling frameworks. These principles are based on the three theories. Two of them are: Tarski's Theory of Truth (1935) and Russell's Theory of Types (1908).

The third foundational theory of the paradigm is the theory of Triune Continuum. Several key features of this theory were presented in this paper. In particular, it was shown that using the theory of Triune Continuum it is possible to introduce and justify minimal sets of modeling concepts that are necessary and sufficient for different modeling frameworks to cover their respective representation scopes. This is an important result, because as it was shown by previous research (e.g. by [7], [8] and [9]) the currently popular system modeling frameworks (in particular, UML [12] and RM-ODP [3]) do not provide satisfactory justifications for introductions of their terminologies. And without such justifications it is impossible to know whether a given terminology is adequate for its modeling tasks (i.e. whether the terminology is necessary and sufficient to represent a chosen modeling domain).

The Triune Continuum Paradigm can be considered as an important contribution to the system modeling domain. The absence of theoretical foundation for the currently prevailing system modeling frameworks favors introductions of ambiguous semantics for the terms of modeling frameworks, encourages inconsistent system specifications in the applications of modeling frameworks and impedes adequacy of modeling frameworks for their representation purposes. The Triune Continuum Paradigm provides the necessary means for elimination of these problems.

Through its applications (in particular through the three applications introduced in this paper) the Triune Continuum Paradigm promotes the use of its fundamental logical theories and philosophical foundations to the practices of designers of Information System modeling frameworks and to the practices of regular IS modelers and architects.

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