The Minimal Ontology Principle
Philosophical Foundations of OPM-based Modelling and Simulation

James Brucato[1] and Dov Dori[2,3]
[1]*Palermo Euro Terminal srl, Banchina Sammuzzo Porto, Palermo, Italy*
[2]*Massachusetts Institute of Technology, Boston, U.S.A.*
[3]*Technion, Israel Institute of Technology, Haifa, Israel*

Keywords: Object Process Methodology, Software Engineering, System Engineering, Computability, Compositional Logics.

Abstract: Traditionally, Software Engineering (SWE) and Systems Engineering (SE) were almost different disciplines with little overlap and with a different set of approaches and concepts. Yet, both SWE and SE reflect two sides of the same coin: both revolve around development and lifecycle support of systems. While SWE focuses on software-intensive systems, SE has focused on systems in general. However, most systems nowadays not only combine hardware and software, ever more intertwined and increasingly interdependent, they also comprise humans and organizations as stakeholders. This work aims to underline the importance of the holism as highly effective approach to both SWE and SE as it is the result of a huge and very representative set of philosophical investigations, partially illustrated in this work, assuming that the historical distinction between SWE and SE is becoming ever less relevant and that it is high time they be treated as one overarching discipline provided with a minimal ontology in order to facilitate the conceptual modelling process and improve models understandability. We propose the Object Process Methodology (OPM), together with its holistic approach to systems modelling and simulation, as main building block of the bridge between SWE and SE disciplines with respect the issues above.

1 INTRODUCTION

This work is intended to investigate the validity and usefulness of the distinction between SWE and SE with respect to the modelling and simulation approach. Since they are considered as different disciplines, despite the fact that they are becoming ever more interdependent because of the highly increasing number of systems that nowadays combine hardware and software to succesfully meet the stakeholders expectations and the users needs, we claim that an effective modelling and simulation approach shall be able to merge all the different aspects pertaining both the disciplines. To reach this goal it shall be provided, first, with a strong philosophical background in order to take into account the most wide set of historical facts, second, it shall be domain independent in order to be highly flexible and useful beyond the disciplines boundaries, third, with the smallest set of symbols composing its vocabulary and its syntax in order to be easy to learn maximizing, in the same time, the system models understandability and sharing.
Along and as results of their evolution, humans have been able to invent a huge set of languages (oral, written, iconic, sculpture, architectural, melodic, scientific and so on) in order to create amazing pictures of the world. Even those all the languages are limited in their constituents (building blocks) they provide the human kind with a source of potentially infinite combinations, but only and only if there is a set of rules to combine simple symbols and/or set of symbols generating more complex combinations of them.

We propose the OPM (Dori, 2002) as a bridge between SWE and SE because of its strongly holistic oriented modelling and simulation approach that properly fulfils the requirements above.

In the same time, the minimal ontology principle is illustrated in order to provide the OPM with a clear definition of its assumtions.

Brucato J. and Dori D..
The Minimal Ontology Principle - Philosophical Foundations of OPM-based Modelling and Simulation.
DOI: 10.5220/0005140804050409
In *Proceedings of the International Conference on Knowledge Engineering and Ontology Development* (KEOD-2014), pages 405-409
ISBN: 978-989-758-049-9

2 PHILOSOPHICAL FOUNDATIONS OF MODELLING AND SIMULATION

From a philosophical point of view, the systems-software dualism can be traced back to the 1950's and early 1960's when the AI (Artificial Intelligence) was emerging as a new, unpredicted and unpredictable discipline, historically identified as a branch of the cognitive sciences paradigm. AI was founded at a conference held during the summer of 1956 at Dartmouth College in Hanover, New Hampshire where John McCarthy, Marvin Minsky, Nathaniel Rochester and Claude Shannon presented a very innovative work able to merge a considerable number of philosophical theories developed in the early 20th century, including linguistics investigations and epistemological approaches, and the most advanced engineering experimental works (McCarthy, Minsky, Rochester and Shannon, 1955).

Since the Dartmouth conference, the international scientific community interest toward the AI rapidly increased and the most part of further investigations proofed the presence of an epistemological lack of effectiveness specially with respect to the human knowledge representation area. This, in turn, led the scientific community to explore the possibility of finding a common terrain where would be possible a productive confrontation between different disciplines, methodologies and approaches in order to establish a new common paradigm serving as scientific and academic theoretical bridge, the Cognitive Science paradigm. Recently it has been defined as a contemporary, empirically, based effort to answer long-standing epistemological questions – particularly those concerned with the nature of knowledge, its components, its development, and its deployment (Gardner, 1986).

It is relevant that there was a close constant overlap between the results and the assumptions of most of those theories similar to a chain reaction even those they were developed in different times and places, sometime very distant one from each other, and that it has been demonstrated that all of them were founded assuming the validity of the Frege's Principle, (Frege, 1893), known as Principle of Compositionality, that states the meaning of a complex expression is determined by the meanings of its constituent expressions and the rules used to combine them (Brucato, 2003).

Early Cognitive Science scopes and assumptions, including for first the Frege's Principle of Compositionality we assume as its main epistemological pillar, they continue to play a central role in many contemporary disciplines like SWE and SE modelling and simulation. More specifically, they are the philosophical foundations of OPM-based modelling and simulation holistic approach to SWE and SE we identify with but not limit to:

- Wittgenstein's Tractatus logico-philosophicus (1921). It contains the distinction between the World, and the Language (s) used to describe (give a picture of) it. This is the main assumption of the well known Picture Theory of the Meaning Wittgenstein developed to state that the language is a picture of the world and it is obtained combining the language building blocks (the signs, later called symbols) into propositions according to the predetermined set of syntactic rules specifically pertaining to the adopted language. He often used to compare the process of composing a syntactically correct proposition to the work of an architect who designs and constructs a new building. If something has been designed wrongly, the building will not be able to be used for the intended purposes, hence it will be basically useless, with respect to the language, if the syntactic rules are not properly followed the proposition will be non-sensed and, in some cases, it will also be not understandable;
- Hierarchy of Languages (Russell, B., 1905). Here Bertrand Russell illustrated the necessity to adopt a higher level language to completely and consistently describe a lower level language. This theory has been formalized as Type Theory;
- The Mathematical Theory of Communication developed by Shannon and Weaver (Shannon, 1938). The communication is assumed to be the result of the information transmitting process. Using a physical channel, a predetermined quantity of information the sender previously compressed through a code he shares with the receiver, is possible to reproduce at one point (the destination) either exactly or approximately a message selected at another point (the source);
- The ballistic researches of Von Neumann (1945) led him to the definition of a stable machine structure, known as Von Neumann Architecture, which served as the basis of all the modern calculators and computational machines;

- Alan Turing's definition of Computability (Turing, 1936), a reformulation of Gödel's Undecidable Problem and inspired by Newman investigations onto the decidability of mathematical propositions.

3 PHILOSOPHICAL OUTCOMES

OPM is different from other modelling languages not only because it allows to go beyond what Wittgenstein called the limit of the Language, consisting of the impossibility to completely describe the World, it also subsumes most of the theories involved in the foundations of the Cognitive Science paradigm.

In addition, OPM provides stakeholders with both the iconic, graphical, view of the systems and its equivalent textual description. The two reinforce one each other recursively through the dual-channel processing, as they cater to the visual and verbal cognitive processing channels (Mayer, 2005; Dori, 2008).

OPM also takes into account both the structure and the behavior of systems in order to provide a comprehensive vision of the building blocks that compose a system together with the processes involved and requested to perform the tasks it has been designed for.

All these widely appreciated OPM features impressively allow to model its own theoretical foundations as well with all the positive effects this can have in particular with respect to SWE and SE as OPM represents a unique and highly effective meta-modelling and simulation domain independent holistic approach.

Following are the Shannon's schematic diagram of a general communications system (Figure 1) and its OPM system model version according to the Shannon and Weaver Mathematical Theory of Communication.

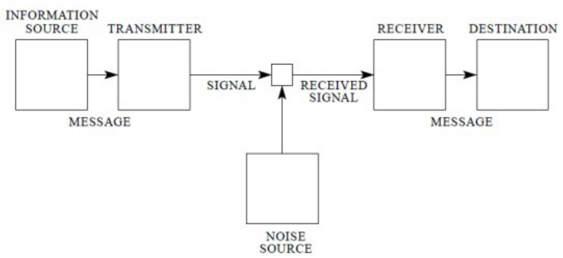

Figure 1: Schematic diagram of a general communications system according to Shannon definition.

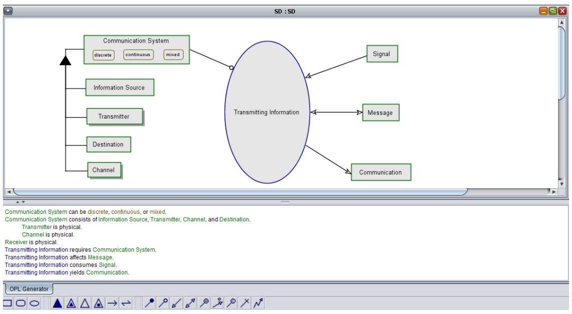

Figure 2: OPD of Shannon's Mathematical Theory of Communication and related OPL.

4 THE MINIMAL ONTOLOGY PRINCIPLE DEFINITION

A parallel development on a smaller scale has happened within both SWE and SE with the realization that models should serve as foundational architecting and design artifacts. For SWE this happened in the early 1990s, when the object-oriented (OO) idea grew out of being a paradigm underlying OO programming languages to the realization that prior to coding, the program, or the software system, should be modelled. Initially there was the "war of languages" with over 30 different notations and ideas trying to prevail. Then, in 1997 UML was adopted under the auspices of OMG with 9 different diagram types, which grew to 13 with the transition to UML 2.0 in 2005. The first author's proposal at an OMG Technical Meeting in Florida in 2000 to extend UML from the software domain to the general systems domain was dismissed with no consideration whatsoever, only to be resurrected six years later with the birth of SysML. SysML was developed and adopted in 2007 in response to OMG UML for Systems Engineering RFP. Like UML 1.x, it had 9 diagram types, but not quite the same set. Some were removed from UML 2, some modified and a couple added. Why 9 diagram type (or views, or viewpoints)? Why 13? Why not more? Isn't it the case that more is better? If so, why not adopt DODAF 2.0 from 2009? It has 51 Viewpoints (BTW, up from 26 in DODAF 1.x from 2003)!

This trend of "diagram creep" – adding more diagram types to a language – just adds complicatedness to an already complicated world of conceptual modeling languages. AS a reaction, in order to put a stop to this trend, we offer the following Minimal Ontology principle: If a system can be specified at the same level of accuracy and detail by two languages of different sizes, then the language with the smaller size is preferred over the one with the larger size.

This principle does not only make perfect sense, it is also in line with the long accepted Ockham's Razor (Ockham, 1495) – a principle attributed to the 14th century logician and Franciscan friar William of Ockham, England. The principle states that "Entities should not be multiplied unnecessarily." Or, in one of its original Latin forms: "Pluralitas non est ponenda sine necessitate." The most useful statement of the principle for scientists is "when you have two competing theories that make exactly the same predictions, the simpler one is the better." Ockham's Razor inspired also the Minimum Description Length (MDL) Principle (Rissanen, 1978), a method for inductive inference that provides a generic solution to the model selection problem, i.e., how does one decide among competing explanations of data given limited observations. MDL is based on the insight that any regularity in a given set of data can be used to compress the data by describe it with fewer symbols than the number of symbols needed to describe the original data. In a similar vein, any symbol system (i.e., a language) that can describe a given system using fewer symbols (a smaller language) is more succinct and therefore preferable over a larger language (a language with more symbols), as using the smaller language exerts a smaller amount of cognitive load on the human modeler. Alleviating the cognitive load off the human modeler is highly desirable because the modeler must cope with the inherent complexities of man-made systems to be built (systems engineering) or natural systems to be investigated (science), so anything that we can do to help by providing a simpler language is of tremendous value.

A second principle that caters to the same objective of facilitating the conceptual modeling process and making the model more accessible and comprehensible is the dual channel processing (Mayer, 2005; Dori, 2008): A model that can be presented bi-modally in both graphic and text is preferred over a model that can be presented in only one of the modalities.

The cognitive-physiological basis for this principle is that the human mind is geared to accept both visual-pictorial-graphic signals and audio-verbal-written signals. Popularly, this is often referred to as the left brain/right brain functions. Indeed the left hemisphere is dominant in language, processing what one hears and handling most of the duties of speaking. The right hemisphere is mainly in charge of spatial abilities, face recognition, comprehending visual imagery and making sense of what we see. Thus catering to "both sides of the brain" through language and pictures is more likely to get the message—in our case the conceptual model—across.

If we accept these two principles, then we need to find the minimal universal ontology—the ontology that is necessary and sufficient to model the universe and systems in it. We start by first asserting that any thing in the universe either exists or happens. We proceed with a series of questions and answers:

Q1: What are the things that exist in the universe?

A1: Objects exist or might exist.

Q2: What are the things that happen in the universe?

A2: Processes happen or might happen. But processes cannot happen in vacuum! So:

Q3: What are the things to which processes happen?

A3: Processes happen to objects.

Q4: What do processes do to objects?

A4: Processes transform objects.

Q5: What does it mean for a process to transform an object?

A5: Transforming of an object by a process means:

- creating (generating) an object
- destroying (consuming) an object
- affecting an object.

Q6: What does it mean for a process to affect an object?

A6: A process affects an object by changing its state. Hence, objects must be stateful, i.e., they must have states.

Q7: What are the main aspects that define any existing system?

A7: A system can be defined with respect to two major aspects: structure and behavior. Structure is the static aspect; it relates to the question what is the system made of?

From the structural aspect, a System is a finite set of components and their time-invariant interconnections. Behavior is the dynamic aspect; it relates to the question how does the system change over time?

Q8: What additional aspect pertains to man-made systems?

A8: Function – the utilitarian, subjective aspect:

why is the system built? for whom? who benefits from operating it? What is the context of its use?

If we accept these answers, then we are ready to prove the following theorem:

The Object-Process Theorem
Stateful objects, processes, and relations among them constitute a necessary and sufficient universal ontology.

The following is a complementary statement:

The Object-Process Corollary
Using stateful objects, processes, and relations among them, one can model systems in any domain and at any level of complexity.

Proof: Part 1 - necessity

Stateful objects and processes are necessary to specify the two system aspects:

Specifying the structural, static system aspect requires stateful objects and relations among them.

Specifying the procedural, dynamic system aspect requires processes and relations between them and the objects they transform.

Proof: Part 2 - sufficiency

Stateful objects and processes are sufficient to specify any thing in any system:

Anything that exists can be specified in terms of stateful objects and relations among them.

Anything that happens to an object can be specified in terms of processes and relations between them and the object they transform.

5 CONCLUSIONS

Having determined and proved the Object-Process Theorem, according to the minimal ontology principle, the optimal conceptual modeling language must have just two types of concepts - stateful objects and processes - along with relations among them. Indeed, this is the theoretical foundation of OPM. It is in the process of becoming ISO 19450 Standard - Publicly Available Specification, a freely available ISO document that defines the syntax and semantics of OPM (ISO, 2014). The document length is around 140 pages, compared with 1400 pages of the current OMG UML 2.2 Standard plus 272 pages of SysML that builds on the UML Standard documentation.

With respect to the current regrettable chasm between SWE and SE, we should do everything in our power to unify these two seemingly disparate disciplines, because both handle two complementary views that each contemporary system features: the physical view (the focus of SE) and the informatical-cybernetic view (the focus of SWE). To marry SE with SWE we need a simple common language that both domains will speak freely. Catering to both physical and informatical things (objects and processes). OPM can serve as an ideal bridge between the two.

ACKNOWLEDGEMENTS

This work was supported by EU FP7 VISIONAIR Project 262044 and Gordon Center for Systems Engineering at Technion.

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