Ontology of Online Management Tools Aimed at Artificial Management Implementation: An Example of Use in Software Design

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Abstract: After the first age of robotics in mechanical processes rapid development of computer science and Internet causes that AI will overwhelm team management in the future. Both, the rapid development of artificial intelligence in business management and the need of an adequate ontology to represent the organizational world has created a significant research gap. As the result of that the research problem should be solved: if it is possible to create a comprehensive, coherent and formalized methodological concept of the management sciences, which will allow to design and implement real artificial management. The aim of the paper is to present the solution to the research problem in its ontological part, and to show the use of such an ontology to replace the human manager with an artificial manager. The paper describes the definition of ontologies and the considerations for their creation in various software applications, presents the results of theoretical and practical research on the creation of a theoretical concept, called the system of organizational terms, which contains an ontology of organizational reality that meets the requirements for the practice of creating ontologies for software and enables the design and implementation of artificial managers.

1 INTRODUCTION

After the first age of robotics in mechanical processes and manufacturing rapid development of computer science and Internet has given opportunities to replace team managers with robots (McAfee and Brynjolfsson, 2016). If this happens, this would be the real accomplishment of P. Drucker's words that in the future "computers" will not only make decisions but they will do much more (Drucker, 1967).

Research on Artificial Intelligence (AI) in management slowly appears as a biggest challenge for the future (Teddy-Ang and Toh, 2020). Firstly, AI in management seems to exceed any other technological breakthrough that humanity has ever seen (Antonescu, 2018). Secondly, human-machine teaming (HMT) seems to be a promising paradigm to approach future situations in which humans and autonomous systems closely collaborate (van der Vecht, van Diggelen, Peeters, Barnhoorn and van der Waa, 2018). Although there are still discussions if AI management will evolve in artificial management or in artificial leadership (Derrick and Elson, 2018), it seems that AI will overwhelm team management in the future (Webber, Detjen, MacLean and Thomas, 2019).

Therefore in recent years, there has been a huge interest in developing ontologies in the area of information communication systems which can gather and build knowledge on the particular human activities. This has been widely used in software systems design (Fonseca, Barcellos, and Falbo, 2017). As a result of this process, there has been an increasing range of software systems which engage a variety of different ontologies in order to management tasks such as creation, storage, search, query, reuse, maintenance the wholes systems (Lee and Goodwin, 2006). As Staab and Studer (2010) claimed, in recent decades the use of ontologies has been used in a great range of applications mostly in knowledge management.

Both, the rapid development of artificial intelligence as the key factor in business management and the need of an adequate ontology to represent the organizational world has created a significant research gap. As the result of that the author of this

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paper formulated the research problem, if it is possible to create a comprehensive, coherent and formalized methodological concept of the management sciences, including an ontology of the organizational reality, which will allow to design and implement real artificial management.

At this point, it is necessary to clarify three adjectives contained in such a formulated research problem. First, it was based on the condition that the concept should be holistic, which means that it should include in its scope all or most of the issues that form the basis of doing management science in order to know what a human manager really does. Second, according to the assumption expressed in the research problem, the methodological concept should be coherent, that is, internally inconsistent and internally complementary. Third, the concept should be formalized, so there should be well-defined rules on how to apply its various elements of a software replacing human managers with robots, defined either in detail or in the form of universal and scaled principles.

The aim of the paper is to present the solution to the research problem in its most important part, and to show the use of such an ontology in the designed and implemented information system, built to replace the human manager with an artificial manager.

Section 2 of the paper describes the definition of ontologies and the considerations for their creation in various software applications. Section 3 presents the results of theoretical research on the creation of a theoretical concept, called the system of organizational terms, which contains an ontology of organizational reality that meets the requirements for the practice of creating ontologies for software and enables the design and implementation of artificial managers. Section 4 describes the results of testing the use of the designed ontology and the software, and Section 5 presents conclusions for further research.

2 ONTOLOGIES IN MANAGEMENT SCIENCE AND SOFTWARE DESIGN

2.1 Philosophical Foundations of an Ontology in Management Science

Ontology is a formal, given in advance description of phenomena in a given slice of reality, the characteristics of which are describable by certain variables or parameters (Chang, Terpenny, and Koelling, 2010).

Marian (2008) defines ontology as a way of organizing knowledge about a certain fragment of reality. Knowledge is usually organized in a hierarchical way, containing the most important entities resulting from the model of this reality, as well as the relations between these entities. On the other hand, ontology is “an enunciated parameterization of a conceptualized phenomenon” (Cui, Tamma, and Bellifemine, 1992, p. 204). W.V.O. Quinn (Brink and Rewitzky, 2002, p. 543) used to say that in terms of ontology, millennia of ontological inquiry can be encapsulated in three words: “what is here?” It must be admitted that this definition, although expressed by a question, is quite suggestive.

Prechtl (2007) gives L. Wittgestein's understanding of ontology, whose philosophy had a significant influence on the approach to the ontology of the system of organizational terms, the methodological concept containing the ontology designed by the author. L. Wittgenstein understood ontology as “the totality of objects, qualities, designations, states of affairs about which certain statements are formed in a given language” (Prechtl, 2007, p. 119). The intention of Wittgenstein was to construct a logically perfect language with which to describe what really is. The influence of Wittgenstein’s perspective on the system of organizational terms is described in Section 3.

From the point of view of management science, two more types of understanding of ontology should be given. The distinction is the criterion of permanence. Namely, M. Javed, Y.A. Abgaz and C. Pahl (2010) define a certain type of ontology, which they call consistent ontology, i.e. an ontology that is unchanging and does not take into account the emergence of new concepts describing a given slice of reality. The second type of ontology is an ontology in which entities are created dynamically based on certain rules. These entities are unpredictable before the moment the ontology is defined (Petrov, 2010). This type of ontology is included in the concept of the system of organizational terms.

Correctly created ontology provides the basis for building knowledge on a given subject and shows the relationship between phenomena, represented by concepts with a precisely defined meaning (Chang, Terpenny, and Koelling, 2010). There is a view in the literature that whatever ontological assumptions are made in a given scientific discipline (e.g., management science – author’s note), different objects of reality (organizational – author’s note) are understood differently by different researchers and within different research projects (Laudan, 1984).

They may be objective, independent of the cognizing subject, or they may be subjective (in the original "values" – author's note), forming an inseparable bond with the subject (Ghenea, 2013). They can also be "quasi-objective" products of the intellect, called conceptual objects and serving as instruments of cognition. Finally, they can be objects that are a mixture of all three approaches above. M. Foucault in his book "Kant on Enlightenment and Revolution" asks: "what, in the present day, lies at the limit of human cognition?". He writes that this is not a question about the theory of truth, but about the ontology of "our time", which is the ontology of "ourselves" (Giri, 2006, pp. 228).

Summarizing the consideration of the meaning of ontology, it can be said that it provides a conceptual framework for the representation, sharing and management of knowledge through a system of concepts, their hierarchy, the relations assigned to them, and the way they are semantically distinguished (El-Diraby, Lima, and Feis, 2005).

As an example of an ontology in management science it can be shown an outline of an ontology using both resource and process approaches. The entities in this ontology are described with nouns (the effect of the resource approach), and are created as a result of activities described with verbs (the effect of the process approach) (Rao, Reichgelt, and Osei-Bryson, 2009). This approach was one of the reference points for the creation of the ontology in the system of organizational terms.

2.2 Purposes of an Ontology in Software Design

Ontology in the area of software design can be defied as "the set of activities that concern the ontology development process, the ontology life cycle, and the methodologies, tools and languages for building ontologies" (Cakula and Salem, 2013, p. 14). In the other way, ontologies in software engineering offer a formal representation of knowledge. They are created for inconsistency and incompleteness, as well as to use a common vocabulary in a specific domain with the purpose of sharing information by concepts and relations between these concepts (Gayathri and Uma, 2018). The motivations for building an ontology in software engineering is sharing a common understanding of the structure of information between users of applications and allowing them to reuse this knowledge.

It is useful to show the research on purposes of using they used ontologies. The research showed, that 72% of respondents expected that an ontology will deliver conceptual modelling and data integration. A little less, 65% of respondents claimed that the purpose of an ontology in software design is to define knowledgebase schemas and linking data from different public knowledgebases. Knowledge sharing and providing common access to heterogeneous data pointed 56% of respondents and 50% of the pointed ontology-based search as purpose of a software ontology (Warren, Mulholland, Collins, and Motta, 2014).

An ontology in software design is the conceptual and terminological description of shared knowledge about a specific domain, which means making improvements in communication using the same system in terms of terminology and concept (Fonseca, Barcellos, and Falbo, 2017). Ontologies are vital parts of applications supporting common life, enabling analysis of high-throughput datasets, data standardization and integration, search, and discovery (Fraga, Vegetti, and Leone, 2020).

3 ONTOLOGY OF THE ORGANIZATIONAL REALITY IN THE SYSTEM OF ORGANIZATIONAL TERMS

In designing the ontological assumptions in the system of organizational terms, three theoretical assumptions, presented quite often in the literature, were tried to be fulfilled. Namely, these were: a need expresses entities in the organizational reality and relations between them, a language of the ontology describes existing entities and their relations; the ontology is the mechanism created so that existing entities and their relations are organised to produce those that are wished for (Hall and Rapanotti, 2017). The notion of entities, in the system of organizational terms called facts, is therefore central to our design theory.

Establishing the ontology of the organizational reality in the system of organizational terms it was a decision to complete and keep software architecture requirements. There were three main question to which the ontology should answer. Firstly, what concepts should be considered in that ontology so it can support the architectural completion process? Secondly, how can the relationships between entities and attributes in question support that process? Thirdly, how could knowledge inference capabilities including knowledge search, tracing and data compatibility be developed by using proper tools and ontology?

The result of the design process was developed and tested in the last years (Flak, 2015; Hoffmann-Burdzińska and Flak, 2015; Yang, Flak and Grzegorzek, 2018; Flak, 2018; Flak, 2019; Flak, 2020; Flak, 2021). The philosophical foundation of the system of organizational terms is based on Wittgenstein's philosophy: his theory of facts (the only beings in the world) and "states of facts" (Brink and Rewitzky, 2002). According to this approach team management can be organised by events and things. From Wittgenstein's perspective both items (things and events) can be described by "states" in every moment of time.

Specifically, as shown in Figure 1, each event and thing have the label n.m, in which n and m represent a number and a version of a thing, respectively. Event 1.1 causes thing 1.1, which in turn releases event 2.1 that creates thing 2.1. Thing 1.1 simultaneously starts event 3.1 which creates thing 3.1. Then, thing 3.1 generates a new version of the first event, i.e. event 1.2. In such a way, a new version of the first thing is created, which is called thing 1.2. So, the managerial action structure consists of, e.g. event 1.1 and thing 1.1. As it was shown in Figure 2, differences between features of goal 1.2 and goal 1.1. let us do reasoning on the team management process (Flak, 2018). This ontology lets us record managerial actions (Figure 2) one by one and it is possible to answer what a team manager and his team members really do (Sinar and Paese, 2016).

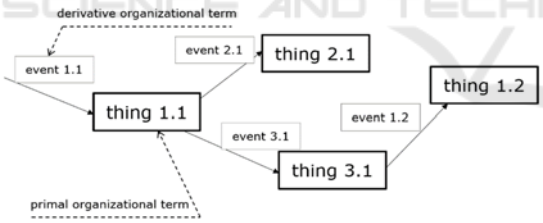

Figure 1: Theoretical pattern of „states of facts" in the organizational reality.

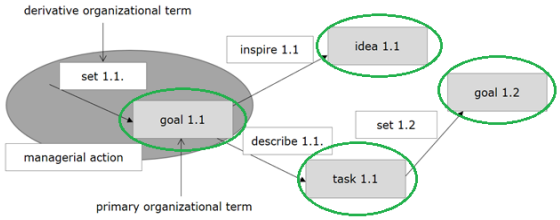

Figure 2: Managerial action structure in software design.

In the system of organizational terms there are 10 basic pairs of items in such an ontology, consisted of things and events. There are: set goals (GOALS), 2 - describe tasks (TASKS), 3 - generate ideas (IDEAS), 4 - specify ideas (SPECIFICATIONS), 5 - create options (OPTIONS), 6 - choose options (DECISIONS), 7 - check motivation (MOTIVATION), 8 - solve conflicts (CONFLICTS), 9 - prepare meetings (MEETINGS), 10 - explain problems (PROBLEMS). Capital letters mean online managerial tools designed as research tools and implemented in the software called TransistorsHead.com, in Figure 3, described in Section 4.

The description of the main ontological considerations should begin with a presentation of the assumption made in the concept of the system, according to which the following principles exist in the ontology of the organizational reality: identity, non-contradiction, excluded middle, sufficient rationale and purposefulness. On the basis of the literature on the subject, it is concluded that the ontology of the organizational reality must include an exhaustive classification of entities and universal rules for creating types of these entities and naming them. It is also necessary to describe the use of natural language to create statements about entities in organizational reality.

It is assumed that the evolution of the organizational reality is modal in nature. The occurrence of certain entities and relations between them entails the exclusion of other entities and relations between them, either increasing the probability of certain entities or implying them necessarily.

It is concluded that there are two classes of entities. The first class includes entities that unchanged persist over time. The second class includes entities that persist over a given interval of time. This assumes that the ontology of the organizational reality is dynamic, which means that the types of entities within a given class of entities occur in the organizational reality as a function of time on the basis of universal rules. It is also inferred about entities in the organizational reality that they can exist either outside or inside a human entity (a manager or an organizational participant). These entities are objective or subjective in nature, respectively.

With a view to the scientific study of the organizational reality, it was assumed that the organizational reality consists of facts. A fact is defined as the result of observation of an entity in the organizational reality, recorded in the form of information. Facts are divided into: invariably lasting over time (facts of the thing class) or lasting over a given period of time (facts of the event class). Facts are divided into either external (objective facts) or

internal (subjective facts) to a human entity (a manager or an organizational participant). It is assumed that the occurrence of a subjective fact is determined only by the individual, and the occurrence of an objective fact is shared by more than one person.

A fact of the thing class is defined as a real object or an intentional object. A fact of the thing class is otherwise a resource of an organization in the resource approach in management science. This assumes that a fact of class thing is represented by a concept whose name is a noun. A fact of the event class occurs when two states of affairs describing the same facts of the thing differ from each other in ways other than simply due to the passage of time, meaning that a fact of the thing class at time t1 exhibited a certain characteristic and at time t2 no longer exhibits it, or vice versa. A fact of event class is a process in the process approach in management science. It is assumed that a fact of the event class is represented by a concept whose name is a verb.

Listing the most important ontological determinants of the organizational reality, from the point of view of the operationalization of organizational quantities, it is still necessary to point out the concept of state of affairs, which is understood as a set of either absolute or relative characteristics of a fact. An equally important thesis, adopted after the literature on the subject, is that the linguistic description of a fact in the organizational reality is an elementary sentence, which is meaningful. Any sentence composed of elementary sentences is a sentence function.

In terms of ontological conditions, two important hypotheses are also put forward. First, it is conjectured that the state of affairs of any fact can be determined by determining the previous and subsequent states of affairs of that fact or other facts occurring in the organizational reality. Second, it is conjectured that the organizational reality can be described by means of adjacency relations between facts or relations of co-occurrence of facts over time.

4 RESULTS OF RESEARCH

4.1 Example of Online Management Tools Design

Software ontology representation, which was designed and implemented by the author of this paper, is the set of online management tools called TransisorsHead.com (dashboard shown in Figure 3) which record parameters of the managerial actions (effects marked with a green round, e.g. a goal 1.1 as a result of set 1.1).

According to the theoretical background of ontology of the organizational reality 10 online management tools were created. They were implemented as online management tools available within the website browser. 10 different tools to track 10 separate managerial actions, e.g. setting goals, describing tasks, checking motivation, explaining problems, preparing meetings, generating ideas. TransistorsHead.com records changes in team management processes, which from the ontological perspective are represented by resources (a fact of the thing class – a primary organizational term in Figure 1). It reminds making a movie of teamwork with frames of features team management processes and the frames are represented by primary organizational terms (resources) in the organizational reality. It is necessary to say this approach to recording human behaviour is in the contrary to the most popular one, which focuses on processes. In TransistorsHead.com there are recorded every version of the resources changed by its process. Than, as a movie with frames, it is possible to reproduce how a human manager behaved in the past (Flak and Pyszka, 2022).

When designing the tools, there were to main assumptions. Firstly, any management tool covers all essential features which could describe a resource (represented by the primal organizational term – see Figure 1). Secondly, any management tool was designed as simple as it was possible. Users should want to use them during the research as research tools without any external motivation.

From the theoretical point of view online management tools have the following features. Firstly, according to the idea of an “unit of behaviour” (Curtis, Kellner, and Over, 1992) every online management tool tracks and records one specific managerial action (green circles in Figure 2). Secondly, when a manager uses any online management tool it is equal to an event which effects in a fact of the thing class, equal to a process which results in a resource, respectively (Flak, 2018) (Figure 2). Thirdly, every tool is useful for recording a certain managerial action (Flak, 2018).

The platform is available at transistorshead.com, after clicking TRY IT a user gets its trial logins and can use the tools (the dashboard after login in Figure 3). There are 10 different tools for different managerial actions, described in Section 3.

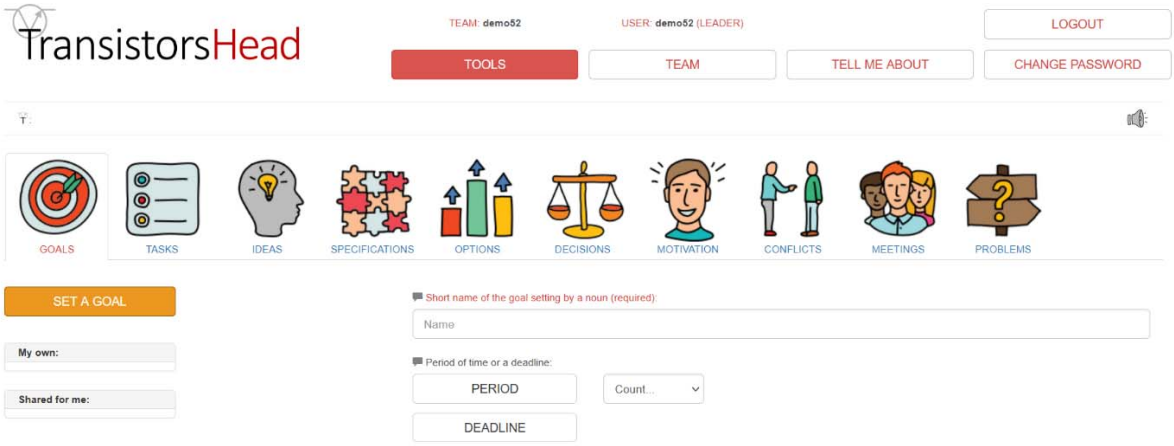

Figure 3: TransistorsHead.com dashboard.

4.2 Example of Online Management Tools Use

A potential of the ontology of the organizational reality designed as a part of the system of organizational and used in online management tools (TransistorsHead.com) were checked and proved in many previous observations conducted by the author of this project in the last few years. In Table 1 there are descriptions of a few research (aims and main conclusions).

Table 1: TransistorsHead.com dashboard.

Respondents, research methods and tools	Student of Management from Silesian universities. Research method: longitudinal observation. Research tools: online management tools (TransistorsHead.com)
Aim of the research	Main conclusions
Assessment of using the system of organizational terms in team effectiveness	It is possible to assess team effectiveness based on the recorded team management processes (Hoffmann-Burdzińska and Flak, 2015).
Using pattern recognition in team management processes	It is possible to assess similarities of managers actions by pattern recognition methods (Yang, Flak, and Grzegorzek, 2018).
Assessment of design thinking effectiveness in teamwork.	Using the system of organizational terms and online management tools it is possible assess effectiveness of design thinking in teamwork (Flak, 2018).
Influence of a culture on teamwork.	Using the system of organizational terms and online management tools it is possible measure an influence of a culture on teamwork (Flak, 2019).
Recording managerial actions in motivating aimed at team management automation.	It is possible to use the system of organizational terms and online management tools, firstly, for recording managerial actions in the field of motivation, secondly, repeat the manager's trajectory of actions by an algorithm (Flak, 2020).
Recording managerial actions in order to imitate a human manager by an artificial manager.	Literature review and own empirical research show the new organizational reality with hybrid virtual teams, consisting of humans as well as artificial agents. In this organizational reality management tasks, or even a leader's role, would be taken over by artificial intelligence (Flak and Pyszka, 2022).

Firstly, it was possible to record managerial actions by online management tools (Flak, 2015; Hoffmann-Burdzińska and Flak, 2015; Yang, Flak and Grzegorzek, 2018; Flak, 2018; Flak, 2019; Flak, 2020; Flak, 2021). Secondly, gathered data enabled concluding trajectories of managerial actions and repeat them by algorithms (Flak and Pyszka, 2022).

5 CONCLUSIONS

The aim of the paper was to present the solution to the research problem, which meant the ontology of the organizational reality, designed in the methodological concept called the system of organizational terms. This ontology is focused on such representation of a manager's work that it would be possible to implement artificial management in real life. This solution of the research problem covers the research gap, which was a marge of the rapid development of artificial intelligence as the key factor in business management and the need of an adequate ontology to implement artificial managers able to replace humans.

As it was described in Section 4.2., the ontology of the organizational reality has been checked in many research since 2015 and particularly the last research promises the ability to use this ontology in replacing human managers with robots (Flak and Pyszka, 2022).

The ontology of the organizational reality meets 5 criteria of ontology evaluation. First, consistency, which means that there is no contradictory knowledge inferred all definitions and axioms. Second, completeness – it is complete based on assumptions and cover all possible states of the reality. Third, conciseness, which means that the ontology does not contain any unnecessary concepts. Fourth, expandability gives a possible of expansion without any changes of definitions. Fifth, sensitiveness – the ontology is sensitive to a small changes in definitions (Gómez-Pérez, 2004).

What is more important, the fact that such a software as TransistorsHead.com is embedded with a function of recording any managerial action taken by a huma manager and team members (Figure 2), who operate in 10 areas of team management, let us think about imitating this human manager by an artificial intelligence. Recorded data together with pattern recognition of human behaviour and machine learning will allow to implement an artificial manager (Flak and Pyszka, 2022). These extraordinary combination self-learning management tools and machine learning algorithms imitating main common managerial actions of human managers are the future research and implementation work planned by the author.

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