BUILDING OF TRAFFIC INFRASTRUCTURE ONTOLOGY FOR MAS

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Abstrakt. Příspěvek se zabývá problematikou ontologií z pohledu informatiky, především pak v souvislosti s GIS a multiagentovými systémy. Snaží se poskytnout ucelený pohled na oblast ontologií obecně a předkládá několik důvodů pro jejich budování. Ontologii považujeme za důležitou z několika důvodů - sdílení informací mezi pracovníky týmu, konceptuální analýza problému, její užití při konkrétním praktickém řešení.

V příspěvku podáváme přehled různých pohledů na problematiku ontologií, uvádíme jednotlivé typy dle jejich účelu a oblasti využití. Definujeme pojem ontologie v informatice dle různých autorů a seznamujeme čtenáře s již realizovanými projekty v této oblasti.

Uvádíme důvody pro vybudování ontologie v projektu Logika a umělá inteligence pro multiagentové systémy (MAS), financovaného v rámci programu Informační společnost Akademií věd ČR. S bouřlivým vývojem v této oblasti souvisí terminologická nejednotnost a neucelenost metodik, se kterou jsme se při naší práci setkali. Hodnotíme i použití některých nástrojů pro zachycení ontologie.

Případová studie projektu, pro kterou je naše ontologie budována, se zaměřuje na oblast silniční dopravy. Mezi východiska, která jsme použili, patřily normy, zákony a terminologie typická pro tuto oblast v reálném světě. Ontologie představuje spojovací článek mezi uvedenými východisky a řešenou případovou studií. Při tvorbě ontologie jsme byli vedeni snahou o vystihnutí těch aspektů dopravní infrastruktury, které jsou relevantní z hlediska rozhodování inteligentních agentů.

Součástí příspěvku je i ukázka části ontologie, zaměřené na strukturu geodat popisujících silniční síť. V ukázce předvádíme některé způsoby prezentace zmiňované části ontologie.

Klíčová slova: multiagentový systém, ontologie, dopravní infrastruktura

Abstract. The paper deals with the problems of ontologies from the informatics point of view and especially in connection with GIS and multi-agent systems. It tries to provide an integrated view of the field of ontology in general and submits several reasons for their building. Ontology is considered important due to several reasons – sharing of information among team workers, a conceptual analysis of the problem and its use in a specific practical solution.

We give an overview of various views of the problems of ontologies in the article and individual types of ontologies according to their purpose and fields of use. We define the term of ontology in informatics according to different authors and familiarize readers with the implemented projects in this field.

We give reasons for building ontology in the project "Logic and Artificial Intelligence for Multi-agent Systems (MAS)" financed within the Information Society programme by the Academy of Sciences of the Czech Republic. Terminological non-uniformity and incompleteness of methodologies we have encountered in our work is connected with dramatic development in this field. We also evaluate the use of some tools for capturing ontology.

The project case study, for which we have built our ontology, focuses on the field of road traffic. Outcomes we used include standards, laws and the terminology typical for this field in real world. Ontology represents a connecting piece among the given outcomes and the solved case study. When creating the ontology, we were led by the effort to catch those aspects of traffic infrastructure which are relevant with regard to making decisions of intelligent agents.

The article also includes an example of a part of ontology of the traffic network. We show some ways of presentation of the mentioned ontology in the example.

Keywords: multi-agent system, ontology, traffic infrastructure

1 Introduction

One of the modern methods of modelling of the real world processes is so called "multi-agent system", hereinafter referred to as MAS. It means complex systems consisting of individual autonomous units, so called agents, equipped with their own intelligence to a different level and the ability of mutual communication. Another important aspect, besides these agents, is the environment they are incorporated in. It is the environment what influences their behaviour in such manner that it, in fact, determines their basic possibilities. An agent may behave meaningfully only if it somehow relates to its environment. The logic of an agent's behaviour is thus highly dependent on the environment and it can be said that the environment becomes an important bearer of the semantic aspect. The environment itself is influenced and modified by agents but always according to certain rules which are inherent to it.

Multi-agent systems do not model the given complex process explicitly, but they rather model only behaviour of their parts, i.e. agents depending on the characteristics of their environment. Behaviour of the whole system will then naturally follow from their mutual interaction. New and unexpected characteristics of the whole system may incur in this way. The occurrence of new qualitative properties by reaching certain level of complexity is called emergence in English. As most phenomena show emergent features, multi-agent systems become a suitable tool for their modelling.

Modelling of common processes has been quite well processed at present. What is missing, however, is the possibility of modelling of spatial processes [RAP06], i.e. processes, whose course and result depends on the position and arrangement of agents in the space forming their environment. This is the field our research performed within the project “Logic and Artificial Intelligence for Multi-agent Systems” (MAS) financed by the Information Society programme of the Academy of Sciences of the Czech Republic focuses on.

A basic requirement put on MAS is the ability of agents to mutually share the information on their environment, as well as the ability to think and decide on their own activities in the spatial context. With regard to the given criteria, we chose the problems of road transport as a testing task for verification of results of our research. Moreover, it is quite a well defined and generally known spatial process, which will be able to be expressed by means of a model of real traffic network described by GIS data.

The necessary condition for the possibility of mutual communication of individual agents and meaningfulness of their behaviour is to assure their interaction with the commonly shared environment. In other words, the environment, where they are to operate, must be suitably conceptually intermediated. One of our basic goals is to propose suitable conceptualisation, or ontology of the space of the world of agents.

2 What Is Ontology?

At present the term “ontology” becomes highly frequent in the context of informatics. It has been taken from the philosophical context, where it was equivalent to the term of metaphysics, which is the determination of the subject, a philosophical discipline, which has been defined as a "theory on being" since Aristotle’s times. Traditional metaphysics tried to capture the world in its true essence regardless of how it appears to a human subject. The base was the effort to describe the world in its complexity and undistorted by human recognition equipment. This description was naturally carried out by language and it was connected with the search for basic concepts and relevant terms for it by which it would be possible to express everything what is. Now we have to clarify the main intuitive differences between the terms „concept“ and „expression“. The concept is the meaning of expression, it is a semantical category, whereas the term is the linguistic expression, it is a syntactical category. For example two synonymical expressions expresses the same concept.

Obviously, the term ontology passed on informatics with specific differences in meaning. Literature most frequently states the following two definitions of *ontology* as the information artefact:

Ontology is an explicit specification of conceptualisation. [GRU93]

Ontology is a formal specification of the shared conceptualisation. [BOR97]

However, both these definitions are incomplete. The concept of ontology blends here with the concept of *conceptual analysis*, although we can speak about light differences between them despite significant proximity.

Definition: Conceptual analysis is a formal conceptualisation of a field by means of a represented system of concepts and by defining relationships among them. It always incurs purposefully and it puts demands for integrity only within the given domain and problems solved therein. There may be many partial conceptual analyses. □

The first sentence of the given definition fully relates also to the concept of *ontology*. Gruber’s and Borst´s definition follows only from this first part, therefore the concept of *ontology* in their interpretation necessarily blends with the concept of *conceptual analysis*. It is because they do not point out one of the basic goals of ontological engineering, which is the effort for wide sharing even outside the respective team, which is using it. For ontologies to

be shared, methodology of their creation must be unified. The main method for building ontology is above all the effort to adapt created concepts to "reality" as much as possible. This “reality” is for us the reality as traditionally understood by a human entity, i.e. the reality as we understand it by our *common sense.* We will now present the definition of the term of *ontological engineering* as given in [SVA07]:
Definition: Ontological engineering is a modern field of informatics which focuses on designing, implementation and application of ontologies: shared and mostly formalized knowledge models supporting correct modelling of reality, semantic interoperability and automatic derivation in software applications.

The aforementioned source places emphases on sharing the ontology in a wider context, but no definition of ontology is explicitly given there. Let us then define the term of ontology as follows:

Definition: Ontology is an outcome of the conceptual analysis of a given problem area (domain). It represents simulated reality by formal specification in such a way so the possibilities of its sharing exceeds the group of closely interested subjects.

When building an ontology, it is observed to keep the common sense criteria in relation to the simulated reality. Also the following commitments are accepted:

- for the formal specification, the well-established terminology with its terms used commonly, is exploited preferentially
- there is an effort to adhere general standards in a case of necessity to insert a special terminology.[4]

This approach includes potential possibility of more extensive sharing of the given ontology. Such sharing exceeds the group of closely interested subjects.
The outcome of ontological analysis is mostly conceptual hierarchy which capture the most crucial entities of respective domain, their attributes and generally valid relations among them. The most important observed relations are requisite relation among properties and the whole-part relation among entities included in the respective concept.

Ontology may be classified in certain groups on the basis of some of their semantic properties. There are many such properties, but it is not the subject of this text to make the total classification of ontologies. Nevertheless, let us give at least basic view of properties of ontologies for detail specification.

An important property is the rate of specificity of the ontology. Ontology may be general, basic and a domain one. General ontologies deal with concepts exceeding the scope of individual domains (e.g. a process, an event), basic ontologies model central concepts of a specific domain, domain ontologies contain concepts specific for the given domain. [SVA07].

A different view of the classification of ontologies may be found in [SVA02] and [FON03]. According to that view, ontologies are divided to:

- *generic ontologies* – or ontologies of the highest level describing the most general terms; these ontologies describe a general concept of space in the environment of geo-information systems,
- *domain ontologies* – they describe terms relating to the generic domain, such as road traffic,
- *task ontologies* – they describe tasks or activities, such as road transport of loads,

[4] The *special terms* are terms of description the phenomena which are not terminologically earmarked in common practice. They represent needs of users related to a concrete application.

- *aplication ontologies* – they describe terms dependant both of a specific domain, and of tasks solved above it; it is a conglomerate of models taken and adapted for a specific application usually including the domain and task part. They represent users´ needs in relation to a specific application, such as the movement of means of transport along the traffic network.

The ontology of traffic infrastructure proposed by us falls into the last mentioned category.

3 Method of Building the Traffic Infrastructure Ontology in our Case Study

As mentioned above, the environment, which is the traffic infrastructure of road network in our case study, must be suitably intermediated to the agents. Only then will the agents be able to rightly decide in the spatial context and to mutually communicate. Building the traffic infrastructure ontology has the following goals:

- assure meaningful behaviour of agents in the traffic infrastructure
- assure meaningful communication of agents necessarily based on mutual sharing of the same ontology among these agents.

When building ontology, we started with searching for the description of the used procedures or methodologies which were successfully verified in other projects. We may include among them Gruniger and Fox's methodology from the TOVE project [GRU95], the procedure according to the KACTUS project [KAC95] or *METHONTOLOGY* described in [GOM04].

We decided to proceed according to the last mentioned *METHONTOLOGY,* because of its transparent logical structure and completeness of its steps which express the process of building ontology. It includes the following tasks – Figure 1.:

- build glossary of terms,
- build concept taxonomies,
- build ad hoc binary relation diagrams,
- build concept dictionary,
- describe ad hoc binary relations, instance attributes, class attributes and constants,
- describe formal axioms and rules,
- and finally describe instances.

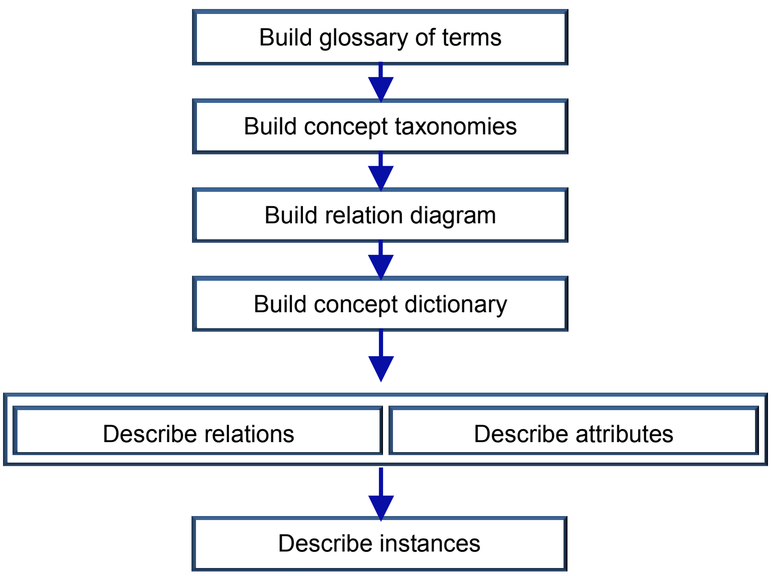

Figure 1. Tasks of conceptualization activity according to METHONTOLOGY.

A basic method we followed from in building the traffic infrastructure in our case study was the effort for our conceptual analysis to capture reality in the aforementioned *common sense.* Due to this reason, we first tried to build a glossary of basic terms standard for the given domain. It is not a coincidence from the logic of the matter that the task *build glossary of terms* is the first task to be done in compliance with the METHONTOLOGY. For this purpose, we used not only various articles dealing with the given domain, but we especially tried to follow from standards used in the field of intelligent transport systems because the mentioned case study deals with transport. A basic outcome was GDF standard, which is available as ISO 14825 in the valid version 4.0. The ISO standard is the result of consensus of quite wide professional group; therefore it can be considered a useful source of basic terms and their definition for ontology. Our focus on GDF standard follows from the effort to interconnect the data modelling real infrastructure in the GIS environment with a multi-agent system – see Figure 2.

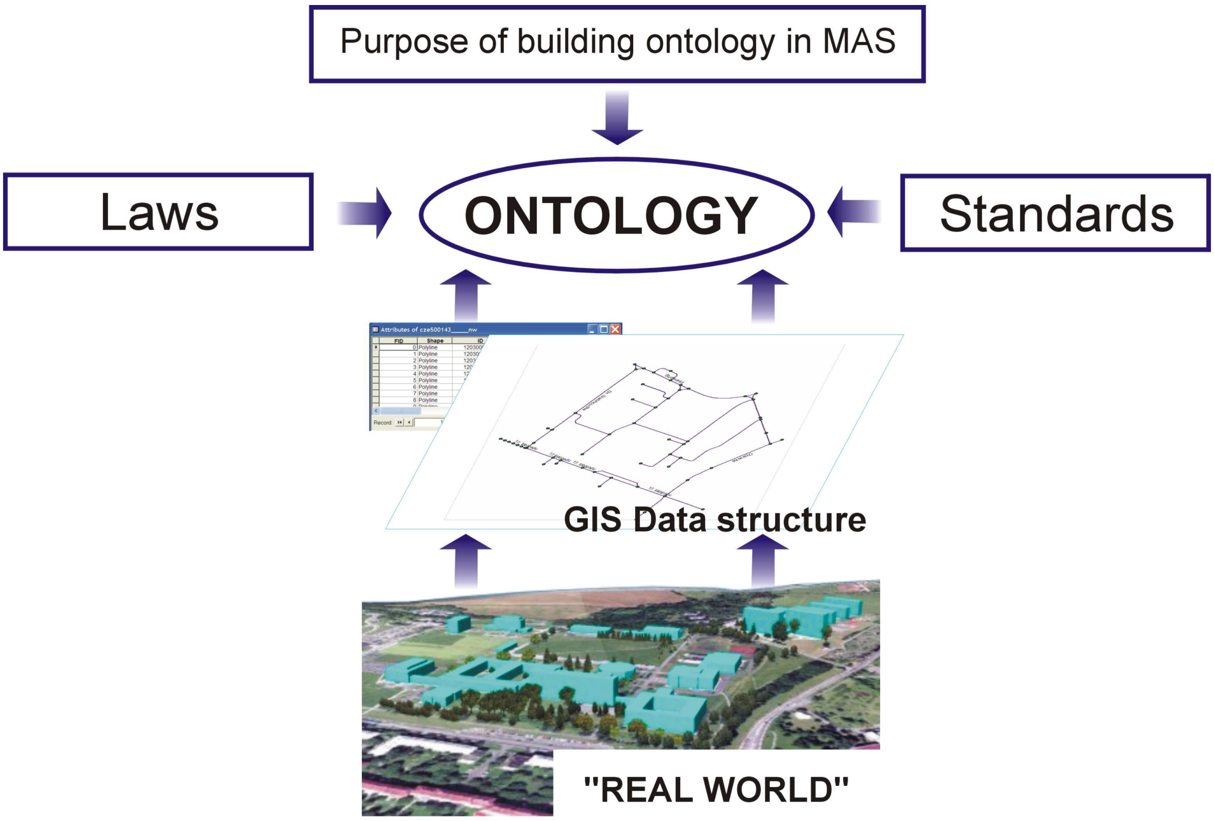

Figure 2. Sources influencing ontology building

One of the requirements for conceptualisation and ontology as such is to be explicitly expressed. Its image hidden in the head of the creator is not sufficient. The requirement for a formalized expression or the use of language with exactly defined syntactic structure is related therewith (and follows from the definition of ontology). At the beginning of creation of ontology, fully informal or semiformal expression by means of a diagram or a structure of tables is possible, which e.g. show a structure of classes and relations. Individual terms may be informally explained by means of natural language both in a free or a structured form. We may simply say that at the beginning of every formal expression of ontology there is its informal description e.g. by means of a glossary.

The source of concepts and their respective terms was not only the mentioned standard. In the beginning we searched a created unified ontology of our domain which could be used for the needs of conceptualisation of our problems. Although there are several works dealing with this field – e.g. [TOM05] and [LOR05], none of them provided a unified view of the transport domain, which was the main reason for the creation of our own proposal. In addition to the aforementioned outcomes, we considered legal regulations during the creation, e.g. Act No. 361/2000 Coll. on Road Traffic.

To create a basic glossary observing the principle of *common sense*, it is generally necessary to follow from specific problems to be solved by the given case study. It was the same in our case. As the agents shall move meaningfully along the traffic infrastructure, we tried to capture those aspects of traffic infrastructure, which are relevant with regard to making decisions of intelligent agents. It means the necessity to create terms even for such phenomena which are not terminologically earmarked in common practice. For demonstration, we give the following example from our case study:

A simple change of the number of lanes may incur on the road in a certain place. This phenomenon must be captured in our case study because the process of decision-making of an agent on the possibility or impossibility of a lane change must necessarily follow. The agent's ability to respond to this situation becomes the key one e.g. in cases, when the lane, in which the agent is moving, ends. To be able to continue driving, i.e. to fulfil its goal, the agent must cross to another lane, which is a continuing lane in the direction of its target. Similarly, in case of lining in front of an intersection it is necessary for the agent to line correctly with regard to its target. If we had not conceptually capture the aspect of change of lanes for the agent's seeing, the agent would not be able to fulfil any of the basic tasks, which is e.g. passage through the intersection according to the given itinerary. It is evident that our ontology must conceptually capture even the phenomenon, when a simple change of lanes on the way incurs. As mentioned before, in the search for a suitable term, we adhered to the basic method of building ontology, which is the effort for shareability. We particularly tried to go through available literature, whether the phenomenon searched by us has a specific term allocated or not. GDF standard was again the outcome for us, specifically the term *junction*.

Every newly captured concept understandably often brings about the need to terminologically introduce other concepts related to it. If we earmark and consequently name a place in the infrastructure, where a simple change of lanes incurs, it is, in fact, a divide, a connection between two different elements of the road. The first element has the original number of lanes, the second element the changed one (higher or lower). To finally define the term of *junction*, it is suitable to capture the concept of *road element*, which is a section of the road, where the number of lanes is not changed. Every lane has a flag, which is negligible for a driver – agent with regard to his decision-making process. We considered:

- the information on the direction in the sense of the driving direction or the opposite direction.
- the information on the fact which lane or lanes continue (a change of the number of lanes, lining up in front of an intersection).

These important terms must be included in the ontology as the lane attributes.

Here we can see that *ontologies* may be fine in different ways, therefore in the beginning of its building it is necessary to clarify what its range is going to be. It means not only the determination of a width of the given domain, but also the clarification of what specific tasks will be solved by means of our ontology, or what it shall serve for. In case that we would like to capture only basic terms, it will be a gross ontology. If it is to serve as a really fine conceptual analysis, we have to accept that terms with no equivalent in common use of natural language will be added to it. These problems are related to the language we will use for the presentation of the ontology. We could say that a direct proportion applies that the finer grained ontology, the language with bigger expressive power should be used.

For demonstration we give basic terms, which were the result of the first step of the mentioned *METHONTOLOGY*, i.e. build glossary of terms – Table 1. Our ontology does not include only concepts, but of course also attributes and relations. We give only a demonstrative example in this article.

Table 1 – Glossary of Terms of our Traffic Infrastructure Ontology

Name	Synonyms	Description	Type
Traffic System(TS)		A set of objects participating in the process of traffic. Every TN object has its allocated position.	Concept
Traffic Network(TN)	Infrastructure	A basic infrastructure or a set of objects of the traffic system forming its static part. In this project, we understand it as a system of *roads (R), junctions (I), signs (TSI) etc.*	Concept
Road(R)		*Road (R)* is a basic element of the traffic infrastructure. It serves for the movement of vehicles; it interconnects individual places – junctions. It starts and ends with an *intersection (I).* A road consists of *road elements (RE)* and their *joins (J).* Every road has at least one *road element (RE)*, every further *road element (RE)* is connected by a *junction (J)* with the previous one.	Concept
Intersection(I)	Crossroad	Intersection (I) is an element of the traffic infrastructure, to which one *road (R)* leads *(a blind street)* or which connects two or more *roads (R).*	Concept
Road Element(RE)		They form a *road (R)* or *an intersection (I)* together with the *junction (J).* Every *RE* starts and ends with a *junction (J)*, by which its orientation is given. It consists of *lanes (L)*, whose number is constant in the given RE.	Concept
Junction(J)		It forms an *intersection (I)* or a *road (R)* together with a *road element (RE).* It represents the connection of two or more *road elements (RE)* or an end of *road elements (RE).* It represents e.g. a connection of two REs with a different number of lanes.	Concept
Lane(L)		It is the smallest unit of the *traffic infrastructure (TN).* One or more lanes lying one next to the other form a *road element (RE).*	Concept

4 Further Procedure of Works

The present proposal of the ontology deals only with the description of the traffic infrastructure with regard to the movement of vehicles along it. The next logical step is its extension by the description of the movement of vehicles along the traffic network and in the end, a summary of terms describing customized transport of loads. By doing so, it will be possible to model specific transport tasks by means of the developed multi-agent system.

It will be an interesting task to generalize the proposed ontology so that it enables also the description of transport of loads on the railway and thus covering the whole field of the land transportation and simulating combined transportation of loads.

5 Conclusion

The goal of this text was to familiarize listeners or readers in detail with the problems of building ontologies at general level. On the basis of giving some existing definitions of the term of ontology, we proposed our own definition, whose purpose is to bring in more light to the whole problems. A classification of different types of ontologies was also described. The methodology of building ontology was described on a specific approach selected by us to the building an ontology in the case study in the field of the road traffic. The article also includes an example of a part of ontology focused on the structure of geodata describing the traffic network.

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