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ONTOLOGIES AND THEIR POTENTIAL FOR KNOWLEDGE REPRESENTATION LAYER FOR A CBR SYSTEM IN FIRE SERVICE

Ontologie i możliwości ich wykorzystania jako warstwy reprezentacji wiedzy w systemie CBR dla straży pożarnej

Summary

The foundations for knowledge representation for intelligent systems in the State Fire Service of Poland (PSP) are presented in this paper. Part of the documentation collected by PSP, particularly that related to operational matters could be collected to form Knowledge Banks that could be utilised during fire and rescue actions, trainings, analyses, etc. Unfortunately, there is a problem resulting from the way this data is stored - the collected documentation is stored in PSP in a way that cannot be processed by computer systems. Namely, the binary data created by text processors doesn't contain enough structure to be automatically processed. A mainstream approach currently is to create ontologies to model the knowledge for a given domain. The basics of what ontologies are and how knowledge can be expressed by them are then described. The authors searched for already created ontologies in other countries in order to reuse them. Only one ontology, named e-Response was found in University of Edinburgh, Scotland. However, this ontology is based on the military ontology and is not specific enough to cover the required entities, so the authors decided to create their own ontology rather than reusing the one that was found. It must be noted, that ontologies must always be designed to serve a special goal. The authors' research is centered around the Case Based Reasoning (CBR) system, which could assist the officers in charge by quickly finding the descriptions of similar actions from the past. A CBR system needs to find similar cases in the database and the ontology is supposed to enhance this process. The article concludes that ontologies sound as a most proper way to address the problem of data organisation in most of domains (including PSP), as they become more and more popular and are actively researched worldwide.

Streszczenie

Artykuł przedstawia podstawy reprezentacji wiedzy dla inteligentnych systemów w Państwowej Straży Pożarnej. Część dokumentacji gromadzonej przez PSP, zwłaszcza tej, związanej z działaniami operacyjnymi mogłaby służyć do tworzenia banków wiedzy wykorzystywanych następnie podczas akcji, szkoleń, analiz itp. Istnieje niestety problem wynikający ze sposobu przechowywania danych - dane są gromadzone w sposób uniemożliwiający ich przetwarzanie przez systemy komputerowe.

Problemem wynika z braku odpowiedniej struktury w binarnych dokumentach tworzonych za pomocą procesorów tekstu. Najpopularniejszym obecnie podejściem do rozwiązania powyższego problemu jest tworzenie ontologii dla modelowanej dziedziny. W artykule opisano podstawy ontologii oraz możliwości wyrażania za jej pomocą wiedzy. Autorzy rozpoczęli badanie od przeglądu literatury światowej w poszukiwaniu ontologii w dziedzinie pożarnictwa. W ramach przeglądu znaleziono tylko jedną ontologię (nazwaną e-Response) na Uniwersytecie w Edynburgu w Szkocji. Okazało się jednak, że ta ontologia bazuje na specyfikacji wojskowej i nie zawiera wymaganych (w dziedzinie modelowania akcji ratowniczych) obiektów. W związku z tym podjęto decyzję o utworzeniu nowej ontologii. Należy zaznaczyć, że przy tworzeniu ontologii należy określić cel jakiemu ma ona służyć. Prace prowadzone przez autorów koncentrują się wokół wnioskowania na podstawie przypadków (CBR) celem wspomagania dowódców w czasie prowadzonych działań ratowniczych. System CBR opiera się na wyszukiwaniu podobnych przypadków w bazie danych i ontologia mogłaby ulepszyć ten proces. W podsumowaniu artykułu stwierdzono, że ontologie są właściwym mechanizmem organizacji danych w wielu dziedzinach (w tym w PSP) co znajduje potwierdzenie w ich rosnącej popularności oraz liczbie prowadzonych nad nimi badań.

1 Introduction

There is various documentation created for the needs of the *State Fire Service of Poland (PSP)*. Part of this documentation, particularly that related to operational matters could be collected to form Knowledge Banks that could be utilised during fire and rescue actions, trainings, analyses, etc. Unfortunately, there is a problem resulting from the way this data is stored - the collected documentation is stored in PSP in a way that cannot be processed by computer systems. This article outlines disadvantages in current documentation storage policy as well as proposals for their improvement possibly triggered by the use of an *ontology*. The first part of this paper reveals the problem of documenting fire&rescue operations. Next an ontology approach to organizing data is introduced and an existing fire&rescue ontology is validated against its appropriateness for the PSP documentation.

2 The problem of documenting actions analyses

A regulation exists in PSP, which orders that analyses be conducted from incidents as defined in the regulation [1]. All significant or otherwise interesting incidents should undergo analysis. These analyses are conducted in conformity with the template found in the attachment to the regulation and concerns the following issues [1]:

1. Elementary data;
2. Description of engaged fire and rescue operations;
3. Operational protection of the factory, plant, incident area, etc.;
4. Preventional protection of the factory, plant, incident area, etc.;
5. General information;
6. Conclusions;
7. Directory of manpower and resources;
8. An outline of the situation.

Analyses are created in a text editor, such as MSWord and, in this form, are sent and registered in the system. Registration is focused on the data input process rather, (data entry, registrar, the object of the analysis, the actual location of the file/documentation) than on the analysis content. This results in a limited ability to search out analyses, even on the computer on which it is installed. The effect is that potentially interested PSP units can't access the analyses.

The problem of analyses accessibility concerns the organization of databases and is the subject of independent research undertakings [2]. The research mentioned above deals with access to the data files and does not cover the method of organizing data in the file itself. The scope of that research is limited to working with meta-data on the content of documents stored in the system (i.e. keywords) and has limited abilities to process binary office documents (MSWord). Data can be organized in the database in the following way:

Keywords: fire, warehouse, paints, varnish, warsaw

The date of the action: 15.07.2005

Analysis commencement: 21.03.2006

File location: /2005/fire/warehouse_warsaw_2005.doc

In the file pointed in the field "File location" MSWord binary data is stored:

73 32 2f 61 63 63 65 6c 65 72 61 74 6f 72 2f s2/accelerator/c

75 72 72 65 6e 74 2e 78 6d 6c 03 00 50 4b 07 urrent......PK..
00 00 00 00 02 00 00 00 00 00 00 00 50 4b 03 ....PK..
14 00 00 00 00 00 03 52 51 37 00 00 00 00 00 ....RQ7......
00 00 00 00 00 00 18 00 00 00 43 6f 6e 66 69 ....Config
75 72 61 74 69 6f 6e 73 32 2f 66 6c 6f 61 74 urations2/floate

The binary data above does not contain any structure which would allow for automatic computer processing. Even though all the information about the incident is available inside the file, one cannot ask the question: "What equipment was used in the action?" Defining a data structure acceptable and apparent for the computer would introduce new possibilities for the processing of analyses:

- the data could form the basis for decision support systems, e.g. *Case-Based Reasoning (CBR)* system proposed at [3];
- the possibility of extracting more information about a given action by asking queries;
- the possibility of carrying out analyses on the given set of analyses;
- the possibility of action visualisation;
- other.

The switch to another form of storing the data is essential to provide the computer with the data in a processable form. This goal can be achieved by organizing prose in a structured way by the use of an ontology [4].

3 Modeling knowledge with an ontology

The term "ontology" comes from the field of philosophy that is concerned with the study of being or existence. In computer and information science, ontology is a technical term denoting an artifact that is designed for a purpose, which is to enable the modeling of knowledge about some domain, real or imagined [5]. According to Gruber an ontology is a specification of a conceptualization [6]. "Conceptualization" refers to an abstract, simplified idea of a domain that is to be modeled.

There are significant advantages that ontologies provide. Based on underlaying ontology for a given domain, intelligent systems can be built which can deliberatively reason about the domain. The knowledge can be captured in an unambiguous way, which results in a commonly agreed upon understanding of a domain. Those advantages are assured by the underlaying logical layer of the ontologies, usually in the form of a first order logic or description logic, where the content is expressed by unary and binary predicates - named concepts and relations respectively [7]. There are a variety of languages and editors for creating ontologies, none of which achieved a position of a de facto standard [8, 9].

Even though there exists an array of different approaches to how to describe the concepts in different ontologies, there are features which are mostly agreed upon:

- There are objects in the world,
- Objects have properties (attributes) which can have values,
- There can be relations among objects,
- Properties and relations may expire,
- There are events which occur at particular moments in time,
- There are processes in which objects participate and which occur over periods of time,
- The world can be in different states,
- There can be effects - events initiated by other events,
- Objects can have parts

Ontologies are more than just a taxonomy or a classification, even though they are frequently and improperly misidentified as such [10]. Ontologies are always expressed in some knowledge representation language which allows for describing not only a hierarchy of objects in the given domain, but also their relations, properties and constraints. The result is that an ontology allows for defining a set of concepts in a machine-readable form, which is considerably more than just a hierarchy of objects.

The ontologies define concepts by using three major kinds of qualities (characteristics) [11]:

- types (e.g. car),
- properties (e.g. fast),
- relations (e.g. next to)

The objects outlined above are different kinds of *Universals* [12]. Universals are what particular things can have in common - there can be many things that, according to the above list are cars, are fast and stand next to something. The short definition is that universals are things which can have instances. *Particulars*, on the other hand are the instances of universals, e.g. *my car*.

4 Formal and Foundational Ontology

The process of creation an ontology may be started either from scratch or, preferably, by choosing some generalized ontology and developing a new one by narrowing the abstract ideas. Such ontologies, which could serve as templates for building more specific ontologies are named *Foundational Ontologies* (or Upper Level Ontologies / Top-Level Ontologies).

Foundational Ontologies can be either *material* or *formal*. The difference between the two is that the material ontology tries to capture the reality by organising it in concrete, material (physical) objects e.g. animals, buildings, cars, while the formal ontology is limited to concepts that are abstract. A well known representative of the material ontology group is *CyC* ontology, while the group of formal ontologies includes *BFO*, *DOLCE*, *GFO*, *OCHRE*, *SUMO* [13].

Although there is no agreed upon strict interpretation, the term *formal ontology* is related to the highest generalization level of such an ontology and the rigorous description of what forms things may have (hence the name *formal* [14, 15]. The abstraction of formal ontologies is considered to enhance the process of constructing a new ontology [16]. The next paragraphs of this section introduce the major concepts of the formal ontologies.

Despite the difference in the terminology among formal ontologies there a few terms which are common:

- Endurant - entities which are permanent and independent of time (continuants). Examples of endurants are material objects like *a car* as well as abstract objects like *an organization*,
- Perdurant - entities which happen and only partially exist in time (occurrences, processes) - in any snapshot of time, only part of the perdurant is present, e.g. *eating*,
- Qualities - properties which only exist to describe the entities and can't exist without them, e.g. *colors*.

5 e-Response ontology

Parallel to the research in general theory of ontologies, the authors focused on the status of the implementations of systems incorporating knowledge representation for fire service both in Poland and abroad. A meeting with the representative of PSP Headquarters revealed that there are no technologies based on ontologies or similar advanced methods. The only technologies for representing knowledge in PSP are based on traditional relational databases, which possess well known limitations.

The authors also made a contact with the representatives of the abroad State Fire Services, searched through scientific papers and the internet to find existing ontologies for fire&rescue domain. The only positive answer came from University of Edinburgh, Scotland [17]. There is an ontology named *e-Response* developed at the above university [18].

The development of the e-Response ontology started after unsuccessful search for already existing ontologies, which is another reason to assume that it is unlikely that more fire&rescue ontologies (or valuable ones) do exist.

The roots of the e-Response ontology are in military area - the ontology was imported from the army and tweaked for the needs of fire&rescue service 1.

According to the authors of e-Response, the ontology was developed for a specific purpose, (although it is intended to be a general ontology), namely to provide a basis for an emergency response-themed demonstrator for the Advanced Knowledge Technologies (AKT) project in the UK [19]. This demonstrator loosely combined a number of separate Semantic Web [20] tools and technologies into a general goals system [17].

e-Response is based on the formal, foundational ontology *DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering)*, which aims at capturing the ontological categories underlying natural language and human commonsense [21]. The fact that e-Response is based on a foundational ontology causes that it is well suited for communication among agents exchanging the information. Foundational ontologies may act as a reference in heterogeneous environments where meaning across various domains needs to be negotiated.

6 The basis for Action ontology

The ontology to be created will be temporarily called *Action* throughout this paper.

Prior to the ontology engineering it is needed that the application for the ontology is precisely defined. The ontologies for the same domain, like fire service can model very different aspects of the domain and they may be used for different tasks. A different approach is needed when the main focus is on the cooperation across external domains and another approach must be taken to operate in one domain only, perhaps to carry out extended inferencing.

There are a lot of research about Decision Support Systems. The support that such systems can provide for commanders during fire&rescue operations can not be overestimated. Major problem of such systems is usually the lack of good content in knowledge representation layer. The authors' intention is to focus their further research on providing an ontology-based knowledge representation layer for a Decision Support System, namely CBR.

Light-weight ontologies, as opposed to foundational ontologies, are another category of ontologies. They are well suited for specific tasks or restricted domains, such as fire service. Usually they are in the form of taxonomic structures containing primitives and composite terms and their definitions and contain simple relationships. Light-weight ontologies are normally used in well-established communities, where the intended meaning of terms is more or less already known in advance [22]. Another advantages of smaller ontologies are their fitness for computationally intensive tasks, such as in CBR applications.

There is no non-controversial way of dividing the world into concepts. This is especially true for the very top of any ontology. The figure 1 lists some examples of different approaches to such a division. The right conceptualization is the one which, among other features, limits *multiple inheritance* - classes which belong to multiple superclasses [23], it is hardly avoidable in practice, though.

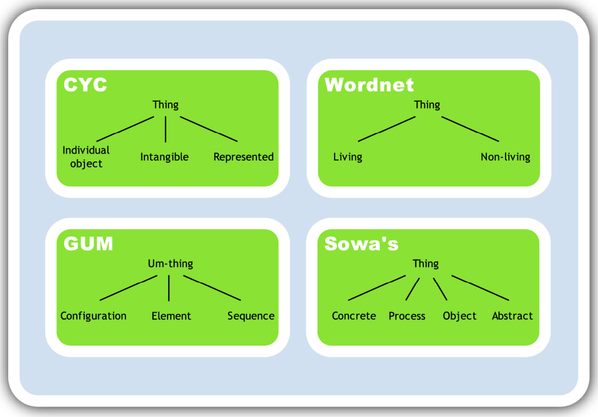

Fig. 1: Example of the most general concepts across different foundational ontologies. Source: [24] /

Ryc. 1. Przykład najbardziej ogólnych konceptów wykorzystywanych w różnych ontologiach podstawowych. Źródło: [24]

On the figure 2 an initial idea of conceptualization of *Action* is introduced. Domain-specific ontologies can contain categorizations along dimensions that are usually outside the general ontology [24] and this is the case in the above proposition. The hierarchy contains little abstraction which makes it a light-weight, material ontology.

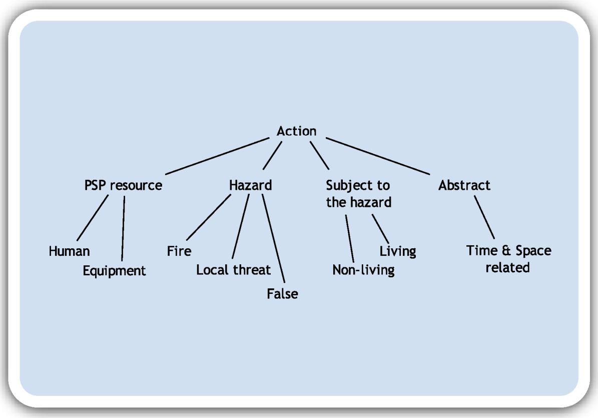

Fig. 2: The proposition of the top level for Action ontology.

Source: Author's work

Ryc. 2. Propozycja najbardziej ogólnych konceptów w ontologii Action.

Źródło: Opracowanie własne

The authors propose a description logic based *OWL-DL* language [25], as the form of expressing the ontology. Description logic is a type of language which allows for knowledge representation and which can be directly translated to first-order logic. There are reasoners, such as *Pellet* [26] which can perform inferencing on the data in the form of description logic. Even though higher order logic allows for superior expression of the concepts, the reasoners implementations are focused on first-order/description logic, so at the time such logics are a safer choice. Another advantage of choosing OWL-DL language is the support for this language in Protege ontology editor [27], which is currently a respected tool for ontology engineering and which is considered best candidate to create the Action ontology.

7 Conclusions

PSP collects data which may often be valuable, but there is no automatic way to access it nor a perspective for computers to autonomously process the data stored in current form. There is a lot of research being conducted on the topic of structuring prose-like data, mainly by the use of ontologies. Ontologies appear as a universal way to conceptualize domains in computer processable format.

A lot of research is also going on in the field of Decision Support Systems. Such systems can significantly improve the comfort of commanding during a fire&rescue action, which is prone to mistakes due to stress and lack of experience, by providing the officer in charge with scenarios on what decisions to take or by finding the reports from similar actions.

The crucial feature of such systems, one of which is a CBR, is the knowledge representation layer. There are various approaches about how to implement this layer; using an ontology is an advanced method for achieving this goal.

There are issues which are still opened. This is an early stage of defining the foundations for the Action ontology, based on theory found in scientific papers. No ontology engineering has been done yet and inferencing possibilities of engines were not extensively researched by the authors. This is the scope of authors' further research and will be more precisely defined as the research progresses.

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