Uncertainty Extensions to Ontologies as a Tool for Semantic Interpretation in Audiovisual Systems

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***Abstract*— This paper deals with semantic interpretation of audiovisual data. It investigates how explicit interpretation of uncertainty can help to bridge the semantic gap. We present a case study of FuzzyOWL — a current uncertainty representation framework — applied in the context of the recent European project CARETAKER focusing on automated situation awareness, diagnosis and decision support. A particular user-oriented task is modelled in FuzzyOWL. The paper briefly summarizes basic features of the formalism, discusses pros and cons and points out difficulties and problems connected to its employment.**

***Index Terms*— uncertainty representation, FuzzyOWL, audiovisual system.**

I. Introduction

Uncertainty representation in audiovisual domain is one of the topics explored within a recent European project – the Network of Excellence K-Space (Knowledge Space of semantic inference for automatic annotation and retrieval of multimedia content). We participate in the preparation of a survey [2] that summarizes advanced features of the current representation and reasoning frameworks dealing with various kinds of imperfect knowledge. The survey discusses pros and cons of particular formalisms and points out the differences. However, the systems are compared from a general point of view, we do not expose the systems to real conditions and do not show their qualities in a real domain. Therefore, there is a danger of missing important aspects needed for their practical application.

That is why we decided to demonstrate one of the formalisms – Fuzzy OWL – in real conditions and to show its features in a case study from a real project. The selected testbed is provided by the current European project CARETAKER (Content Analysis and REtrieval Technologies to Apply Knowledge Extraction to massive Recording) in which the first author participates. CARETAKER focuses on the extraction of a structured knowledge from large multimedia collections recorded over networks of camera and microphones deployed in real sites. The produced audio-visual streams, in addition to surveillance and safety issues, could represent a useful source of information if stored and automatically analyzed, in urban planning and resource optimization, environment planning and disabled/elderly person monitoring for instance [1]. We deal with a particular situation of the subway monitoring system in this paper and show how the selected scenario can be modelled in the given framework.

To demonstrate the main features of the formalism, we defined the following task connected to subway monitoring: There are 4 cameras installed in a station – 2 in the corridor (different directions), and one for each platform. There is a microphone array in the main corridor. The cameras report an unusual (for non-peak hours) crowd of people in the main corridor. One of the cameras there shows that most of people are not standing in a reading distance from the travel info sign. Although quite a long time elapsed from the departure of the last train, there is a fuss (strong noise) detected by the microphones. The system should fire alarm for the operator.

II. Fuzzy OWL for Uncertainty Modelling in CARETAKER

As the name suggests, Fuzzy OWL combines OWL with the fuzzy logic [7]. Two different approaches have been proposed: the first one [5] permits only A-box fuzzy axioms in the form $\langle a : C \bowtie n\rangle$ and $\langle (a, b) : R \bowtie n\rangle$, where $\bowtie$ is one of $\{\leq, <, \geq, >\}$, C is a concept, R is a role, and a, b are individuals. A new reasoning tool based on the first approach is currently under development.[1]

The second approach [6] permits T-box fuzzy concept inclusion axioms in the form $\langle \alpha \bowtie n\rangle$, where $\bowtie$ is one of $\{\leq, <, \geq, >\}$ and α is a non-fuzzy $\mathcal{SHOIN}$ concept inclusion axiom and R-box fuzzy role inclusion axiom in the form $\langle \alpha \bowtie n\rangle$, where $\bowtie$ is one of $\{\leq, <, \geq, >\}$ and α is a non-fuzzy $\mathcal{SHOIN}$ role inclusion axiom.

As the non-fuzzy T-box and R-box of ontology can be developed by standard techniques, we decided to use just the first mentioned approach for demonstration purposes (although the second approach is more expressive). Our use-case does not need the representation of uncertainty on T-box or R-box levels.

To evaluate Fuzzy OWL representation of uncertainty, we developed simple domain ontology in Protégé.[2] It is designed as a spatio-temporal ontology based on DOLCE [4]. The spatial part consists of a system of space regions. The temporal part complies with the OWL-Time specification [3].

The described ontology (see Figure 1) consists of a T-box terminology and a partial A-box containing information about "static" individuals like microphones or physical sectors of subway stations. The second part of the A-box is defined

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[1] http://www.image.ece.ntua.gr/~nsimou/

[2] http://protege.stanford.edu

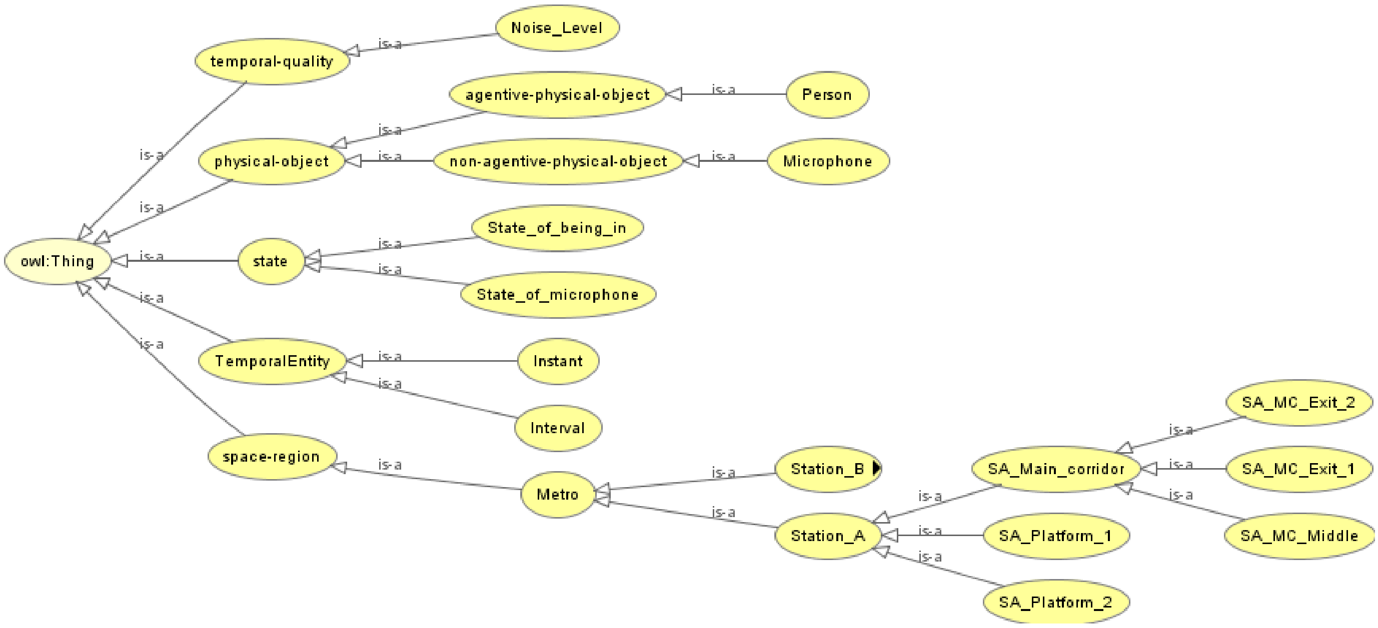

Fig. 1. A simplified OWL ontology for the use-case

as a result of real world analysis of sensory data. Resulting features contain typically vague or uncertain information. Microphone can report noise in the corridor at level 0.8 between `No_noise` and a chosen top level `High_noise`. One can append this information in Fuzzy OWL form to the A-box (as a fuzzy instance of the relation `has_noise_level`). Similarly, we could include fuzzy A-box axiom of relation `is_crowded_in_time` between a given sector and the current time instant which can be computed from the number of people in particular physical sectors.

III. Discussion and Future Directions

Various aspects of Fuzzy OWL have been taken into account in our work. We paid attention especially to the complexity of reasoning, the way of dealing with imperfect knowledge, availability of tools for reasoning, the support for ontology development, the complexity of the modelling from the user point of view, and the possibility to present frequent patterns in an intuitive form.

In summary, reasoning in Fuzzy OWL is decidable. The formalism handles imperfect knowledge in both – ABox and TBox. There is a prototype of a reasoning tool for Fuzzy OWL available for download. It does not use the standard XML-based OWL syntax. Ontologies (T-boxes) can be developed using standard tools (e. g., Protégé) if one decides to include fuzzy information on the A-box level only. A general conclusion of the work can be that the fuzzy approach is appropriate for the textual specification of the vague and possibly ambiguous description of the use-cases given in the natural language. On the other hand, it is rather tricky to model the dependencies expressed by conditional probabilities.

Our future work will focus on the development of an intuitive user environment enabling application-specific visualisation of the domain knowledge. Future directions of our research will also lead to a detailed specification of the background knowledge for the subway monitoring task. The scenario-based approach will allow us to create user-friendly interfaces, to enable end-users to introduce context information about a new scene, add new scenarios adapted to a specific environment, and define the specification compliant with the given ontology.

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