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بسم الله الرحمن الرحيم

HANAA ALY

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HANAA ALY

Features and Limitations of Employing Reasoning in Description Logics for Sketch Recognition

A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN SCIENCE (COMPUTER SCIENCE)

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Abstract

People intuitively use hand-drawn sketches as a way of communication and to conceive each other's ideas. For better interactions with human users, it seems essential to endow machines the ability to understand hand-drawn sketches. The simplicity of using hands makes people prefer scribbling sketches over verbally expressing their thoughts or visually describing how they perceive objects in scenes. This is also motivated by the handiness of devices equipped with touch interfaces, which recognize human inputs only as raw gestures. But inherent properties of sketches, particularly impreciseness, make the process of recognizing hand-drawn sketches very challenging for computers. Moreover, there is a difficulty in finding a correspondence between low-level features of a sketched object and what humans have in mind about the same object as a whole concept.

One way to resolve the indicated difficulties is to represent hand-drawn sketches in a high-level and formal way, so that machines can somehow easily understand and deal with them. A formal representation reflects the human understanding of sketches in an application domain in terms of concepts that the sketches represent as well as interrelationships between the concepts constructing background knowl-

edge.

This thesis aims to study the possibility of using description logics for interpreting hand-drawn sketches through constructing descriptions of sketches in terms of concepts provided in an ontology. This is first initiated by empirical results of experiments involving human participants that study how humans perceive and recognize sketches. The proposed approach works by combining "low-level features" (such as geometric shapes, sizes and spatial relations of the components) of a sketched object with a high-level knowledge about sketches that gives thought to the meaning of a certain composition of low-level features. The approach accentuates the potential effectiveness of interpretation via description logics as well as the difficulties encountered in such interpretation. The proposed formalization is introduced and illustrated with some examples. The results of an implementation, along with detailed explanations, are presented to show how the semantics of hand-drawn sketches of definite categories of objects can be extracted.

Summary

The aim of the thesis is to study features and limitations of description logics and how to utilize them for describing hand-drawn sketches. This helps, to some extent, in formally enabling machines to deal with sketches in a way similar to how people accomplish it.

This thesis proposes an empirical, logic-based, ontological approach for sketch description and recognition. Firstly, necessary steps that one could follow to describe hand-drawn sketches are summarized. These steps are then illustrated throughout the thesis to see how they can be applied on a specific category of objects. The steps start with conducting experiments with human participants to give a glimpse on how humans conceptualize and understand an object that a sketch represents. This allows an empirical approximation of dealing with sketches in a human-like way. Then, the analyses of the experiments help greatly to find out the low-level features of sketches and how their combinations affect the process of recognition. The analyses also provide the basis for formalizing and building the proposed ontology to understand sketches. Afterwards, the whole interpretation phases that start from drawing a sketch until getting a guess of what this sketch may represent are presented, along with detailed examples. Finally,

analyses and discussions of applying the proposed approach to four objects of a definite category show the potential performance of using description logics in the interpretation of sketches and the complex challenges that we faced to ensure the representation of some cases in the right way using only description logics.

This thesis consists of six chapters, an appendix, and a list of references. A brief summary of their content is given in the following:

Chapter 1 gives a general view about the thesis by stating the motive, objectives, and contributions.

Chapter 2 presents an overview of the formal representation of the language used throughout the thesis, namely Description Logics (DL). This covers different aspects of DL including: syntax, semantics, and reasoning services. The Web Ontology Language (OWL), which is based on DL, is introduced as well.

Chapter 3 presents a literature review of sketch recognition including the meaning of a sketch and different techniques of recognition. Qualitative spatial relations and their representation in OWL are presented in this chapter.

Chapter 4 focuses on the design of the proposed approach. This chapter starts with describing a general methodology that one could follow to interpret hand-drawn sketches. It then summarizes the conducted experiments and their important findings that are related to the proposed approach. The chapter also presents the process of ex-

tracting low-level knowledge from a sketch's components. It finally elaborates on our formalization of representing and recognizing hand-drawn sketches in DL.

Chapter 5 presents the interpretation process of hand-drawn sketches, with a detailed description of the proposed approach. It also presents the empirical findings and compares the performance of the proposed approach with that of others. The chapter finishes with listing and discussing some of the limitations that are encountered and found to affect the performance.

Chapter 6 gives conclusive remarks, along with recommendations for future areas of research.

Appendix A clarifies more about some of the results obtained and presented in Chapter 5. It also illustrates a part of the script codes of our implementations using the OWL API, which is based on the programming language Java.

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