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Human-like Prototypes for Psychologically Inspired Knowledge Representation

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Abstract

We evaluate human grouping of everyday objects for a psychologically inspired knowledge representation based on prototype theory, named prototype-based knowledge representation (ProKRep). Our overall aim is to develop a knowledge representation system that one day could be used by kitchen robots. We conducted a study in which participants had to sort different kitchen objects into a digital kitchen. We chose a kitchen as a use case, since people have to tidy up dishes every day. We identified object groups whenever at least half of the participants put two items on the same shelf. Out of these categories we calculated the respective prototype. We then tested the similarities of all categories to all prototypes, which turned out to be reasonable.

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1 Introduction

In our aging society household robots are becoming more and more important. In order to ensure a satisfying human-robot interaction, it is necessary that the robot finds human-like, flexible solutions to everyday problems. Human knowledge representation is characterized by a high degree of ambiguity and situation-specific adaptation. A spoon is at the same time a tool for eating and a measuring device for cooking; when we have flowers but not a vase, we use a drinking glass or some other geometrically suitable container. When machines interact with people, they should show the same flexibility of interpreting and using objects. An example application underlying our present work is a household robot that should be able to arrange objects in a kitchen in such a way that users can intuitively find them without being told. For example, after a relocation, or simply tidying up dishes that have been in the dishwasher. A

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second application could be, as mentioned, to find similar objects if the desired one, e.g. a vase, is missing [12].
In previous work, we have proposed a mathematical formalized prototype-based knowledge representation [17] that is based on a model from psychology [14, 11]. The model was validated qualitatively with a set of dishes, where predefined object categories containing these dishes were used to create prototypes. We could show that this model provides the desired flexibility needed by robots interacting with humans.

Beside our approach there are other feature-based paradigms in knowledge representation: for example, the exemplar-based model [9]. In oder to categorize objects they are compared to all stored *exemplars* that have already been classified [10]. Further, there are systems like Dual PECCS using hybrid representations named *heterogeneous proxytypes*, which combine prototype- and exemplar-based representations [8, 7, 13]. An alternative approach to object replacement is described by Olteţeanu and Falomir [12]. They consider objects similar if they have at least one common feature, for example, the shape. Besides connectionist models and artificial neural networks [7], logic-based paradigms constitute another approach. Ontologies, for example, are able to store a wide range of everyday knowledge and they work well with automatic reasoning techniques [6, 16]. Ontology classifications, however, are unambiguous: an object either belongs to a category or not and reasoning gives definite answers. One application of an ontology is *Taaable*, a Case-Based Reasoning system that uses a recipe book as a case base to answer cooking queries [1, 2, 3]. They utilize an ontology to represent ingredients.

In our opinion, for interacting with people, a machine should contain a representation of prototypes that is similar to the prototypes used by users. Our goal was to create realistic prototype representations for the specific, everyday task of arranging objects in a kitchen. To this end, we conducted a study, in which participants had to stow away a set of given objects in a simulated kitchen. From the observations of the study, we calculated categories of objects. These categories represent things that are somehow considered as being similar in the context of the given task. For each category we calculated a prototype from the object properties in the category, thus building an abstracted model of kitchen objects. To test this model we averaged over the similarities of all objects of each category to each prototype.

2 The Kitchen Study

We conducted the study in a kitchen simulation that represents kitchen shelves, drawers and typical kitchen objects. We used a kitchen simulation instead of a mere grouping experiment, because we wanted to simulate some real aspects of a kitchen like having wall cupboards and a stove amongst others. But also having some constraints, e.g. the size of cupboards. Users drag-and-drop 134 objects – frequent objects like cutlery and plates had been multiplied – into the shelves (Fig. 1). The kitchen simulation is a web application but the study was done offline and every participant used the same laptop computer. An investigator was always present, but did not answer any questions except questions regarding the handling of the web application. The goal was to distribute the objects onto the cupboard shelves just as you would do if you were organizing a new kitchen. There was no time limit to the study and each participant received the same written instructions. The 23 participants (12 female), aged between 22 and 65 years (M = 38.7 years, SD = 16.61 years), were recruited among students from the University of Tübingen, acquaintances, family and friends. They received no reward and all gave informed consent.