Cooking an Ontology*

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Abstract. An effective solution to the problem of extending a dialogue system to new knowledge domains requires a clear separation between the knowledge and the system: as ontologies are used to conceptualize information, they can be used as a means to improve the separation between the dialogue system and the domain information. This paper presents the development of an ontology for the cooking domain, to be integrated in a dialog system. The ontology comprehends four main modules covering the key concepts of the cooking domain – actions, food, recipes, and utensils – and three auxiliary modules – units and measures, equivalencies and plate types.

Key words: ontology construction, knowledge representation, dialogue systems, natural language processing

1 Introduction

An effective solution to the problem of extending a dialogue system to new knowledge domains requires a clear separation between the knowledge and the system: as ontologies are used to conceptualize information, they can be used as a means to improve the separation between the dialogue system and the domain information. Having a generic spoken dialogue system able to manage specific devices at home, such as TVs, lamps and windows, a natural step was to extend it to other domains. The cooking domain appeared as an interesting application area since the dialog system was being used in an exhibition called ”The House of the Future”. At that point we had an electronic agent that could answer to voice commands allowing easier control of home devices using only voice. Ontologies are used to conceptualize knowledge. So, if we managed to “teach” the system how to use the ontological knowledge, we would increase independence

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easing the task of adding new domains, since this would be as easy as plugging an appropriate ontology.

The paper is structured as follows: section 2 presents a brief state-of-the-art in ontology engineering; section 3 presents previously developed ontologies that could be used if adequate; section 4 presents our ontology; section 5 details its development process; section 6 describes the work done so far in integrating the ontology in the dialogue system; future work and conclusions complete the paper.

2 State of the art

The work on the ontology field goes back to the beginning of 1990. The first ontologies were built from scratch and made available in order to demonstrate their usefulness. By that time no methodologies or guidelines were available to guide or ease the building process. After some experiences on the field, [1] introduced some principles for the design of ontologies. Gruber's work was the first to describe the role of ontologies in supporting knowledge sharing activities, and presented a set of guidelines for the development of ontologies. The ontology building process became clearer, with the continuous development of several other ontologies. As a consequence, the first methodologies for building ontologies were proposed in 1995, leading to the emergence of the ontological engineering field.

According to [2], three different generations of methodologies can be distinguished. The first generation corresponds to the first attempts on understanding how ontologies could be built. The building process was the main issue, postponing problems, such as maintenance and reuse. Methodologies used in TOVE [3] and ENTERPRISE [4] fit in this first generation. The second generation considers performing specification, conceptualization, integration, and implementation as often as required, during the ontology lifetime. The initial version of METHONTOLOGY [5] belongs to the second generation. The current version of the METHONTOLOGY and OTK [6] can be included in this last generation of methodologies, where topics such as *reusability* and *configuration management*, became activities of the development process. Currently, neither a standard methodology exists, nor a sufficiently mature one was found having a considerable user community.

Recent years have seen a surge of interest in the discovery and automatic creation of complex, multi-relational knowledge structures, as several workshops on the field illustrate. For example, the natural language community is trying to acquire word semantics from natural language texts. A remaining challenge is to evaluate in a quantitative manner how useful or accurate the extracted ontology classes, properties and instances are. This is a central issue as it is currently very hard to compare methods and approaches, due to the lack of a shared understanding of the task at hand and its appropriate metrics.

3 Related ontologies

The motto *ontologies are built to be reused* [5] conveys in an appropriate manner the ideas originally proposed by [1]. Therefore, the first step was to survey existing knowledge sources on the cooking domain and check their adequacy. Of these sources: (a) USDA National Nutrient Database for Standard Reference is a database made by the United Stated Department of Agriculture to be the major source of food composition data in the United States. In its 18^{th} release (SR18) comprehends 7,146 food items and up to 136 food components [7]; (b) AGROVOC is a multi-lingual thesaurus made by the Food and Agriculture Organization of the United Nations (FAO) that has about 17,000 concepts and 3 types of relations (preferred term, related term and broader term) [8]; (c) [9] presents the development of a wine (main focus), food and appropriate combinations of wine with meals ontology; (d) [10] presents a specialized wine ontology that covers maceration, fermentation processes, grape maturity state, wine characteristics, and several classifications according to country and region where the wine was produced; (e) [11] describes an ontology of culinary recipes, developed to be used in a semantic querying system for the Web.

These ontologies did not cover what was intended in our project: some were too specific, focusing on issues like wine (c and d) or nutrients themselves (a), others not deep enough (e), focused (as stated in their objectives) in building a classification – adequate to a specific application – of part of the knowledge we intended to structure.

4 Cooking ontology

The development of the cooking ontology did not follow a specific ontology development methodology, but was strongly influenced by the ideas presented in [12].

In brainstorm meetings the comprehension of the domain evolved to the identification of four key areas of the cooking domain. As this areas are wide and independent enough they were split into modules: (i) actions; (ii) food; (iii) recipes; (iv) kitchen utensils. Also three auxiliary modules were found: units and measures, equivalencies, and plate types. To define the scope of the ontology, informal competency questions were formulated, figure 1. These questions addressed specifically each of the previously identified areas and guided

[recipes]
How do I make recipe *R1*?
What are the quantities to use when making recipe *R1* for 4 persons?

[actions]
How do I do *A1*?

[times]
Which are the recipes that take less than 10 minutes to make?

[food]
Which recipes have food item *F1*, but not *F2*?
Which are the recipes that have as main ingedient food item *F1*?

[utensils]
Which utensils are used in recipe *R1*?
Which recipes can be made using the microwave?

[equivalencies]
How many liters is a cup?

Fig. 1. Competency questions.

the building process. Their satisfaction was continuously evaluated: whenever a new release was made available it was checked if they were being correctly answered.

Figure 2 shows the relations between the main concepts. A Recipe is organized into three Phases: *preparation*, *cooking* and *presentation*. Each Phase is an ordered sequence of Tasks, some of which may be optional. A Task is composed by an Action, its duration time, and incorporates information about *needed* and *produced* Ingredients. Some of the Ingredients of the Tasks are also part of the Phase that uses them (intermediate result Ingredients are not accounted in the Phase concept). The Phase also has a duration (Measure of time Units). Each Recipe has a Classification, a list of Ingredients and required Utensils.

The current version of the cooking ontology has about 1151 classes, 92 slots (of which 52 establish relations between classes) and 311 instances, distributed by the seven modules.

5 Building process

When building the ontology, activities like brainstorm sessions, knowledge validation and disambiguation, conceptualization and formalization, or evaluation, among others, were done along the project by all team members in weekly meetings. Acquisition, conceptualization, and formalization of specific knowledge was divided into the identified areas and assigned to different team members.

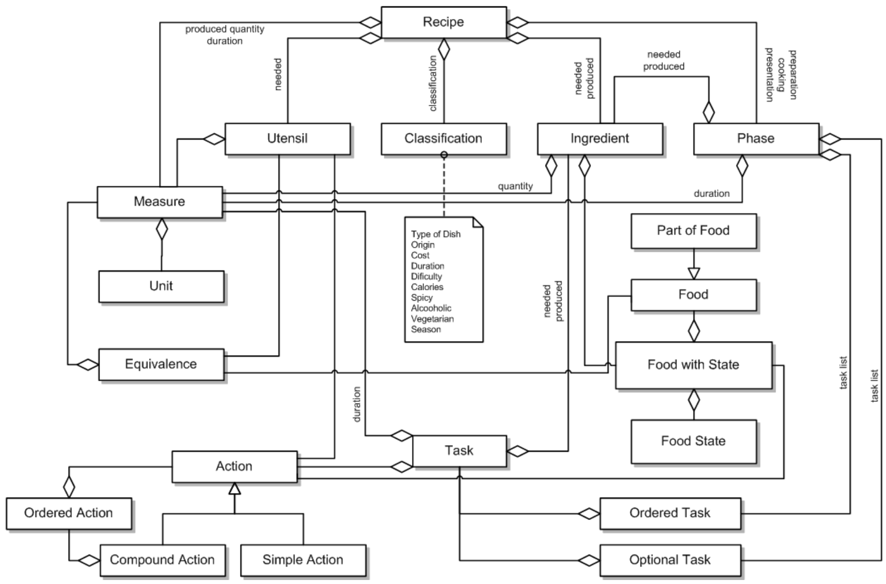

Fig. 2. Main concepts.

The knowledge model was formalized using Protégé [13], which can also be used to automatically generate the ontology code.

The requirements specification was defined from the dialogue system context, the earlier phases of knowledge acquisition, and the competency questions.

5.1 Knowledge acquisition

Knowledge acquisition, the first step of the building process, began with reading and selecting available cooking books. The knowledge sources had different views about the subject, but they all agreed on the separation of concepts. For example, almost every source had a description of the kitchen tools; animal (cow, pork, rabbit, etc.) parts; and fish types. The first step to organize concepts was the knowledge in these sources. Recipes were viewed as algorithms used to define a set of basic actions that later were used to describe Recipe concepts.

5.2 Conceptualization

The main activities in conceptualization were (i) identification of concepts and their properties; (ii) classification of groups of concepts in classification trees; (iii) description of properties; (iv) identification of instances; (v) description of instances. During this phase, discussion and validation sessions were also held to identify the relations between classification trees; initial debates were held to discuss how concepts should be modelled (classes versus instances); and, harmonization of the identified properties (within the several composing modules) and their definitions was performed.

5.3 Formalization

One of the main issues in formalization concerned relations between concepts. As it was described before, several concepts (for example, Food and Utensils) entail own hierarchies. Concepts within these hierarchies were associated through IS-A relations. Attribute-based relations were used to associate concepts from the several hierarchies and the other concepts (such as Task and Recipe). For example, a recipe uses utensils and that is stated as a slot in the Recipe class.

Another key issue in formalization was to decide if each concept should be formalized as a class or instance. Several discussions and experiments were needed to understand the best way to formalize the concepts and their relations. Here the main complexity arose from the needed global coherence as the knowledge formalization must be capable of describing a Recipe and all its related information.

Some concepts were formalized as classes and their instances use the defined hierarchies as taxonomies (the values of the attributes are of class type). For example, a Recipe has several attributes of this kind.

Food and Utensil concepts were formalized as classes. Food (abstract) classes will have no instances as they are used as a taxonomy to characterize Ingredient instances. Utensil instances depend on the usage of the ontology. For example, considering the context of a dialog system (like the one described earlier), Utensil instances would be the real utensils that the user can operate. Actions were formalized using classes and instances: classes to arrange the hierarchy and instances to describe the leaves of the classification tree.

5.4 Evaluation

Two types of evaluation were performed, neither using a standard methodology like OntoClean [14], nor [15]: an internal evaluation performed by the whole team during the ontology life cycle, and an external evaluation performed by the client. The client supervised the releases mainly by asking the defined competency questions and checking whether the ontology could answer them. Since no inference is available at the moment, all verifications were done by checking whether the information was available and if the right relations existed. In later stages, this checking can be done automatically by using an inference engine.

6 Integration in a dialogue system

Some work has already been done that showed the advantages of using ontologies to enrich spoken dialogue systems with domain knowledge [16, 17].

As the motivation for this project was extending an existing spoken dialogue system [18], the next step is to use the resulting ontology to enrich it.

The current version of the ontology is useful and usable in that context. Some preliminary tests have been made to allow the autonomous agent to start helping in kitchen tasks. The current version of the system takes a list of recipes, asks the user which one he wants to hear and reads it to the user.

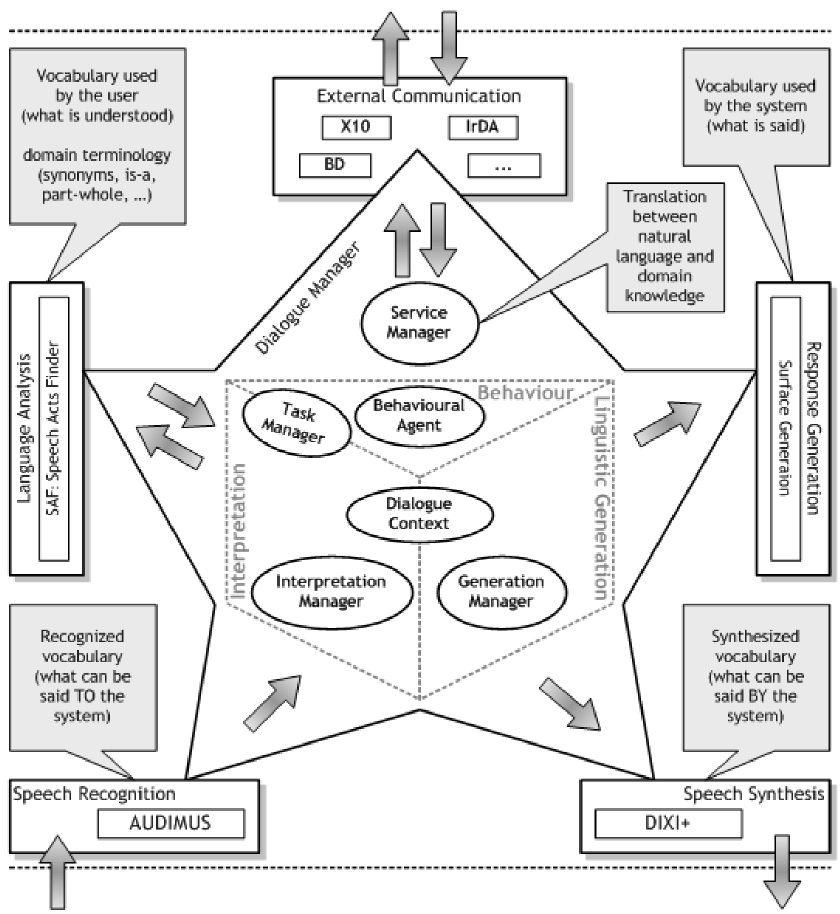

Fig. 3. STAR architecture.

Figure 3 shows the main architecture of our system. The system has six main modules: speech recognition, language analysis, external communication, response generation, speech synthesis and – at the centre, communicating with all the others – a dialogue manager. For each of the modules, a gray box shows the domain knowledge that can be used to produce better results. In the middle, the components of the dialogue manager are presented: interpretation manager, dialogue context, task manager, behavioural agent, service manager and generation manager. This modules are responsible for the interpretation, the behaviour and the linguistic generation.

When the user says something, speech recognition needs to know the words related to the domain to add them to the language model. After the speech is transformed into text, the meaning of what was said depends on the dialogue context (what has been said before) and on the knowledge domain. For instance, the taxonomical knowledge allows a smarter reasoning and a better dialogue sequence. After understanding what has been said, it is necessry to translate that into the external systems language. Once again, this knowledge can be arranged in a Ontology. After the execution of the user's commands, a response is produced to inform on the results. The naturality of the system depends on the chosen vocabulary. For instance, the usage of synonims in the communication. Also when there is the need of some clarification, the sequence of the questions can be enhanced if the questions are produced ordered by their relatedness.

The ontology gathers all the knowledge that currently is spread through the modules of the system. This is an advantage as all the knowledge information will be concentrated in the same module, the ontology. Presently, is already necessary to collect the knowledge when integrating a new domain. Using an ontology, instead of splitting that knowledge into the relevant modules, turns it pluggable (plug-and-play).

Our dialogue system has an architecture similar to the well known used by TRIPS [19]. It will be interesting to explore how the knowledge stored in an ontology can be used automatically and dynamically by a dialogue system. For example, the words that name the concepts can be used to collect the related vocabulary. The usage of a spread architecture eases the transference of this technique to similar systems.

7 Future Work

Apart from adding new concepts, sharing, reusing, maintaining and evolving, which are important issues for the future, each module has its own characteristics that can be improved.

In the food module, an interesting possibility is to add new food classifications based on different criteria. For example, a flavour based classification or one based on the nutrition pyramid would increment the information level about food items. The observation of a large set of important characteristics of kitchen utensils suggests that additional information can be added to each concept, either in the scope of the documentation, or in the set of defined properties. An improvement to the actions module could be the integration of a process ontology to define complex actions and recipes. Such restructuring should be carefully thought, since the benefits may be outweighed by the difficulties.

In the future, when using the ontology in our Dialogue System, the application could include a personalized configuration to specify the real utensils that the user has at home as Utensils instances. In that case, when referring to the objects the system could even refer the place, for example the drawer, where they are stored. User adaptation could focus on issues – with different impacts on the work done – like the following: kind of dish could be extended to take some cultural differences into consideration – *Pasta* is eaten before the main dish (as an appetizer) by Italians while Portuguese people eat it as a main dish or even as companion for the meat or fish –; the origin of plates could be connected to a Geographical Ontology in order to allow inference on geographical proximity; and, the Season of the year when a meal is more adequate could lead to a new module to be used replacing the current discrete values.

8 Conclusions

The aim for this work consisted on developing an ontology on the cooking domain, in order to be integrated in a dialog system. The resulting ontology covers four main areas of the domain knowledge: food, kitchen utensils, actions and recipes. Food, utensils and actions areas of knowledge are formalized as class hierarchies with instances (in what concerns actions), covering in a considerable extent – at least, accordingly to the used information sources – the target domain. Recipes concepts interconnect concepts from all the other areas, in order to define an adequate model of the cooking domain. Two instances of Recipe were created to demonstrate the usability of the developed specification.

The ontology building process was strongly influenced by METHONTOLOGY and the phases of specification, knowledge acquisition, conceptualization, implementation and evaluation were essential to achieve the intended result.

Despite the problems found, the ontology reached a usable state. All concepts were structured and well documented. The integration with the dialogue system is work in progress and only preliminary tests were conducted, since that effort is part of an on going PhD thesis project.

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