Using an Ontology Conceptualisation Method to Capture an Advice Giving System's Knowledge

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Abstract. In order to produce effective advisory messages, knowledge coming from different research fields has to be reconciled. Domain knowledge is only part of what is needed: sociological theories of behaviour change are of great help, and, as the messages have to be conveyed with some wording, argumentation theories are definitely crucial. The issue of integrating diverse knowledge representations is among those which have been raised in recent years by researchers in Ontological Engineering, and various methodologies to help conceptualising knowledge have been suggested by a number of research groups. In this paper we take advantage from this community experience, and apply one of the methodologies proposed to the design of an advice giving system which uses argumentation techniques to produce counselling messages in the nutrition education domain.

1 Introduction

Advice is a message "given or offered as an opinion or recommendation about future action or behaviour" [17]. The effectiveness of advice may depend on many factors: a good adviser has of course to be conversant with the domain of discussion, but other, not necessarily factual knowledge is also important. As advice is mainly aimed at promoting a particular behaviour/attitude, a good adviser should be aware of which mechanisms make people change. Moreover, the choice of words, the tactic to use to present opinions, or in other words the argumentation technique to employ may change dramatically the impact of the advice. When trying to create computer systems able to replicate an adviser ability, all these factors have to be taken into account.

We will describe in this paper our experiences in designing a system able to produce counselling messages about healthy nutrition. We will focus here on a particular aspect of the system's design, namely the conceptualisation of its knowledge. We will ignore then architectural and strategic components of the system, together with implementation details, which are described elsewhere [5].

In order to build such a system, we needed to reconcile all the different sources of knowledge mentioned above, in a coherent and harmonised knowledge base. The combination of different representations of various aspects of the reality is among the issues the Ontology Engineering community has been studying in recent years. The aims are diverse, the most important of which is perhaps to build knowledge that can be re-used. Many researchers in this community have proposed several methodologies, both to build and to integrate knowledge. In designing the knowledge base of our adviser, we therefore thought it wise to take advantage of this experience, and we used one of these methodologies as a guideline.

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In this paper we present such exercise, with a twofold purpose: on one hand we suggest that in order to build effective advice giving systems we need more than just domain knowledge, and we propose our solution to this problem. On the other hand we provide the researchers in ontology issues with a case study, in which methodologies are put into practice by different researchers, and in a different scenario from the one the methodology was designed for. This would, hopefully, help to give more insight into the formalisation of such methodologies.

2 Advice Giving to Improve Dietary Habits

Recent studies have stressed the importance of promoting healthy dietary habits in order to decrease the incidence of illnesses such as cardiovascular disease or cancer [2, 19]. However, studies have also shown that many factors, other than just the knowledge of the consequences of a poor diet, influence people's behaviour, and that stereotypes and folk beliefs are sometimes difficult to eradicate, making the activity of health promotion similar to advertisement [4].

Computer systems aimed at carrying on some educational or promotional campaign should take this aspect into account: too often the expertise of such systems is based only on the domain knowledge, sometimes augmented by linguistic knowledge to produce more fluent messages (a notable exception is [14]).

The system of which we present some aspects here, tries to bridge this gap, being "armed" with notions of a health promotion and behavioural change theory, coupled with a well established theory of informal argumentation. In this section we will briefly introduce these theories, well aware that a full appreciation of them would require much more space.

2.1 Behavioural Change Theory

The system's behavioural change knowledge is based on a theoretical model which is widely used in health research, the transtheoretical model of change, or **Stages of Change Model** (SCM) [13]. The SCM suggests that individuals progress through very distinct stages on their way to change their behaviour. In a first *precontemplation* stage, people see no problem with their behaviour and have no intention of changing it. People in the *contemplation* stage come to understand their problem, and start thinking about solving it, but have no immediate plans. In a following *preparation* stage, people are planning to take an action in the immediate future, and have already made some small changes in this direction. The *action* stage characterises people who are actually in the process of actively making behaviour changes. Empirical studies and theoretical research have shown that interventions based on the SCM tend to be more successful [15], and

have also provided a set of guidelines to help people progress from stage to stage, by also exploiting people's health beliefs [1] about susceptibility to certain negative or positive situations. The SCM has also already attracted AI researchers' interest, see for example [14].

2.2 Argumentation Theory

It is essential for an advice giving system to be equipped with a good argumentative ability. However, we were much more interested in having a system capable of producing "effective" arguments, rather than "sound" arguments (two properties that are not always related in real life). This requirement excluded some models of argumentation, such as [18], concerned primarily with the basic structure of arguments, and not how the detailed content of such arguments can be selected. It also excluded discourse organization theories, such as RST [11], which, while useful and successfully applied in text generation in general, say very little about how to generate persuasive arguments.

We based the system argumentative ability on the New Rhetoric [12], a well established theory of *informal* argumentation. Such theory, rather than defining an a priori "logic of value judgments", investigates how humans argue, by collecting and classifying arguments that are successful in practice in a series of schemas, according to different categories (a few examples are given in Fig. 1):

1. *Quasi-logical argumentation*, using an exposition structure which resembles a logical or a mathematical proof (e.g. argumentation by incompatibility).
2. *Argumentation based on the structure of the reality*, based on how the audience perceives the reality (e.g. pragmatic argumentation, or argumentation by ends and means).
3. *Argumentation establishing the structure of the reality*: presenting a relation which is not already known or evident to the audience. This can be done, for instance, by an example (*Fruit is very sweet: consider pineapples*), or by appealing to a model.
4. *Argumentation by dissociation*, introducing a division into a concept that the audience considered as a whole. For example: *You said that people who are concerned about diet are self-centred, but I prefer to consider them just responsible persons*.

Central to the theory is the notion of *audience* (the same argument may have different effects on different people) and of *values*, or preferences of a particular audience, as opposed to facts.

3 Building an Adviser Knowledge: an Ontological Engineering Approach

Our model of adviser needed to reason about values and opinions, as well as facts of the domain, to handle the concepts in the New Rhetoric theory, the concepts specific to the health promotion model we use, and basic nutrition information. We used an ontological approach to integrate the three categories of expertise [21].

Although an ancient concept in philosophy, ontology study has only relatively recently become an explicit trend in the Knowledge Representation community (see for example [9]). The ontology approach to the construction of a knowledge base is especially useful to solve problems arising when knowledge is provided by different sources (people, systems etc.). In the present case study, the different sources correspond to the different theories (nutrition, behaviour change, argumentation) that needed to be represented.

Schemas	Description	Example
Incompatibility	X and Y cannot coexist	You can either go out with your friends or see me tonight.
Pragmatic	Y is a consequence of act X	Eating less fat helps lowering cholesterol levels.
Ends/Means	X is a means to Y	Competition would let the prices fall.
(Anti) Model	X is a person (not) to imitate	Italians know everything about healthy eating.

Figure 1. Examples of New Rhetoric's schemas

Despite the importance, and the historical character of ontological issues, very few methodologies have been proposed to guide the ontology conceptualisation process, and research in this field still has to agree on a standard approach [3, 10].

In this work we use the methodology proposed in [20], whose stage approach was felt to be more appropriate to our purposes. The stages proposed by [20], as used also in [7] to build an enterprise ontology, are as follows:

1. capturing the motivating scenarios (story problems or examples);
2. formulating informal competency questions (queries the ontology must be able to represent);
3. specifying terminology of the ontology within a formal language;
4. formulating the competency questions in the formal terminology;
5. specifying axioms and definitions for the terms in the ontology within the formal language;
6. justifying axioms and definitions by proving characterisation problems.

In the next section we will show how we interpreted these guidelines for our purposes.

4 Designing the Adviser Ontology

4.1 Capturing Motivating Scenarios

A series of experiments were conducted, with the aim of collecting a corpus of "real" conversations to analyse, primarily in order to prove the appropriateness of the theories involved to the case of study. The same corpus was also used as a source for realistic "motivating scenarios". The experiments were conducted via e-mail: a group of nutritionists and a group of users were contacted, who agreed to take part to a series of e-mail exchanges on the subject of dietary habits. In the e-mails with the nutritionists, the experimenters took the role of subjects in search for advice. In those with the users, the experimenters took the role of the adviser. The experiment lasted a month, involving 51 participants, of which 5 nutritionists, with more than 500 e-mail messages exchanged overall. Fig. 2 gives an excerpt of a dialogue, as an example.

The corpus was analysed with the objective of finding further support for the use of the theories we chose in giving advice on diet. But we also considered the dialogues as typical situations, scenarios, that we wanted to be able to replicate in our system.

4.2 Informal Competency Questions

On the basis of the motivating scenarios, some informal competency questions (ICQ) could be formulated. As suggested in [20], ICQs were defined in a *stratified manner*, in terms of higher level questions

Adviser: *you don't like fruit, do you?*

Advisee: *I enjoy eating fruit in summer. I like bananas, melon, figs, mango, pears, apples, nectarines, peaches, apricots. I drink fresh orange juice each morning (freshly squeezed) and I eat a banana halfway through the morning as a snack (when I remember to bring one to work!).*
So I have to disagree with you in your assumption. I do like fruit its that I don't eat much of it which is slightly different.

Adviser: *So why you don't eat much of it?*

Advisee: *I do eat lots of fruit in summer because I find it is refreshing. I don't eat lots of fruit in winter because: (1) it is harder to get organic fruit in winter, (2) there is not much variety of what you can buy and (3) the cost is quite high.*

Figure 2. Example of Motivating Scenario

and of the lower level questions needed to solve them. For each ICQ, a schema was filled in, consisting of the following slots:

ICQ number: a progressive number to identify the question.
Question: an expression in natural language of the question.
Rationale: the reason why such a question is needed. This may either refer to another ICQ, to answer which this question is needed, or to an excerpt of a motivating scenario, or to a New Rhetoric schema which the question is meant to implement.
Decomposition: what is needed to know in order to answer the question.

For example:

ICQ number:	10
Question:	Is there an argument by Incompatibility in favour of an action A?
Rationale:	Solve ICQ 2 and implementation of New Rhetoric schema 5.
Decomposition:	One of the following: 1. Action A leads to a state S, and there is an argument by Incompatibility in favour of S. 2. There is an action A_1, which is unvaluable, and A and A_1 are not compatible

As the main purpose of the adviser is to provide opinions, that is to argue for or against some topic, most of the ICQ were originated by an analysis of the corpus in the light of appropriate New Rhetoric schemas. A total of 61 ICQs were identified, forming the basis for the restriction of the New Rhetoric theory and the SCM that the system was going to implement.

4.3 Informal Specification of the Terminology

We needed to represent mainly two types of knowledge.

A **knowledge describing behavioural changes** was needed, for representing the stages of change and the beliefs about health. Having as basic concepts *actions* (e.g. "eating fruit"), *states* (e.g. "having high cholesterol values") and *persons*, we wanted to express that:

- an *action* can(not) {*achieve/maintain/favour/strengthen*} a *state*;
- a *person* can be {*susceptible/unsusceptible*} to a *state*;
- a *person* can be {*Precontemplator/Contemplator/InPreparation/Active*} towards an *action*.

A **knowledge for representing arguments** was also needed, and especially a way to express the fact that a topic is "valuable", at least from a certain perspective. We wanted to express sentences like: *EatingFruit can be seen from the Health perspective*, *Cancer is Bad from the Health perspective*, or even that *the fact that EatingFruit can Prevent Cancer is Good from the Health perspective*. Therefore, with basic concepts *topics*, *values* (Good/Bad/Indifferent) and *perspectives* (e.g. QualityOfLife, Health) we wanted to be able to express that:

- a *topic* can be considered from a certain *perspective*;
- a *topic* can have a *value* from a certain *perspective*;
- a triple {*topic, perspective, value*} can be more valuable than another triple {*topic, perspective, value*};
- a *perspective* can be more valuable than another *perspective*;
- a *perspective* can be more general than another *perspective*.

Less crucial to our study, but necessary for the adviser, two other subontologies are needed, for representing **knowledge about states and actions**, and, or course, for representing our domain, that is **knowledge about nutrition**.

4.4 Specification of the Formal Terminology

The above requirements led to the construction of the adviser cognitive ontology, whose specification is conveyed by an Object Oriented representations of concepts and relationships in Figg. 3 and 4[2].

Central to the **argumentation ontology** (Fig. 3, top) is the concept of *Opinion*. An opinion exists whenever an association can be made between a given topic and a certain perspective, with an evaluation (Good/Bad/Indifferent). An important restriction we introduced was to constrain the attribution of a value to a topic to be made via a perspective: in this view, for example, having high cholesterol values is not good or bad *per se*, but it is good/bad, say, from the health perspective. This, we believe, facilitates a more natural style of argumentation, in which the same topic can have simultaneously good and bad values with respect to different points of view. Essential element in describing an opinion is the specification of who holds it: the spirit of our adviser is that there are no incontrovertible truths, and each opinion is related to somebody. *People* can be either single individuals (*Pavarotti*) or groups (*Italians*), and various relations may hold between people in general and perspectives, in order to be able to express arguments by model/antimodel, by authority etc.

The **behavioural ontology** (Fig. 3, middle) expresses concepts from the Stages of Change model, plus health beliefs about a person's susceptibility to a state.

The **state/action upper ontology** (Fig. 3, bottom) expresses the high level concepts of act and state, and the relationships among them, defined as:

- **Behaviours**: with this class we wanted to express the notion of undertaking an act for a certain purpose, and the type of this implication is characterised by a Modifier (achieve, favour, maintain, strengthen) with a Sign. Therefore we can say that eating fruit helps slimming by using a modifier with Type = "Favour" and Sign = "+".
- **Circumstances**: with this class we wanted to express the notion of two states being related. The same class of modifiers is used to connect an *initial* state and a *final* state, so that we can say that "having high cholesterol levels does not favour being healthy".

Ontologies describing states and actions, and food/meal properties, have been developed by many projects, which should be possible to

[2] The notation for the OO representation is the one in [16].

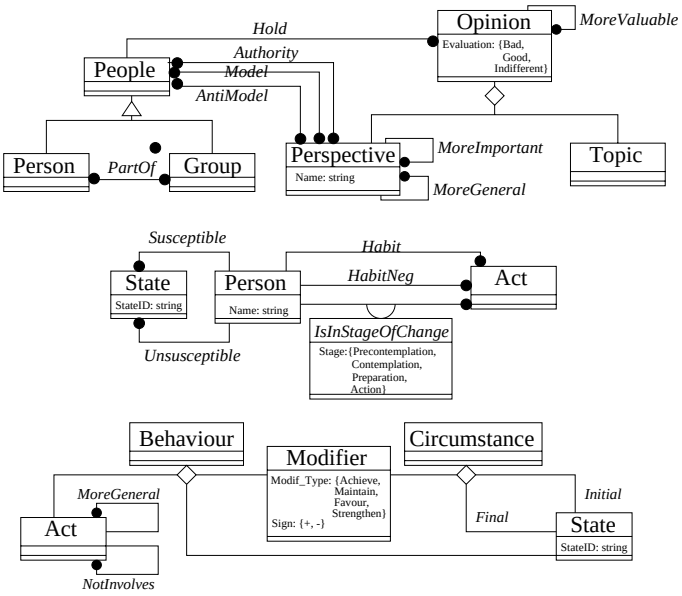

Figure 3. Sub-Ontologies

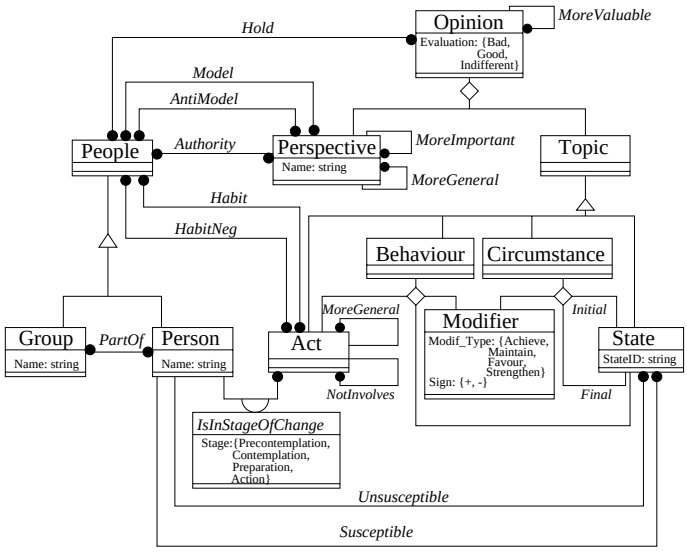

Figure 4. Adviser Integrated Cognitive Ontology

"plug-in" our system, especially if developed according to Gruber's principle of *minimal ontological commitment* ("an ontology should make as few claims as possible about the world being modelled to allow the agents committed to the ontology freedom to specialize and instantiate the ontology as needed" [6]). We have not explored in detail this possibility, preferring to leave our first prototype of adviser with a somewhat naive notion of states, actions and food (as suggested by the scenarios analysis). We believe, however, that the requirements we have expressed, derived by the analysis of the motivating scenario and the theories, will help choose a prospective ontology that could be safely embedded in our system.

After constructing all sub-ontologies, an analysis of the classes introduced, on the basis of the competency questions they help to solve, identified the common concepts and favoured the creation of the **main adviser ontology**. Figure 4 shows how the various sub-ontologies are related to one another, and in particular the fact that opinions can be expressed on one of the following topics:

- Acts (e.g. "eating fruit is good from the health perspective");
- States (e.g. "having high cholesterol values is bad from the health perspective");
- Behaviours (e.g. "the fact that eating fruit favours lowering cholesterol levels is good from the health perspective");
- Circumstances (e.g. "the fact having high cholesterol levels does not favour being healthy is bad from the health perspective");

This admittedly cumbersome attribution of values helps implementing the mechanism of "value passing" the New Rhetoric entails. For example, the claim "eating chips increases cholesterol levels" will be perceived as having a negative valence if and only if the audience attributes a bad value to high cholesterol levels, from at least one perspective (typically "health"). The bad value is then hopefully passed to eating chips, which favours it. The adviser may assume that this will happen when presenting such an argument (on the basis of a belief model of the audience) but it may well be that the audience sees no relation between having high cholesterol values and being healthy, thus making the argument against eating chips fail.

4.5 Formal Competency Questions

Here follows, as an example, the representations in Horn clauses of some of the ICQs we identified. Note that the parameters in the form $?x$ represent variables and those in the form $!X$ represent constants.

1. We can argue in favour/against of a topic if there exists a perspective from which such topic has a Good/Bad value:
   - $HasVal(?topic) \subset Perspectives(?p), Opinion(?topic, ?p, !Good)$
   - $HasValNeg(?topic) \subset Perspectives(?p), Opinion(?topic, ?p, !Bad)$
2. A state or an action leads to a state of affair if the state or the action achieves (or favours, maintains or strengthens) such state:
   - $ModifierPos(?x, ?y) \subset Achieve(?x, ?y, !+)$
3. We can use an argumentation by authority in favour a topic if there exists an authority who has a good opinion on such topic:
   - $HasAuth(?topic, ?perspective) \subset People(?authority), Authority(?authority, ?perspective), Hold(?authority, Opinion(?topic, ?perspective, !Good))$
4. We can use an argumentation by model in favour/against an action if there exists a model who has/has not such action as a habit:
   - $HasModel(?action, ?perspective) \subset Action(?action), People(?model), Model(?model, ?perspective), Habit(?model, ?action)$

   Note that whether an instance of People is a model (or an authority) from a certain perspective depends on assumptions in the model the adviser has of the beliefs of the audience.

All other informal competency questions were solved similarly, by establishing appropriate relations among predicates.

4.6 Axioms Specification

The main effort of an arguer, from the New Rhetoric perspective, is to operate on the audience's values and let them pass from one topic to another, in the hope to make the latter more acceptable. The central

set of axioms we need, therefore, is aimed at establishing how such "value passing" occurs, for example:

- $HasVal(?topic, ?perspective) \subset HasAuth(?topic, ?perspective)$
- $HasVal(?state, ?perspective) \subset State(?state_2), LeadsTo(?state, ?state_2), HasVal(?state_2, ?perspective)$
- $HasVal(?action, ?perspective) \subset State(?state), Prevent(?action, ?state), HasValNeg(?state, ?perspective)$

To express the above axioms we also need a set of axioms to relate chains of states to a state or to an action, for example:

- $LeadsTo(?state_1, ?state_2) \subset ModifierPos(?state_1, ?state_2)$
- $LeadsTo(?state_1, ?state_2) \subset State(?state_3), ModifierPos(?state_1, ?state_3), LeadsTo(?state_3, ?state_2)$

These two sets of axioms enable to create chains of arguments which can be presented to the advisee within one of the New Rhetoric schemas.

4.7 Problem Solving

The reasoning unit of the system consists of a problem solver, coupled with a reason maintenance system to help dealing with potentially withdrawable information. The problem solver is based on a clausal form logic restricted to Horn clauses.

The particular form used for expressing values allows the system to conceive worlds in which there can be mixed feelings about a topic, without the world being inconsistent. For example: *HasVal(!EatingFruit, !SocialLife)* and *HasValNeg(!EatingFruit, !SocialLife)* and are not considered as opposite (nor related) so both can be held by the same agent at the same time, each with its own justifications, whose track is kept by the reason maintenance system.

5 Conclusions

The implementation of an effective, believable advice giving system requires expertise from different fields. In particular, a good adviser must be able to construct efficacious, which may not necessarily mean sound, arguments. Appeal should be made to well established theories, both in behavioural change and in argumentation studies. In order to reconcile these different sources of knowledge, an ontology engineering approach can be useful. In this paper this exercise has been presented, aimed at conceptualising the knowledge of an advice giving system in the nutrition education domain.

The use of explicit guidelines, coming from an ontology conceptualisation methodology, has proved to significantly help in focusing our effort. Although useful for providing a general protocol of actions and deliverables, when addressing the single stages of the process, however, the methodology was not detailed enough to give sufficient advice. From the point of view of mere "users" of the methodology, we would have been helped, for example, by some more guidelines on how to collect and organise motivating scenarios, and how to use them to generate informal competency questions. In fact, we found that the early stages the methodology suggests, the ones we were most interested in, were not discussed in sufficient detail: we had to define our own protocol for collecting and classifying competency questions, as no clue was provided by the methodology, and decide a policy for establishing which aspects of the competency questions were needed to be considered when defining the basic concepts of the ontology.

As pointed out in [10], no methodology has so far addressed the problem of how to identify ontological concepts, and we also suspect that such identification depends strongly on the theories that the ontology needs to account for: we wonder whether our conceptualisation would have been different had we used a different behavioural or argumentation theory, even with the same corpus of motivating scenario as a starting point. This, we believe, does not depend so much on having a functional notion of the knowledge, but rather on seeing "the nature of the real world" from a different point of view. We agree with [8] that the most interesting issues are at the highest levels of the conceptualisation process, and research on these aspects should benefit from the intervention of many and diverse disciplines.

We hope that our exercise may be of some help, as a case study, to researchers addressing ontological issues, believing with [10] that more of these efforts are needed, so that an ontology engineering practice may be established, based on the experience of as many projects as possible.

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