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Who's that? - Modelling Social Situations for Behaviour Support Agents*

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Abstract. Behaviour support agents need to be aware of the social environment of the user in order to be able to provide comprehensive support. However, this is a feature that is currently lacking in existing systems. To tackle it, first of all we explore literature from social sciences in order to find which elements of the social environment need to be represented. We structure this knowledge as a two-level ontology that models social situations. It consists of an upper level which contains general elements of social situations, and a lower level which describes domain-specific features. We formalize the elements that are needed to model social situations, which consist of different types of meetings between two people. We conduct a pilot experiment to evaluate our knowledge structure using feedback from the subjects, and to test whether we can use the data to reason about the priority of different situations. Subjects found our proposed features of social relationships to be understandable and representative. Furthermore, we show these features can be combined in a decision tree to predict the priority of social situations.

Keywords: Socially aware agents · Social situation modelling · Knowledge representation

1 Introduction

Applications that help users live healthier lifestyles or form desired habits are spreading rapidly. However, they focus only on modelling the user, and they lack the tools to model the environment surrounding the user. For instance, an app that helps its user be more punctual will send reminders at different intervals when it sees that a meeting is approaching. However, not all meetings have the same priority: for most people, being on time for a job interview is more important than being on time for an informal dinner with friends. Therefore, help has to be situational. Behaviour support agents need information about *what is going on around the user* in order to provide comprehensive support.

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In this work we focus on modelling the social environment of the user for behaviour support agents. To do this, we will use the concept of *situations*. What key elements should be modelled and perceived in order to capture the social essence of a situation? Our research on social science literature reveals a set of variables for representing the relationship of the user with another person, as well as a set of variables for representing situation cues. We organise this information in a two-level ontology: an upper one involving general concepts needed to model situations, and a lower one with more specific domain-related features. In this work we limit ourselves with offering a set of elements of the environment that have to be represented and reason on it, and do not focus on how this information is acquired.

To evaluate our approach, we conduct a pilot study where subjects provide information about their relationship with people in their social circle, and then answer some questions about potential situations involving these people. These situations are daily life meetings such as: “You have a weekly work meeting with your colleague”. The purpose of the pilot study is two-fold: we evaluate our proposed procedure and test whether the methods that we plan to use can yield good results. More specifically, firstly we get feedback from the subjects on our proposed relationship features - results suggest that subjects have a high level of agreement with our proposed features. Secondly, we test whether we can use these features to predict the priority of different situations using decision trees - results show this is indeed the case, which means our proposed knowledge structure can be used to infer meaning about situations. The accuracy of the predictions will be tested in a full fledged study. The usage of pilot studies to evaluate both procedures and methods is customary in medical research [27].

The rest of the paper is structured as following: Section 2 gives relevant background information. In Section 3, we discuss related work and position our approach. Section 4 introduces our proposed knowledge structure and offers a formalisation of the features needed to model the social environment. In Section 5, we present our pilot experiment and discuss the results. Section 6 shows how we can use decision trees to predict priorities of events based on data from subjects. Section 7 concludes the paper.

2 Background

The theoretical foundations of our approach are based on one hand on social sciences literature related to situations and social relations, and on the other hand on the concept of decision trees as a reasoning tool. These concepts are introduced in the following subsections. The reviewed literature is non-exhaustive, and we do not aim at providing a comprehensive overview of the fields. We focus on literature related to daily life situations and aspects of social relations which are relevant for these situations.

2.1 Features of the Situation

Rauthmann and colleagues [24] propose that features of situations can be discussed in three different levels: *cues*, which are physical and objective elements (who is present, what activity is taking place, etc.), *psychological characteristics*, which are dimensions that can be used to describe situations (such as duty, intellect, etc.), as well as *classes*, which are abstract types of situations (such as social situations, work situations, etc.). For the scope of this work, we will focus on situation cues and classes, since these are concrete concepts that can be elicited from the user. Psychological characteristics, and how to automatically infer them, will be explored in future work.

Rauthmann et al. [24] divide situation cues in three categories: persons, events/activities, and locations. Saucier et al. [26] identify similar categories in an experiment in which students describe their daily situations, namely locations, associations (i.e. people/interactions), as well as actions and positions. [23] focuses instead on building situation classes based on reports from subjects. Most of the subjects' daily situations were clustered as *work situations*, *family situations*, *friends/recreation situations* and *private recreation situations*.

2.2 Features of Social Relationships

Social relations can be studied from different points of view, and in this section we review literature which considers numerous aspects of relationships. Based on this, we will select the features of social relationships that need to be modelled.

Kahn and Antonucci [17] explore the role of social relations as a form of support for (elderly) people. The support system is conceptualized as a Convoy model - three concentric circles representing three levels of closeness. Different aspects of the relationship are considered in order to establish someone's position within the convoy model, such as: *quality* (e.g., positive, negative), *contact frequency* (e.g., irregular, yearly, monthly, etc.), *geographic proximity* (e.g., closer or more far than a 1 hour driving), *range* (number of life domains included in the interaction), etc. [17, 2].

Social relations are also considered from the organizational point of view. Mainela [20] gives an overview of types and functions of social relationships that can be relevant in the organization of a joint venture. For example, Granovetter [15, 14] talk about strong ties and weak ties in work relationships. The strength of a tie in a network depends on the amount of *time spent on it*, the *emotional intensity*, the *intimacy*, and the *reciprocity*. Furthermore, the author argues that ties are stronger when the *level of acquaintance* is deeper. In a similar manner, Uzzi [29] talks about arm's-length ties and embedded ties. The former, similarly to weak ties, lack reciprocity and repeatedness, and concern narrow economic matters. The latter are characterized by trust, reciprocity, exchange of tacit knowledge, etc. Coleman [8] and Ring and Van de Ven [25] talk about role relationships and personal relationships. Lastly, another feature of social relationships in an organizational context the *hierarchy level* between the individuals [30].

2.3 Reasoning about Situations

In order to evaluate whether our proposed knowledge structure can be useful in practice, we will explore how to use its elements in order to reason about the priority level of situations. Different strategies can be used to reason about the priority of an event. The most straightforward approach would be to combine the situation cues in an Expected Priority (EP) function, such as:

$$EP = \sum_{c \in \mathcal{C}} w_c v_c$$

where $\mathcal{C}$ is the set of all cues considered, and where for all $c \in \mathcal{C}$, v_c refers to the cue value and w_c to the relative weight of cue c in this computation. However, there are two main issues with this approach. First of all, most of the cues that we are dealing with have nominal values, so quantifying them is difficult. Furthermore, based on the literature on preference profiles, see e.g., [4], in many decision situations, we hypothesize the weight values to be dependent on the individual, making the correct initialization of the weight values a challenge.

Another option is to use decision trees (e.g., [5]). Literature suggests that the structure of decision trees is appropriate for reasoning about social relations. First of all, cognitive psychology proposes that social intelligence can have a modular nature [13]. This means different "scripts" are activated in different settings. People recognize these settings from environmental cues, and in turn decide to behave in a certain way. This is similar to the concept of decision trees, in which different combinations of cues lead to different decisions. Endsley also suggests that people use different "schemata" to organize and combine knowledge and perceptions in order to comprehend the situation [10]. An additional argument in their favour is that the decision process of decision trees is predictable and transparent. This would allow the agent to *explain* to the user why a certain priority level is assigned to a specific event.

Decision trees are graphical representations of a set of rules which can be used to make classifications. Each node of the tree represents a question regarding certain features of the object that is being classified, and each branch represents a different answer to that question. Nodes below a given node either contain another question, or are given a *label* which assigns a class to the object. The latter are called *leaf-nodes*. Given an object with a set of features and a decision tree, in order to classify the object we traverse the tree until we reach a leaf. The question remains how to build decision trees which accurately classify data. A common approach is to *learn* the tree models based on a set of data, and then use it to classify new instances. One of the most used methods because of its high accuracy is the Classification and Regression Trees algorithm ($CART$) [5].

CART models are binary trees, which means for every parent node there are two child nodes. Learning a CART model involves selecting features and split points on those features until a suitable tree is constructed. This selection is performed by using a greedy algorithm which minimizes a cost function. For classification tasks, CART uses the Gini index as a cost function. This measure is an indication of how "pure" the nodes are (i.e., how mixed the training data assigned to each node is). The Gini index for a set of objects with N classes, suppose $i \in \{1, 2, \ldots, N\}$, is computed as:

$$G = \sum_{i=1}^{N} p_i(1 - p_i)$$

where G is the Gini index over all classes and p_i is the proportion of objects which are part class i. A node in which all objects are of the same class (perfect purity) would have $G = 0$. For every node, CART selects features that maximize the purity of the split. The procedure continues until a certain stopping criterion.

3 Related Work

Context and situations are well studied concepts in computer science. In this section, we introduce approaches that have been used to model arbitrary situations from peoples' lives, and position our work in relation to them.

Kokar and colleagues [18] present a formalization of situations based on the situation theory developed by Barwise [3] and extended by Devlin [9]. This formalization is compatible with the interpretation of situation awareness in terms of human awareness provided by Endsley [11]. According to the assumption by Barwise [3], situations are simply limited parts of the world perceived by people. The main elements of situation theory are *objects* and *types*. Some of the basic types are **IND**, representing the type of individuals, $\mathbf{REL}^n$, representing n-place relations, **SIT**, representing the types of situations, etc. The basic information about a situation is expressed by *infons*, written as: `<<R,`a_1`,...,`a_n`,0/1>>` where R is an arbitrary n-place relation, $a_1, ..., a_n$ are *objects* appropriate for R, and 0/1 is the *polarity* of the infon, showing whether the relation holds for those objects or not. For instance, the infon `<<chases, dog, cat, 1>>` would express that the relation `chases(dog, cat)` holds. Kola and colleagues [19] provide an extension of this ontology with relations that support modelling social relationships. We believe that explicitly modelling people and relations is something useful, and we share the view that situations should be modelled from the point of view of the user. However, the way relations are modelled is very abstract. This can be problematic when modelling situations from peoples' lives, therefore we believe that a more structured approach is needed. This is the approach we are taking in our two-level ontology.

Yau and Liu [31] also offer an ontological approach that models situations for pervasive computing applications. They differentiate between situations, defined as "a set of contexts in the application over a period of time that affects future system behavior" and contexts, defined as "any instantaneous, detectable, and relevant property of the environment, system, or users". Their ontology is based on this division, and they specify a context layer, which models context definition and contextual data, and a situation layer which is built on top of the context layer and aggregates context into situations. This forms the core of their upper ontology, whereas the elements of the lower ontology can be specified depending on the domain. This approach does not fundamentally differ from ours, and their definition of context seems similar to our definition of situation cues. However, similar to Kokar et al. [18], this approach is very abstract and building the lower level domain specific ontologies is not a trivial task. The only example provided in the work models a very specific situation (*ReadyForMeeting*) and does not provide general elements that need to be represented for the domain as a whole. In our work we provide these elements for the domain of social situations.

Zavala and colleagues [32] offer a framework which can be used to build *place-aware mobile applications*. To do so, they build a place ontology which models the concept of place not only as a geographical location, but also in terms of activities that occur there. For instance, someone can have an office in two different cities, but both of them would count as a *work place* since similar activities occur there. In Murukannaiah et al. [21], this approach is extended and social circles are learned based on the places that people are met (following the previous example, people met in workplaces would be classified as colleagues). Their approach goes beyond modelling very abstract concepts, which we believe is crucial for building applications that can be used by people. However, the concept of places is just one aspect of situations and does not cover the full picture. Our approach fills this gap.

We believe these approaches form a good starting point for modelling situations. Our work is inspired by the first two when it comes to the overall structure and the subjective point of view, and by the third one when it comes to the explicit and structured way in which concepts are modelled. In the following, we will combine these concepts in order to form an explicit and practical knowledge structure for modelling social situations.

4 A Knowledge Structure for Social Situations

A social situation can be described in different ways, based on the domain that is being modelled. For this reason we will use an ontology which consists of an upper and a lower level [16], where the upper level contains concepts which can be used to characterize arbitrary social situations, and the lower level describes more specific features which can be domain-, or context dependent. For the upper level, we start by defining a social situation:

Definition 1 (Social Situation)**.** A social situation $s \in \mathcal{S}$, where $\mathcal{S}$ refers to the set of situations, is defined as:

$$s = \langle People, Cues \rangle$$

Cues are elements of the social situation that need to be represented. These concepts will be formally defined in the next subsection. People stand in specific social relationships. In this work we focus on dyadic relationships, and thus concern ourselves with social situations involving two people. In some literature people are also considered as situation cues. We decide to consider them separately since their presence in a situation and their social relationships are the core aspects which make a situation *social*.

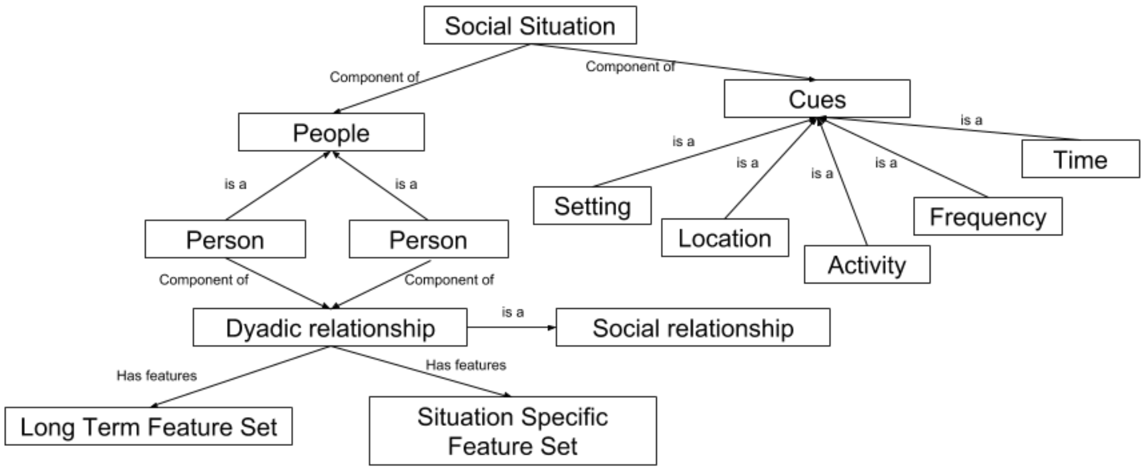

Fig. 1: Upper ontology of dyadic social situations.

Figure 1 offers a schematic representation of the knowledge structure. As depicted in the figure, a dyadic relationship can have two arbitrary people in it. In our case, one of the people will be the user who is being supported. The distinction is made because the situation is seen from the point of view of the user, and in future work we will model different features from the user than from the other person.

In the following subsections, we introduce the elements of a lower ontology which can be used to model daily life social situations. We provide an informal description and a definition of the situation cues, as well as the features of the dyadic relationships. In the following, situations are seen as events or meetings. $\mathcal{D}$ refers to a set containing the value-ranges for the cues we define. The set $\mathcal{A}$ refers to the identifiers of the human actors that are part of a social situation (referred to as *people* in Figure 1). Note that our pilot experiment should also inform us on the appropriateness of the value-ranges we associate with cues and features. Depending on the reactions of our subjects in the pilot experiment, we might change these ranges to other indicators.

4.1 Situation Cues

The literature on situation taxonomies provides a large set of situation cues that can be used to describe situations. We cluster them in the following definition:

Definition 2 (Situation Cues)**.** The set of cues involves the following concepts:

$$Cues = \{setting, location, activity, frequency, time\}$$

However, for the scope of this work, we limit ourselves on modeling the setting and frequency of the event, and leave modelling locations and activities for future work. A good starting point can be the work of Zavala et al [32].

The concept of a *situation setting* describes in which context a certain event is taking place, and is inspired by the concept of situation classes, as defined in Section 2.1. The setting can give insight into which psychological characteristics are relevant for the specific situation. The activities are user-dependent and therefore, the range of activities we present includes the most common situation classes that the users face in their daily life. Note that this range might need to extended for a specific user. In this example, we base the range of activities on Pervin [23]. The situation cues proposed in Rauthmann et al. [24] can also be clustered into these settings.

Definition 3 (Situation Setting)**.** is a relation defined by:

$$setting : \mathcal{S} \times \mathcal{D}_{setting} \text{ where } \mathcal{D}_{setting} = \{\texttt{work\_related, casual\_meeting,} \\ \texttt{sports\_activity, family\_related}\}$$

Event frequency refers to the frequency with which the event takes place. This variable is not explicitly mentioned as a situation cue in the literature, however some situation taxonomies (e.g., [22]) suggest typicality as one of the psychological characteristics of the situation. From our pilot experiment we see that frequency can help determine how typical a situation is.

Definition 4 (Event Frequency)**.** is a relation defined by:

$$event\_freq : \mathcal{S} \times \mathcal{D}_{efreq} \text{ where } \mathcal{D}_{efreq} = \{\texttt{regular, occasional}\}$$

In some cases, it is important to know who initiated a meeting, since it can make the user feel more obligated to attend it. We formally define it as:

Definition 5 (Event Initiator)**.** is a relation defined by:

$$event\_init : \mathcal{S} \times \mathcal{D}_{init} \text{ where } \mathcal{D}_{init} = \mathcal{A} \cup \{\texttt{none}\}$$

4.2 Features of Dyadic Relationships for Daily Life Situations

In this section we introduce the key features of dyadic relationships that a behaviour support agent can use to model daily life social situations of a user. The sets of features are part of the lower ontology, and can (and should) be adapted to the domain of use. Therefore, the list presented in this section is not exhaustive, but serves as an example and was used to model the scenarios in our pilot experiment. We distinguish between a *long term feature set* of properties of social relationships that do not have to be adapted for each situation, and a *situation specific feature set* of features that do change per situation.

Note that the range of some features is $\texttt{Likert}_5$, which denotes a 5-point Likert-type scale, where 1 is the lowest/most negative value and 5 the highest/most positive value. The information is subjective, from the point of view of our user.

Long Term Feature Set
The first feature is the *quality of the relation* between the two actors, and is also one of the features used in the convoy model [1].

Definition 6 (Quality of the Relation)**.** is a relation defined by:

$$rel\_quality : \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{quality} \text{ where } \mathcal{D}_{quality} = \texttt{Likert}_5$$

The feature *role* refers to the role of the second actor towards the first actor in dyadic relations. Knowing how the user (first actor) is related to the other person (second actor) is important since it can help inferring the expectations that come with the role. The range of roles is taken from the general social survey [6].

Definition 7 (Role)**.** is a relation defined by:

$$role : \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{role} \text{ where } \mathcal{D}_{role} = \{\texttt{partner, parent, sibling, child, extended\_family, coworker, neighbor, friend, supervisor, group\_member, other}\}$$

Hierarchy level refers to the power dynamics between the first and second actor. Higher (respectively same and lower) means that the second actor is higher up (resp. at the same level, and lower) in the hierarchy than the first actor. In case there is no hierarchy amongst actors, this is indicated by "n.a.". The feature hierarchy is relevant when assessing the priority of meetings, especially for users who are in working relations, or actors that come from a culture with some sort of caste system. More information on the concept of hierarchical ranking can be found in, e.g., [12, 30].

Definition 8 (Hierarchy)**.** is a relation defined by:

$$hierarchy : \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{hierarchy} \text{ where } \mathcal{D}_{hierarchy} = \{\texttt{higher, same, lower, n.a.}\}$$

The next feature is the *frequency of contact* between the two actors. The degree of interaction can help assessing the closeness of people, and also the importance of a specific situation [1, 2].

Definition 9 (Frequency of Contact)**.** is a relation defined by:

$$rel\_cfreq : \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{cfreq} \text{ where } \mathcal{D}_{cfreq} = \texttt{Likert}_5$$

Level of Trust in the relationship refers to the level of trust that the first actor has towards the second actor. The amount of trust can complement information on the quality of the relation. Level of Trust is mentioned as feature in [29].

Definition 10 (Level of Trust)**.** is a relation defined by:

$$rel\_trust : \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{trust} \text{ where } \mathcal{D}_{trust} = \texttt{Likert}_5$$

Depth of Acquaintance is a feature of the first actor towards the second actor. This feature can play a similar role to the level of trust, or in general inform on the expectations that actors have from the relationship. This feature is mentioned by Granovetter [14].

Definition 11 (Depth of Acquaintance)**.** is a relation defined by:

$$acq\_depth : \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{acq} \text{ where } \mathcal{D}_{acq} = \texttt{Likert}_5$$

The *default geographical distance* refers to the physical proximity of the two actors. It can influence the relationship of two people since it affects how often they can see each other. This feature is mentioned by Antonucci and Akiyama [2]. For the range we opted to measure distance in terms of time that it usually takes to get to that person.

Definition 12 (Default Geographical Distance)**.** is a relation defined by:

$$def\_geo\_dist : \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{geo} \text{ where}$$
$$\mathcal{D}_{geo} = \{\texttt{0-1hr}, \texttt{1-2hr}, \texttt{2-4hr}, \texttt{flight needed}\}$$

The last feature refers to the *Level of Formality* in the relationship. This feature can inform on the expectations of the relationship, and is mentioned by Ring and Van de Ven [25].

Definition 13 (Level of Formality)**.** is a relation defined by:

$$rel\_formal : \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{formal} \text{ where } \mathcal{D}_{formal} = \texttt{Likert}_5$$

Situation Specific Feature Set

The first two features to consider are situation specific roles and hierarchy levels. They become relevant when in the specific situation they differ from the default ones. For instance, if you go to a basketball game with your boss, in that situation you are both team-mates, and if you are the captain you are the one holding a higher hierarchy level in that situation. The variables are defined in the same way as the default ones, although the specific situation is also part of the definition:

Definition 14 (Situated Role and Situated Hierarchy)**.** are relations defined by:

$$role_{sit} : \mathcal{S} \times \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{role}$$
$$hierarchy_{sit} : \mathcal{S} \times \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{hierarchy}$$

The feature *help dynamic* refers to whether in the specific event the first actor is giving or receiving help from the second one. The fact that they have to give or receive help can influence how obligated the actors feel to attend a certain event. It is formally defined as:

Definition 15 (Help Dynamic)**.** is a relation defined by

$$help\_dynam : \mathcal{S} \times \mathcal{A} \times \mathcal{A} \times \mathcal{D}_{help}, \text{ where}$$
$$\mathcal{D}_{help} = \{\texttt{giving, receiving, neither}\}$$

The situation cues and relation features form the core of a user-specific user study, in which we test their perceived relevance.

5 User Study

In order to evaluate how well our knowledge structure is able to model realistic situations, we conducted a pilot experiment in which subjects had to answer to a survey. In the following sections we will introduce the experimental setting, as well as present and discuss the results.

5.1 Experimental Setting

Pilot Subjects
We tested 20 subjects (15 male, 5 female) who answered to all three parts of the experiment. Subjects were university employees (mostly PhD candidates). The average age was 31.1 years old (SD=7.6yo).

Design and Procedure[1]
The experiment was implemented as an online survey, and consisted of three parts. In the first part, subjects were asked to think about six people from their social circle. For the purpose of the study, they were instructed to select at least one family member, one friend, and one person who had a higher hierarchy level than them. Note that, in the full experiment, we will ensure we also get information on relationships with people lower in the hierarchy. For each of these people, subjects were asked about all long term features (Section 4.2). The first part was concluded with an evaluation section in which the subjects were asked whether the questions were understandable, whether the amount of questions was appropriate, and whether they thought the questions represent their social relationship with someone. Furthermore, they had the option to propose more aspects of social relationships which they thought are relevant.

In the second part, subjects were shown with 20 social dyadic scenarios of daily life. Each scenario involved one of the six people that they had mentioned in part 1, selected randomly[2]. We made the study subject-specific to enable them to reflect on their own relationships, instead of presenting them with hypothetical relationships. Scenarios consisted of different parameters of the situation cues and situation specific features of social relationships. A scenario could represent a social situation such as: "You have invited *Person X* for a work meeting on Tuesday morning because you need some feedback on your recent project". In this case it is a work setting, the event is occasional, the subject is the initiator and he/she is expected to receive help.

For each scenario, subjects were asked about the priority of the meeting, how obligated they would feel to attend the meeting and how much they would enjoy it. Furthermore, they were asked how they think the other person would answer these questions. Lastly, they were asked about the likelihood of that scenario

[1] The questions for each part of the experiment can be found in the Appendix.
[2] Apart from the scenarios in which a family setting or a higher hierarchy work setting were being tested, which were restricted to family members and people with higher hierarchy, respectively.

happening in their daily life. Subjects had to answer on a 5-point Likert scale. In order to assess priority, they were instructed to take into account how difficult it would be for them to cancel the meeting, how important they think it is to be punctual, and any other thing they would consider relevant.

In the third and last part, scenarios were paired randomly and subjects were asked which of the two meetings would they choose to attend in case of a conflict between the two scenarios. Furthermore, they were asked what reason would they give to the person whose meeting they were canceling: the real reason, some other reason, or no reason. Each subject was presented with six pairs of scenarios.

5.2 Results and Discussion

In this subsection, we will present and discuss the results of each part of the pilot experiment separately.

Part 1

The selected people from the subjects' social circle had an average age of 37.6 years old (SD=13.55yo). They were mostly friends (29%), followed by people from work (18% supervisors and 10% coworkers) and family members (11% parents, 8% siblings and 7% members of the extended family). Partners consisted of 10% of the selected people. Overall 74% of the people were not in a hierarchical relation with the subjects, 22% were on a higher level and 4% on a lower level. 36% lived within an hour of distance from the subjects, 18% between 1-2 hours, 4% between 2-4 hours, and for the remaining 32%, the subjects would need to take a flight in order to meet them. Subjects mostly chose people with whom they have strongly positive relationships (average of 4.15, with 82% being a 4 or 5). Furthermore, they chose people whom they trust (average of 4.13, SD=0.88) and the relationships have a low level of formality (average of 1.81, SD=1.11). In the full experiment, in order to have more representative data from a larger variety of relationships, we will control some features when asking the subjects to think of people from their social circle. For instance, we will ask some subjects to think about a coworker with whom they do not have a positive relationship.

The evaluation questions (all posed with a 5-point Likert scale in possible answers) showed that the subjects found the questionnaire understandable, with an average of 4.59 (SD=0.51). The number of asked questions was appropriate (the average answer was 3, SD=0.61, on a 5-point scale where 3=`appropriate`). When asked how much this information represents their relationship with someone (Likert range from 1 = `very little` to 5 = `very much`), the average answer was 3 (SD=0.79), confirming that social relationships have subtle aspects not captured in our questionnaire. Whether we need to add more features, depends on the strength of the correlations between the current features and the choices the subjects make in Part 2 of the questionnaire. The subjects (mostly being PhD students), seemed to understand this point, as some subjects indicated that the answer to this question depends on the purpose of the study. This is something that we will take into account in future experiments.

When asked whether they could think of additional aspects of social relationships which should be present in the survey, 35% of subjects answered with

"Yes". Some of the suggestions included: dependability, understanding, fun, respect, how important is the other person, common interests, etc. However, none of the suggestions appeared consistently. In the full experiment we plan to keep this open question to see whether we can see patterns in the suggestions.

The value-ranges of the relationship features were appropriate for our test group. We received no indications to the contrary from our subjects.

Part 2

In this section subjects were asked to evaluate different scenarios. Table 2 presents the average results.

	Subject	*Other person*
Priority	4.11 (SD=0.86)	3.87 (SD=0.91)
Obligation	3.67 (SD=1.08)	3.54 (SD=1.04)
Enjoyment	3.76 (SD=1.02)	3.88 (SD=0.86)

Table 1: Average answers for Part 2 scenarios. The column *Subject* indicates the average answers given by the subject, while *Other person* indicates what answers would the other person give to that scenario, according to the subject.

Subjects mostly assign a high priority to the meetings. This was expected given that scenarios included people with whom the subjects have a close and positive relationship. This is also reflected in how much they enjoy these meetings. The average likelihood of the scenarios was 3.14 (SD=1.42), which means the scenarios were relatively likely despite being chosen randomly. We notice a high standard deviation, caused by the fact that some of the scenarios had a low likelihood, possibly because of the random person-meeting combination.

Subjects seem to consider a high level of reciprocity when thinking about the level of priority/enjoyment/obligation from their and the other person's point of view. This is shown by the moderately strong positive correlations (0.63 for priority, 0.63 for obligation and 0.71 for enjoyment). For the full experiment we will consider social relationship features related to reciprocity.

Next, we check the correlations between priority, obligation and enjoyment from the subjects' perspective. Our expectation was that priority would have a positive correlation with obligation and enjoyment, while obligation and enjoyment would not be correlated with each other.

Variables	*Overall correlation*	*Correlation in casual setting*	*Correlation in meeting with someone with higher hierarchy*
Priority-Obligation	0.496	0.45	0.77
Priority-Enjoyment	0.41	0.64	0.33
Obligation-Enjoyment	0.01	0.18	0.18

Table 2: Correlation between different variables.

As expected, priority has a moderately strong positive correlation with obligation and a moderate positive correlation with enjoyment. Obligation and enjoyment do not correlate. Interestingly, priority has a stronger correlation with enjoyment in situations with a casual setting (e.g., going out for drinks). On the other hand, it correlates with obligation in meetings with someone who has a higher hierarchy or in work meetings. This suggests that obligation and enjoyment are two aspects that are considered when deciding on the priority, and that their respective impact depends on the situation type. In future work the full experiment is expected to make the strength of these correlations more precise.

Part 3
In this part, subjects were given pairs of scenarios (from part 2), and they had to select which one they would attend if they could attend only one. We notice that in 69% of the cases, subjects would select the meeting to which they had assigned a higher priority in part 2. This suggests that priority is a good indicator of how people break ties. However, it is not the only thing. We noticed that in most of the cases in which subjects select meetings to which they had assigned a lower priority, those meetings have also a low likelihood. This suggests that when breaking ties between different meetings, subjects also take into account how difficult would be to reschedule each of the meeting. Also, in this section we see differences between individuals, since there were subjects who consistently chose a certain type of meetings. This can link to the subjects' *personal values*.

Subjects were also asked about the justification that they would give to the person whose meeting they would cancel. In 89% of the cases, subjects reported that they would give the real reason. Most of the cases in which the subjects would give no reason or a different reason (and not the real one) took place when they chose to attend meetings with a lower priority. Furthermore, many cases involve either not reporting to someone with a higher rank, or not giving details about their meetings with family members.

6 Predicting Priority of Events with Decision Trees

Representing elements of the environment is useful, however these features need to be combined before conclusions can be drawn about how people evaluate situations. In Situation Awareness literature, this process is called *comprehension* [11]. In this work we explore one general and abstract characteristic of a given situation, namely its *priority*. This can be considered a first step towards having sufficient information about situations and offer support.

As a method to reason about meeting priorities, we use decision trees. We build the model using the R package `rpart` [28], which implements the *CART* algorithm [5] introduced in Section 2.3. We use 70% of the data as a training set from which the tree structure was learned, and then test it on the remaining 30%. As a pruning mechanism we limit the maximal depth of the tree to 4. Since we lack a benchmark in this domain, we compare our result with an algorithm which would predict a random priority (as we offered 5-point scale, chance corresponds to 20%) and with an algorithm which always picks the most selected class (i.e. priority 4, which was selected in 41% of cases). To determine the accuracy of the models, we use the following definition:

$$accuracy = \frac{Number\_correct\_predictions}{Number\_overall\_predictions}$$

Our model has a 47% accuracy on the test set, performing better than the other two algorithms that we used as a benchmark. This means we are able to predict priority of a particular event better than chance. This result is important, especially when we consider that:

- This is a first benchmark result in this domain, it proves that predicting priority based on elements of the situation is possible, and it opens the path to exploring different techniques;
- We built the model using a small data set, and learning algorithms need more data in order to generalize better. This is also shown by the high level of over-fitting which takes place, as noticed by the fact that the accuracy on the training set is 65%;
- The data is unbalanced, since people mostly give a priority of 4 or 5 to events. The presence of lower priorities would make the evaluation of the algorithm more realistic since we would be able to measure not only the number of correct predictions, but also how far off the incorrect predictions are. The low variance in the data can be explained by the fact that subjects chose people who are very close to them, thus they would prioritize those events.

In the model, we notice that the most informative features are: *role*, *relationship quality*, *event setting* and *meeting initiator*. This means these features offered the highest information gain throughout the tree. The actual model that was learned is depicted in Figure 2.

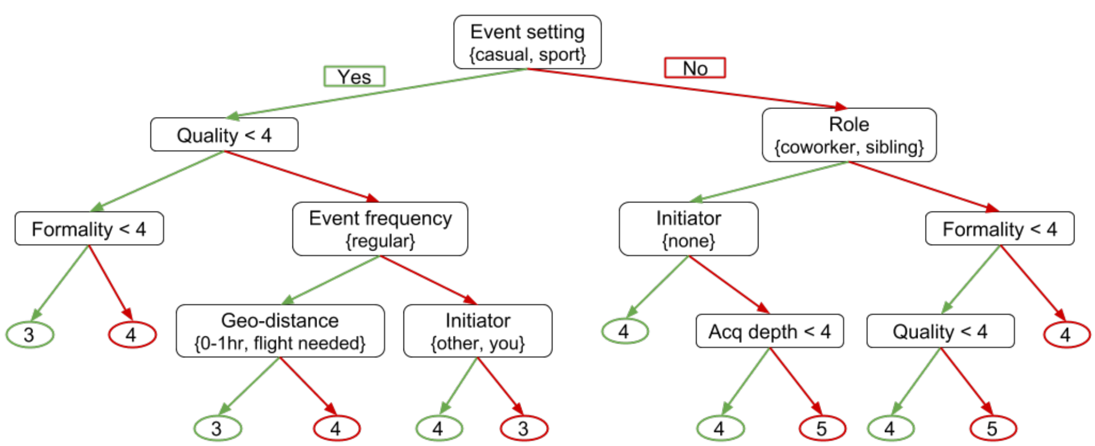

Fig. 2: Decision tree built based on the data. Nodes with categorical features, such as event setting, should be interpreted as "is *event_setting*=`casual OR sport`?"

We remark that, to us, many of the tree splits are intuitive. For instance, the first information that is checked is the setting of the meeting, with casual and sport events on one hand and family and work events on the other. This split was to be expected since subjects assigned higher priorities to family and work events. Methodologically, our pilot experiment also shows that we can use the full fledged experiment to obtain an informed decision tree. How accurate that will be is, of course, still remains to be seen.

7 Conclusions

For the benefit of the development of behaviour support agents with social situation awareness, this paper provides the following contributions:

- a conceptualization and formalization of a knowledge structure that represents the salient situation cues and features of dyadic social relationships. The knowledge is based on theoretical work from social psychology, and organized as a two-level ontology.
- an evaluation of this knowledge structure via a pilot experiment. Results show that subjects find the concepts understandable and representative.
- testing whether our idea of learning decision trees to predict the priority of events is feasible in practice, which proved to be the case.

This provides the foundations needed for building socially aware behaviour support agents. Now we have the elements that need to be modelled as well as we show that it is possible to reason about these elements and infer meaning. This opens the way for many research options, which we present below.

Based on the findings reported in this paper, a full fledged experiment can be confidently carried out to obtain a detailed social model that can serve as a background model for behaviour support agent to advice on how to choose between social situations. This can be achieved by deriving norms about the priority of situations, which can be learned from subjects' data.

Another interesting approach is to analyze how *personal values* affect the way in which subjects think about social situations. Part three of our pilot experiment suggested the existence of individual differences in how people decide which meetings to attend. We will explore whether people with shared personal values make similar choices.

The current model relies fully on information that is acquired directly from the users. In future work, we would like to add sensory data to inform our model. Literature shows that sensory data can be used to perceive social information (e.g., [7]). This line of research would provide useful ways to acquire information without interrupting the user.

Finally, in this work we mostly focus on modelling social situations. The next step is to dive deeper into situation comprehension, and reason about different dimensions of the situation (other than priority). This would lead to having a more complete profile of the situation, which in turn enables behaviour support agents provide more comprehensive help.

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Appendix

Part 1
For each person, the following questions were asked:

- What's the name of the this person? (i.e. Alice)
- How punctual is Alice usually? options: $\texttt{Likert}_5$
- How annoyed would Alice get if you cancel a meeting? options: $\texttt{Likert}_5$
- How annoyed would you get if Alice cancels a meeting with you? options: $\texttt{Likert}_5$
- What is the role of Alice towards you? options: {`partner, parent, sibling, child, friend, extended family member, neighbor, coworker, supervisor, member of the same group (e.g., sports team), other`}
- What's the hierarchy rank (from a formal point of view) of Alice towards you? options: {`higher, lower, same, n.a.`}
- How would you consider the quality of your relationship with Alice? options: $\texttt{Likert}_5$
- What's the geographical distance between you and Alice? options: {`0-1hr, 1-2hr, 2-4hr, I would need to take a flight`}
- How well do you know Alice? options: $\texttt{Likert}_5$
- How often are you in touch with Alice? options: $\texttt{Likert}_5$
- How much do you trust Alice? options: $\texttt{Likert}_5$
- How formal is your relationship with Alice? options: $\texttt{Likert}_5$

Part 2
For each scenario, the following questions were asked. For all, the answer option was a 5-point Likert scale:

- What priority would you assign to this meeting?
- What priority do you think the other person would assign to this meeting?
- To what extent would you feel obligated to attend this meeting?
- To what extent do you think the other person would feel obligated to attend this meeting?
- To what extent would you enjoy attending this meeting?
- To what extent do you think the other person would enjoy attending this meeting?
- How likely are you to encounter this scenario in your life?

Part 3
Two scenarios were chosen randomly and shown to the subject, and the following questions were asked:

- If they were planned to happen at the same time, which of the two scenarios would you attend? options: {`Scenario 1, Scenario 2`}
- What explanation would you give to the person whose meeting you would have to cancel? options: {`no explanation, the real reason, some other reason`}