Preferences with Qualitative Thresholds and Methods for Individual and Collective Decisions

(Extended Abstract)

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ABSTRACT

In this paper, we propose a way to model preferences so agents base their decisions on beliefs and can reason about such preferences. This connection allows agents to build arguments about their preferences or to explain decisions, and update preferences as they review beliefs. We also discuss how agents can reach decisions and the role played by preferences in deliberation towards collective decision situations.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multiagent systems

General Terms

Theory

Keywords

Reasoning (single and multiagent); Preference Handling; Decision Making (single and multiagent)

1. INTRODUCTION

Autonomy is closely related to making decisions. As such, autonomous agents are frequently required to make choices, and are expected to do so according to their beliefs, goals, and preferences, however, beliefs are rarely connected to the preferences of the agent, especially in collective settings. Dietrich and List argue in [1] that logical reasoning and the economic concept of rationality are almost entirely disconnected in the literature. We consider this disconnection is, indeed, notorious and make a step towards integrating beliefs and preferences: We introduce preferences based on unary predicates used to compare options and yield their utility, then consider *qualitative thresholds* to understand the quality of such options. Such concept of quality can be used by agents to build arguments and explain their decisions.

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Rossi et al. argue in [5] that much work has to be done to achieve a single formalism to model problems with both constraints and preferences of many kinds, and solve them efficiently. We believe our proposal is a good step in this direction, as we integrate reasoning with expected utility rationality in a way they influence in one another. By doing so, we allow agents to (i) work with different perspectives of preferences; (ii) build arguments to explain decisions; (iii) deal with preferences under uncertainty; and (iv) automatically update preferences if they perform belief revision.

The paper is organized as follows: Section 2 presents our approach to model preferences and some properties. Next, Section 3 shows reasoning about preferences. Section 4 discusses decision making. Section 5 concludes the paper.

2. PREFERENCES AS UTILITY + BELIEFS

We defend that the preferences of an agent should arise from beliefs, but as well take part in such beliefs so the agent can reason about them. We achieve this by means of an utility function based on the truth value of certain predicated formulas that describe options (alike with whats done in *weighted propositional formulas* [3]). The thresholds indicate utilitarian requisites for an option to be classified as good, poor or neutral, so the agent is clear about whether to support or avoid an option. This feature can be particularly important for participating in collective decisions.

Definition 1. (preference profile) Let $Pred$ be the set of all unary predicates expressing attributes of objects in the language of an agent. A *preference profile* is a triple $Pr = \langle Ut, Up, Lw\rangle$ with an utility function $Ut : Pred \to \mathbb{R}$, and upper and lower utility thresholds $Up, Lw \in \mathbb{R}$, $Up \geq Lw$.

An agent can have as many preference profiles as desired for each kind of decision the agent may get involved. Given an agent theory and a preference profile $Pr = \langle Ut, Up, Lw\rangle$, to rank the possible outcomes is straightforward: Let $Alt = \{o_1, \ldots, o_n\}$ be the set of options available in a decision situation, each option o_i, $1 \leq i \leq n$, has an expected utility

$$Ut^S(o_i) = \sum_{P(x),\ P(o_i)\ \in\ S} Ut(P(x)),$$

where S is a model of the agent's knowledge base. In the context of a particular model S, o_i is a *good option* if $Ut^S(o_i) \geq Up$, a *poor option* if $Ut^S(o_i) < Lw$, and neutral (neither good or poor) otherwise. In that sense, if $Up = Lw$, there are only good and poor options in the eyes of the agent.

The concept of preference profile in Definition 1 induces, for each model S of the agent theory, a *total preorder*[1]

$$\succcurlyeq^S = \{(o_i, o_j) \mid Ut^S(o_i) \geq Ut^S(o_j)\}$$

over the set of available options.

Dietrich and List propose two axioms in [1] which should govern the relationship between an agent's beliefs and their preferences in different profiles. It can be shown that

THEOREM 1. *The preference relation $\succcurlyeq$ satisfies Axioms 1 and 2 from [1] in each model S.*

3. REASONING ABOUT PREFERENCES

We will now show how to deal with beliefs about preferences and allow agents to reason about them.

Given an agent logical theory KB, and a preference profile $Pr = \langle Ut, Up, Lw\rangle$, let R^* be the set of all predicates relevant to the decision, i.e., any $P(x)$ with $Ut(P(x)) \neq 0$ in Pr. To build the set KB_{Pr} of preference rules, first compute

$$^R Ut = \sum_{P(x)\in R} Ut(P(x)),$$

for each $R \subseteq R^*$. Then, for each such R, KB_{Pr} should have a rule r in the general form

$\bigwedge(\{P(x)|P(x) \in R\} \cup \{\neg P(x)|P(x) \in R^* \setminus R\}) \rightarrow conc(r)$,

where $conc(r) = G(x)$ if $^R Ut \geq Up$, $conc(r) = \neg G(x)$ if $^R Ut < Lw$, and $conc(r) = N(x)$ otherwise.

We assume the predicates $G(x), N(x)$ do not appear anywhere in the original program P. These predicates stand for *good* ($G(x)$) and *neutral* ($N(x)$) options, and options known not to be good are *poor* ($\neg G(x)$). If the agent $Ag = (KB, Prefs)$ is to reason according to Pr, it will consider the models of $KB \cup KB_{Pr}$. Different logical formalisms of KB may ask for different structures of rules.

4. MAKING DECISIONS

A decision problem is one in which a set of agents $A = \{a_1, \ldots, a_n\}$, $n \geq 1$, tries to reach a common choice out of a set of options (outcomes) $O = \{o_1, \ldots, o_m\}$, with $m \geq 2$. We say it consists of a collective decision problem whenever $n \geq 2$. In a decision problem, each agent has their own preferences over the options. When two or more agents agree on a particular decision, i.e., they are all in favor of electing the same outcome, it is said that they reached consensus.

4.1 Single Agent Decision

When there is no uncertainty, the decision of a single agent should be straightforward: Just maximize utility. Since options in our approach can satisfy positive and negative features, maximizing utility can be perceived as comparing and weighting such features. A principle concerning such kind of decisions is that of *Bivariate monotonicity* [2].

THEOREM 2. *If there is no uncertainty, maximizing utility as in Section 2 satisfies bivariate monotonicity [2].*

In case of uncertainty, our approach relates to game theory as such scenarios induce the construction of a payoff matrix, so we base the decision in criteria from game theory [4].

[1]A *total preorder* is a relation that is transitive, reflexive and in which any two elements are related. Total preorders are also called *weak orders*.

By the *maximin* criteria [4], $o_i \succcurlyeq_{MAXIMIN} o_j$, iff $MIN(\{Ut^S(o_i) \mid S \in AS\}) \geq MIN(\{Ut^S(o_j) \mid S \in AS\})$. The agent should choose a maximal element of $\succcurlyeq_{MAXIMIN}$.

THEOREM 3. *The maximin criteria for decision making under uncertainty satisfies bivariate monotonicity [2] in the case of multiple scenarios.*

4.2 Collective Decisions By Deliberation

In a collective decision context, the agents involved are supposed to seek the best outcome for *the group*, however maximizing the utility attributed to an option by all agents may be difficult or somehow infeasible. In a deliberation dialogue, the exchange of opinions (arguments) can work in a way to combine the knowledge of agents (such as in Sá and Alcântara [6]) and some opinions can change the minds of other agents. Usually a dialogue starts with a proposition and agents assume positions towards it: the proponent defends the proposition while the opponent attacks it. In a discussion about one option beings good/neutral/bad for the group, our proposal of model of preferences allows agents to pick a side (proponent if they believe the option is good, opponent if bad) or even play both (if the option is neutral) while being impartial. This behavior allows agents to play their preferences and combine opinions to build collective qualitative opinions about each option available. The group decision consists of picking any option amongst the best rated ones in the collective opinion.

5. CONCLUSIONS

In this paper we propose a way to model agent preferences such that they emerge from beliefs while agents get able to reason about them. We believe our proposal is a good step in connecting rational decisions with reasoning and beliefs. In our model, agents work with different perspectives of preferences such as a utility-based cardinal order, a regular ordinal order and a classification in good/poor/neutral options. Remarkably, we achieve all these results with a simple mechanism which we called *qualitative thresholds* that take part in the specification of a preference profile.

6. REFERENCES

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