# Effective Negotiation with Partial Preference Information*

# (Extended Abstract)

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## ABSTRACT

Users' preferences play a key role in automated negotiation since they dictate how an agent will act on behalf of its user. However, elicitation of these preferences from the user is difficul when there are dependencies between preferences. In many settings, expecting a user to provide a total ordering of her preferences is unrealistic. Thus, it is essential to build agents that can negotiate with only partial preference information. In order to achieve this goal, we develop negotiation strategies that work on qualitative preference representations, such as CP-nets that require only partial preference information.

## Categories and Subject Descriptors

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

## General Terms

Algorithms, Experimentation

## Keywords

Negotiation, Preference, Testing of agent systems

## 1. INTRODUCTION

In agent-mediated negotiation, a consumer and a producer agent interact to devise a mutually acceptable outcome [3]. As far as the agents' negotiation strategies are concerned, understanding and reasoning on their users' preferences are important to generate the right offers on the behalf of their users.

A user's preferences can be represented as an ordering of alternatives according to their desirability for the user. For example, someone may prefer a two-bedroom apartment over a one-bedroom when renting an apartment. In general, a negotiation domain involves multiple issues and more importantly, preferences on some of these issues depend on each other. For instance, the user prefers a two-bedroom apartment only if the apartment size is larger than a certain size; otherwise prefers a one-bedroom apartment.

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To negotiate effectively, preferences of a user should be elicited with a powerful representation, such that enough information should be elicited but the user should not be overwhelmed with questions.

Contrary to quantitative representations of preferences that are widely used in the literature, we advocate qualitative representations such as CP-nets [1] for preference elicitation and reasoning. Representing user's preferences with CP-nets eases the preference elicitation phase for the user since this representation is more intuitive and natural to the user. However, all potential orderings cannot be captured by a CP-net. Here, there is a tradeoff between the simplicity of the elicitation of the preferences and the amount of the information gained. If we prefer preference representation based on utility functions, we will have a total ordering of the outcomes but the preference elicitation phase will be more difficult If we choose CP-nets for the preferences, it would be more intuitive and natural for the user to assess her preferences but we will have a partial ordering of the outcomes. Hence, we develop negotiation strategies on CP-nets that can work even on partial ordering of preferences. To achieve this, we construct a preference graph from a given CP-net and develop some heuristics on this preference graph to obtain an estimated total ordering of the alternative services in order to generate requests and to decide whether a counter offer is acceptable or not.

## 2. CP-NETS

Conditional Preference Networks (CP-net) are graphical models for representing partial preference ordering in a qualitative way [1]. The preference statements are interpreted under ceteris paribus semantics, "everything else being equal". Consider the apartment renting domain including three issues: *Price*, *Neighborhood* and *Parking Area*. Assume that there are three neighborhoods: *Etiler*, *Kadikoy* and *Kartal*. The price is categorized as *High*, *Medium* and *Low*. A parking area may exist or not. Thus, the domain for parking area has two values: *Yes* and *No*. The preference statement such as "I prefer *Etiler* to *Kartal*" means that an apartment at *Etiler* is better than that at *Kartal* when all other issues such as parking area and price are the same.

In a CP-Net, each node represents an issue and each edge shows the preferential dependency among issues. Each node is also associated with conditional preference table (CPT) indicating the preference ordering. Each preference statement in these tables shows which issue value is dominant over others. For example, according to the given CP-Net in Figure 1, $Low \succ Medium$ means that *Low* is preferred rather than *Medium* for the price if the remaining issues are the same. Further, the preference on a particular issue may depend on the instantiation of other issues. In CP-Nets, the preference on a child node depends on the instantiations of the parent issues. Here, if there is an edge from node $X$ to $Y$, the variable

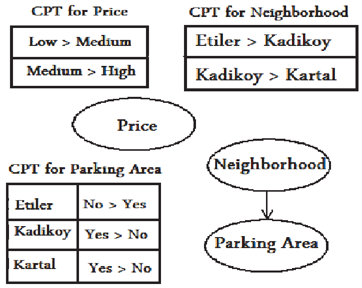


**Figure 1: A sample CP-net for apartment renting domain**

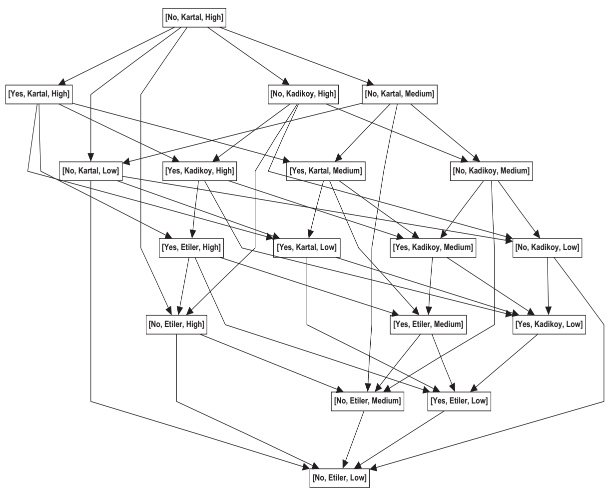


**Figure 2: The preference graph constructed from the CP-net in Figure 1**

$X$ is called the parent node whereas $Y$ is called the child node. To illustrate this, consider the CP-net in Figure 1. According to this CP-net, *Neighborhood* is the parent of *Parking Area* because the user's preferences on parking area depends on the neighborhood. By using the preference statements specifie  in the CPT for the parking area, we can infer conclusions such as if the price is the same for two apartments and neighborhood is Kartal, the user will prefer an apartment having a parking area. In the case that the neighborhood is Etiler, she will prefer an apartment not having a parking area.

## 3. NEGOTIATION STRATEGIES

This study focuses on negotiation strategies for the consumer agent, which keeps its user's preferences in a CP-Net form. The consumer agent uses these preferences to generate its service request and to decide whether the producer's counter offer is acceptable or not. A service request can be considered as a vector of issues, which represents the service. For instance, a consumer can request the service: (*Yes*, *Etiler*, *Low*), denoting a low-price apartment having a parking area at Etiler.

To generate a service request, the consumer firstl  induces a preference graph whose nodes are possible services by reasoning on the given CP-Net. The edges of the induced preference graph are established via *improving flips* on a given CP-net. An improving fli is changing the value of a single issue with a more desired value by using the CPT of that issue. Therefore, the instance obtained via this method is more desirable. The preference graph of the sample CP-net in Figure 1 is drawn in Figure 2. The agent starts with the worst choice and by applying improving flip  it gets more desired services. The direction of the edges is from the less preferable service to the more preferable service. The root element(s) of the induced graph represents the worst choice whereas the leaf node(s) expresses the best one. From top to bottom, the choice becomes more desired. For intermediate nodes, we only compare the nodes having a path from others. The nodes having no path to each other cannot be compared under ceteris paribus interpretation.

In negotiation, the consumer generates the most desired service as a firs  request. Then, it concedes over time: it generates a service whose desirability is equal to or less than its previous request. To do this, it should be able to compare two services. Since CP-nets only capture partial information, not all alternatives are comparable. To obtain an estimated total ordering, we develop two heuristics to be able to compare the services.

**Depth Heuristic**: This is based on the on the idea of capturing the depth of a node in the graph. Note that the depth of a particular node is the longest path from the root node. The intuition here is if there is an edge from $x$ to $y$, we ensure that the depth of $y$ is higher than that of $x$. According to this approach, the higher depth a service has, the more likely to be preferred by the user.

**PageRank Heuristic**: PageRank is a heuristic to rank Web Pages, to determine the ranks of the nodes in the graph. It measures the importance of Web pages. There is an intuition in PageRank that we can easily map to our preference ordering problem. A Web page is considered as important if other important pages links to this page [2]. We apply the same intuition to our domain: A service node is preferred more if it is pointed by other preferred services. Note that the direction of the edges from less preferred to more preferred services. We can say that if a service is preferred to another service which is highly preferred, that service is a highly preferred service as well.

A consumer agent uses one of these two heuristics to decide which service it will request next. That is, it requests services in descending order of preferences with respect to their heuristic value over time. For example, if the consumer applies depth heuristic, the service whose depth is the highest should be its firs  request. The consumer accepts the producer's counter offer if the heuristic value of the offer is equal to or higher than that of the consumer's previous offer. Otherwise, the consumer generates a new request.

Our results over simulations show that consumer agents can negotiate well with partial preference ordering by applying these heuristics. The overall utility gained by consumers with these strategies are comparable to that of other negotiation strategies that have a total ordering of user preferences.

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