Interest-Matching Comparisons Using CP-nets

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Abstract

The formation of internet-based social networks has revived research on traditional social network models as well as interest-matching, or match-making, systems. In order to automate or augment the process of interest-matching, we describe a method for the comparison of preference orderings represented by CP-nets, which allows one to determine a shared interest level between agents. Empirical results suggest that this distance measure for preference orderings agrees with the intuitive assessment of shared interest levels.

Introduction

An increasing amount of research is being conducted in the areas of interest-matching or match-making systems. A decision to interact with another agent is based strongly on what level of interest is associated with some aspect of that agent. This interest often reflects a similarity of preferences or desires.

For computational purposes, it is helpful to develop a model that formalizes the characteristics of an agent that are necessary for making an interest-matching comparison. Preference information is a natural way of capturing what it is that an agent wants or intends to do. In particular, conditional preference networks (CP-nets) are a natural, compact representation of some preference information operating under the *ceteris paribus* semantics (Doyle, Shoham, & Wellman 1991; Boutilier *et al.* 1999; 2004).

We have developed a method for facilitating interest-matching comparisons between agents in a social multi-agent environment that uses preference information represented as a CP-net (as in Figure 1). Furthermore, we show that the distance measure of orderings computes reasonable and intuitive shared interest levels (Wicker 2006).

Definitions

We assume an enumerated finite set of features $\mathcal{F}$. Each feature $f \in \mathcal{F}$ can be instantiated over a finite domain, denoted by $Dom(f)$. Let $\mathcal{N}_F$ be the set of all CP-nets defined over features $F \subseteq \mathcal{F}$, where $\mathcal{N}$ is the set of all CP-nets. We denote the CP-net for agent i defined over feature set F as $N_i \in \mathcal{N}_F$. The set of all outcomes over F is $O_F = \prod_{f \in F} Dom(f)$, with the product taken in the enumerated order of $\mathcal{F}$. The set of all strict partial orderings over O_F is Ω_F. Each CP-net $N \in \mathcal{N}_F$ represents a strict partial ordering $\omega \in \Omega_F$. We define the "meaning" of a CP-net N as the strict partial ordering it represents, denoted by $[\![N]\!]$.

We restrict our attention in the following to CP-nets over binary features (i.e., $|Dom(f)| = 2$ for each $f \in \mathcal{F}$) that form directed acyclic graphs (DAGs).

Distance Metric

Bogart (1973) generalizes work by Kemeny and Snell (1962) that obtains a distance measure on strict partial orderings as the unique metric satisfying several natural axioms. This metric, which we will call the KSB metric, is defined in terms of a matrix representation of the orderings.

We call the matrix M an *ordering matrix*. For an ordering, we construct an ordering matrix $M = [m_{ij}]$, where

$$m_{ij} = \begin{cases} 1 & \text{if } i \text{ is strictly preferred to } j, \\ -1 & \text{if } j \text{ is strictly preferred to } i, \\ 0 & \text{otherwise.} \end{cases} \quad (1)$$

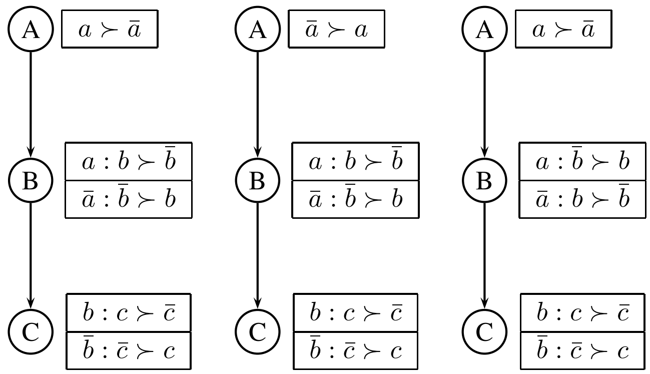
An ordering matrix is in canonical form if the outcome column and row labels are ordered lexicographically with respect to the binary digit interpretation of the binary feature values in each outcome. Let m_{ij} and m'_{ij} be the corresponding ordering matrix entries from the respective orderings ω,$\omega' \in \Omega_F$ for some $F \subseteq \mathcal{F}$. The KSB axioms are satisified by the distance function

$$d_\Omega(\omega, \omega') = \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} |m_{ij} - m'_{ij}| \quad (2)$$

where $n = |O_F|$.

We derive a maximum distance from the KSB distance between two orderings as $d^\Omega_{max} = n(n-1)$. A *shared interest function* $I : \mathcal{N} \times \mathcal{N} \to [0, 1]$ is defined using d_Ω and d^Ω_{max} as

$$I(N, N') = 1 - \frac{d_\Omega([\![N]\!], [\![N']\!])}{d^\Omega_{max}} \quad (3)$$



(N_1) (N_2) (N_3)

Figure 1: CP-nets N_1, N_2, and N_3

We say that two agents, whose preferences are represented in CP-nets N and N', share a common interest in each other if and only if $0 < I(N, N') \leq 1$, share a maximum interest in each other if and only if $I(N, N') = 1$, and share no interest in each other if and only if $I(N, N') = 0$.

Wicker (2006) describes a feature set expansion method which permits comparison in the case where the CP-nets are constructed over different feature sets. By using this expansion method, we have produced a metric on all CP-nets $N \in \mathcal{N}$.

Exemplary Comparison

Figure 1 depicts the CP-nets $N_1, N_2, N_3 \in \mathcal{N}_{\{A,B,C\}}$ representing the preferences of three different agents. We want to assess whether agent 1, whose preferences are represented in N_1, has a higher level of shared interest with agent 2 or agent 3, whose preferences are represented respectively in N_2 and N_3.

An informal level of relative feature importance is interpreted from the relations of the feature nodes in a CP-net. If a feature f is a parent of feature f', then we say that f is more important to that agent than f'. Intuitively, two agents with opposing preferences on a feature that is most important to each will have less shared interest in each other than if they disagreed only in a less important feature. Note that the preference for feature A is the only difference between N_1 and N_2, and the preference for feature B is the only difference between N_1 and N_3.

We construct an ordering matrix from the preference orderings represented in each of the CP-nets. For example, the ordering matrix for the preference ordering represented in N_1 is:

$$M_1 = \begin{bmatrix} 0 & -1 & -1 & -1 & 1 & 0 & 1 & 1 \\ 1 & 0 & -1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & 0 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 0 & -1 & 1 & 1 \\ 0 & -1 & -1 & -1 & 1 & 0 & 1 & 1 \\ -1 & -1 & -1 & -1 & -1 & -1 & 0 & 1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & 0 \end{bmatrix}$$

The ordering matrices for N_2 and N_3 are constructed in the same manner using the canonical form.

Using the KSB metric, we find that $d_\Omega([\![N_1]\!], [\![N_2]\!]) = 30$ and $d_\Omega([\![N_1]\!], [\![N_3]\!]) = 18$. The shared interest function I is computed using $d^\Omega_{max} = n(n-1) = 56$, where $n = |O_F| = 8$, yielding

$$I(N_1, N_2) = 1 - \frac{d_\Omega([\![N_1]\!], [\![N_2]\!])}{d^\Omega_{max}} = 1 - \frac{30}{56} = 0.464 \quad (4)$$

$$I(N_1, N_3) = 1 - \frac{d_\Omega([\![N_1]\!], [\![N_3]\!])}{d^\Omega_{max}} = 1 - \frac{18}{56} = 0.678 \quad (5)$$

Returning to our initial statement about the expected results, we can see that it is indeed consistent with our intuition since

$$I(N_1, N_2) < I(N_1, N_3) \quad (6)$$

Thus, we conclude that agent 1 would be most interested in agent 3, given also the preferences of agent 2. Note that this does not mean that agent 1 is not at all interested in agent 2.

Conclusions and Future Work

We have described the motivating factors and methods of the ongoing research on interest-matching comparisons using CP-nets.

The time complexity of the shared interest computation outlined in this abstract is exponential in the number of feature nodes in a CP-net. We are developing a distance metric on CP-nets that is polynomial in the number of feature nodes. Such a more efficient metric will permit the application of this approach to social multi-agent environments in which agents have large numbers of preferences.

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