EXTENDED CONSTRAINT HANDLING FOR CP-NETWORKS

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Abstract: CP-networks are an elegant and compact qualitative framework for express preference, in which we can represent and reason about preference rankings given conditional preference statements. However, represent constraints in such framework is one difficult problem. We therefore propose a new approach, i.e. mapping CP-networks to constraint hierarchy, thus we can reason preferences with constraint solving algorithms. We compare it with related work finally.

Key words: CP-networks, constraint hierarchy, preference, reasoning

1. INTRODUCTION

Representing and reasoning about preference is an area of increasing interest in theoretical and applied AI[1]. In many real life problems, we have both hard and soft constraints and qualitative conditional preferences. Now, there are few work on reasoning with these information. For example, constraint hierarchy (CH) solvers [2] are good at hard and soft constraint solving, while CP-networks[3]are most suited for representing qualitative conditional preference statements. In this paper, we combine two approaches, so that we can handle both constraints and preference efficiently.

2. CONSTRAINT HIERARCHY

A constraint hierarchy is a finite set of labeled constraints defined over some set of values D called domain, e.g. real numbers. Given a constraint hierarchy H, H_0 is a vector of required constraints in H in some arbitrary order with their labels removed. Similarly, H_1 is a vector of the strongest non-required constraints in H etc. up to the weakest level H_n, where n is the number of non-required levels in the hierarchy H. We set $H_k = \emptyset$ for k>n. Recall, that if i<j then the constraints in H_i are stronger (more preferred) than the constraints in H_j. We call the sets H_j hierarchy levels.

A assignment for the set of constraints is a function that maps variables in the constraints to elements in the domain D over which the constraints are defined. A solution to the constraint hierarchy is a set of assignments for the variables in the hierarchy such that any assignment in the solution set satisfies at least the required constraints, i.e., the constraints in H_0, and, in addition, it satisfies the non-required constraints, i.e., the constraints in H_i for i>0, at least as well as any other assignment that also satisfies the required constraints.

3. CP-NETWORKS

CP-networks were introduced as a tool for compactly representing qualitative preference relations[3]. First it consist of a set of features, {A,B,C,…}.Each feature can have a finite domain of values. Without loss of generality, we assume features have just two possible values (true or false), written a or a'. The user has a preference ranking, a total preorder>on assignments of values to features.

Example 3.1 Consider the CP-network N with the CPT: a>a' , b>b', (a ∧ b') ∨ (a' ∧ b):c>c', c: d>d'.

a>a' is n unconditional preference statement, it has the semantics that whatever values are taken by the other features, we will prefer an assignment to A of a over a'. c:d>d' is a conditional preference statement, it has the semantics that having assigned a to A, we will prefer an assignment of b to B over b'.

One important question is whether one assignment is better than another, i.e. a dominance query[3], we employ another semantics[5].A refined notation of dominance would consider all the features that are at the same level w.r.t the hierarchy included by the preference statements.

Definition 3.1 Assume the CP-networks N is acyclic, the corresponding hierarchy N_H consists of n levels: level 1 is the node (feature) with an indegree of zero, and level 2 is the node whose father nodes are in level, until level n, there no other nodes remained.

Definition 3.2 Consider one acyclic CP-network N and it's hierarchy N_H, s_1 and s_2 are two assignment, we say s_1 dominates s_2, written as $s_1 \rhd s_2$, iff started at the highest level, its assignments win on the majority at the same level, we call this the majority lexicographic order.

Example 3.2 See the CP-network in example 3.1, the corresponding hierarchy is $N_H=\{l_1:<A,B>,\ l_2:<C>,l_3:<D>\}$, consider two assignment s_1=ab'cd and s_2=a'bc'd', and $s_1 \triangleright s_2$.

4. MAPPING CP-NETWORKS TO CONSTRAINT HIERARCHIES

Thanks to Rossi[4], whose study enlightens us on the connection with constraint hierarchy, we can transform a cyclic CP-networks N to the constraint hierarchy CH_N, following show the procedure with pseudocode.

Trans(N_H, CH_H)

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for i=1 to k do
    H_i= Ø;
    for every feature in l_i do
        consider the preference statement about feature A_i ;
        if its form is a_i>a_i' then H_i=H_i ∪ {X_ai=a_i}
        else if its form is b_i∧…: a_i>a_i' then H_i=H_i ∪ {X_bi=b_i∧…∧X_ai=a_i}
        else if its form is (b_i∧b_j…) ∨…: a_i>a_i'
                         then H_i=H_i ∪ {(X_bi=b_i∧X_bj=b_j…∧X_ai=a_i) ∨…}
    enddo
   i=i+1;
enddo
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Given a cyclic CP-networks N and its hierarchy N_H, after running the procedure, we get the constraint hierarchy, thus reasoning about CP-networks i.e. solving of the constraint hierarchy.

Example 4.1 The constraint hierarchy of the CP-networks in example 3.1 is: $H_1=\{X_A=a,\ X_B=b\};H_2=\{(X_A=a \wedge X_B=b' \wedge X_C=c') \vee (X_A=a' \wedge X_B=b \wedge X_C=c')\}$; $H_3=\{X_C=c \wedge X_d=d\}$

We can use the comparator to compare two assignments. for the sake of keep identical semantics of CP-network, we define a global comparator.

Definition 4.1 Let c be a constraint and θ is a assignment, the expression $c\theta$ is the boolean result of applying θ to c, the trivial error function $e(c\theta)$ is defined: $e(c\theta)=0$, if $c\theta$ holds, otherwise $e(c\theta)=1$.

Definition 4.2 If a assignment θ is better than σ, written as $\theta \succ \sigma$, there is level k in the constraint hierarchy such that for i<k, $g(E(H_i\theta))=g(E(H_i\sigma))$,and at level k, $g(E(H_i\theta)) < g(E(H_i\sigma))$, where < is a lexicographic ordering, E is the form of e operate on the constraints set, and g is sum-better combining function, $g(v)= \Sigma v_i$, $i=1,\cdots,|v|$, v is a vector.

Example 4.2 See the hierarchy in example3, given two assignment, $\theta_1=\{X_A=a,\ X_B=b',\ X_C=c,\ X_D=d\}$ and $\theta_2=\{X_A=a',\ X_B=b,\ X_C=c',\ X_D=d'\}$, using the trivial error function, we get two vectors <<0,1>,<1>,<0>> and <<1.0>,<0>,<1>>, then using the sum-better global comparator we get <1,1,0> and <1,0,1>, show that $\theta_1 \succ \theta_2$.

Theorem 4.1 The constraint hierarchy CH_H generated from an acyclic CP-networks N, is an information preserving of it, i.e. for each pair of assignments s_1 and s_2, we have $s_1 \rhd s_2 \Rightarrow s_1 \succ s_2$.

5. CONCLUSION

There are another approaches, e.g. combining the CP-networks with semiring-based CSPs[5,6] and logic programming framework[7], and etc. [5]provides the connection between the CP-nets and soft constraints machinery. But as far as the semiring-based CSPs itself is concerned, efficient algorithms are still under development. The work presented in [7] based on a reduction to the problem of computing stable models for nonmonotonic logic programs, thus provide a new techniques for computing optimal outcomes. Furthermore, we will combine our approaches with HCLP, which would be comparable with the work in [7].

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