More than the sum of its parts: compact preference representation over combinatorial domains

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Abstract

In this dissertation we present a framework for compactly representing cardinal preferences over combinatorial domains and show the feasibility of using this framework for auctions and voting.

Our framework uses goalbases—sets of weighted propositional formulas—to represent utility functions. We compute the utility of an alternative as the aggregated value of the weights of the goals the alternative satisfies. Goalbase languages are formed by restricting the formulas and weights which may appear in goalbases. Due to their parametric nature, these languages are scattered all across the representational landscape. In order to make practical use of goalbases, we must first know the lay of the land. In particular, we explore the landscape of goalbase languages in three directions:

Expressivity: Given a goalbase language, what utility functions are representable in it? Many goalbase languages with natural definitions correspond exactly to classes of utility functions having well-known properties. Furthermore, we show that some goalbase languages have precisely one representation for any representable utility function, and provide methods for finding these representations.

Succinctness: Given two goalbase languages, are the smallest representations in one significantly smaller than equivalent smallest representations in the other? We systematically compare more than two hundred pairs of languages to determine which languages are more succinct.

Complexity: Given a goalbase language, how difficult is it to answer queries about goalbases which are its members? We consider the computational complexity of finding optimal states for individuals and groups, and finding pessimal states for individuals. These problems tend to be intractable for more expressive languages; for those which are solvable in polynomial time, we provide algorithms demonstrating that.
After determining the properties of many goalbase languages, we consider two possible applications of them:

**Combinatorial Auctions:** Combinatorial auctions cannot generally be conducted without concise bidding languages. Goalbase languages may be used as bidding languages, and are sometimes more and sometimes less succinct than bidding languages already in use. We give an integer programming formulation of the Winner Determination Problem using goalbases as bids, as well as branch-and-bound heuristics for solving the WDP directly, and present experimental results which demonstrate the feasibility of using goalbase languages for auctions of moderate size.

**Voting:** We consider the problem of insufficiently expressive voting methods, and suggest voting with goalbases as ballots as a possible remedy. Common single-winner voting methods do not extend well to multi-winner settings like committee elections due to interactions between candidates. We suggest an extension to Approval Voting, where properties of the outcome are approved (or not) rather than particular outcomes as in standard Approval Voting.

In summary, this dissertation provides a clear view of the power of goalbase languages for preference representation, and points to potential areas of application.