Agent Aware Organizational Design

(Doctoral Consortium)

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ABSTRACT

I study creation of multiagent organizations via an automated computational process. My organizational design problem frames design decisions in terms of the quantitative impact that an organization is expected to have on the agents' reasoning and behaviors. I develop techniques for efficiently solving this problem via incremental search of the organizational design space, and extend my organizational design process to provide supplementary information alongside its design that agents can use to inform organizational adaptions.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Coherence & Co-ordination, Multiagent Systems*

General Terms

algorithms, performance, design, theory

Keywords

organizational design; Dec-MDP

1. INTRODUCTION

As cooperative multiagent systems (MASs) grow in size, interconnectivity, complexity, and longevity, coordinating the reasoning and behaviors of the agents becomes increasingly difficult. One approach to combat these issues is the use of organizations (see Dignum and Padget [4] for a recent overview of such research), which generally speaking provide guidelines to each agent such that, by following its guidelines, an agent can make globally-useful local decisions without have to explicitly reason about the complete joint coordination problem. While the research community has made progress into understanding organizations as related to MASs, surprisingly little work has been done towards a computational formulation of how organizations are created. Rather, prior work has focused on developing organizational modeling languages to enable humans to encode their expert knowledge as an organization [4], or on adaptive processes to allow (typically implicit) organizations to emerge via repeated interactions with the environment [2].

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In my research, I study how to create organizations via an automated organizational design process (ODP). I characterize organizational design as search, and define the search space (i.e., the organizational design space) by leveraging the agents' reasoning framework to provide a principled organizational specification language. To measure the quality of a candidate organizational design, I again leverage the agents' reasoning framework, this time to construct quantitative performance metrics based on the expected impact that an organization will have on the agents' reasoning and behaviors. Unsurprisingly, analysis of the organizational design space reveals that creating a provably optimal organizational design is computationally intractable, and thus I develop techniques for improving the efficiency of my ODP via approximating the incremental impact of an individual organizational influence. Finally, I look at how an ODP can inform agents' organizational adaptation decisions (e.g., in the event there is a mismatch between the ODP's expectations and the actual execution environment) by providing second-order information about its organizational design

2. ORGANIZATIONAL DESIGN PROCESS

In contrast to prior, problem-centric approaches where organizational design is viewed as decomposing and solving a problem as a MAS [4], my agent-centric approach views organizational design as influencing agents' reasoning and behaviors to impart desirable coordination patterns upon a MAS. The idea is that, by grounding decisions in the agents' reasoning and behaviors, an ODP can reason about the expected performance of candidate organizations in a principled, quantitative fashion that directly mirrors how the organization is expected to impact the MAS in the execution environment. My methodology for creating an organizational specification language follows from this philosophy. First, I commit to a specific agent reasoning framework, in this case I have elected to use the decentralized Markov decision process (Dec-MDP) due to its generality for a wide range of problem domains, and its principled, well-understood mathematical formalism [1]. Then, I use the formalism of the decided-upon reasoning framework to enumerate the ways in which an organizational design could possibly influence the agents, which defines my organizational specification language. For the case of Dec-MDPs, the specification language consists of influences to the agents' state representations, action spaces, transition/reward functions, etc. [6, 7].

To search through the space of organizational designs (as defined by the organizational specification language), an ODP needs a way to measure the quality of candidate

organizations. Since my specification language is directly derived from the agents' reasoning framework, by definition an organizational influence has principled impact on the agents and can be directly measured by an ODP. For example, in the Dec-MDP framework, an organizational influence (that for example modifies an agent's action space) has well-defined effects on the agents' expected reward and/or the number of states and edges in their planning problems. Using these performance metrics, an ODP can search through the space of organizational designs to find the (approximately) optimal organization that has the largest expected, long-term benefit to the MAS.

My ODP approach makes heavy use of a global perspective of the domain model to construct an organizational design, which implies that if the ODP's model is inaccurate (e.g., the agents possess individual expertise, the dynamics of the problem domain are non-stationary, etc.) then the ODP's design could be poorly suited for the actual execution environment. I mitigate this concern in two ways: by avoiding micromanagement of the agents, and by supporting organizational adeptness. Prior research [5] has identified that providing abstract influences as opposed to detailed micromanagement can yield more robust organizations. For my ODP approach, I have shown that focusing on influences to the possible inter-agent dependencies prevents the ODP from micromanaging the agents [7].

The second method I investigate to mitigate the effect of ODP-model inaccuracies is organizationally adept agents [3], agents who use second-order information about their organization to intelligently reason about adaptations to their current organization. The focus of my research, in this aspect, is on how an ODP can supply the necessary supplementary information alongside an organization to enable such agent adeptness. My approach centers on the observation that an organizational design is conditional on certain expectations, both in that an organization is created based on certain environmental expectations (e.g., domain dynamics, agent capabilities, etc.), and that an organization imparts expectations on the MAS (e.g., task responsibilities, interaction patterns, etc.). So long as the ODP's expectations are met, then the organization it creates is appropriate for the agents and should be followed, and only when the environment deviates from those expectations should the agents make adaptations to their organization. Thus, the supplementary information that an ODP provides should inform the agents of the underlying expectations of the organizational design.

3. FUTURE WORK

While my preliminary investigations have thus far demonstrated the promise of my approach, there are several remaining challenges to overcome. Although it is intuitively reasonable that my organizational specification language defines a principled organizational design space that stems from the agents' reasoning framework, it is not obvious that all of the language constructs are necessary, or if other constructs should be added. Given that I have committed to a specific agent reasoning framework, however, it is possible to analytically prove the necessity and completeness properties of my language (w.r.t. the reasoning framework), which would conclusively define the space of influences my ODP can consider (for my specific agent reasoning framework).

The theoretical worst case complexity of my organizational design problem is exceptionally high, ($O(|\pi|!)$ for a joint policy space with cardinality $|\pi|$), meaning that efficient approximation algorithms are important for practical application of my methods. To date, I have identified several general purpose properties than can simplify organizational design search. For example, if an ODP can compute the incremental impact of an individual organizational influence (rather than wholesale evaluation of a candidate organization's performance), then it can embed those calculations within incremental search algorithms (e.g., greedy hill climbing, Monte Carlo, A*, etc.). While the incremental impact of an organizational influence is well-defined by the agents' reasoning framework, *efficiently* computing this information is non-trivial since the incremental impact of an influence is conditional on the current candidate organization. My research has revealed how to make these incremental calculations independent of the current candidate organization for action influences (which allows an ODP to efficiently search through the action influence space), but more work remains to extend my ODP to efficiently search through the remaining influence forms.

In principle, an ODP could provide all of its expectations alongside an organizational design, and let the agents figure out which of the expectations are important and which have insignificant consequence. This could be undesirable, however, if the number of expectations is large, as is likely to be the case since the ODP has an expectation associated with each transition (of which there are $O(S_i \times A_i \times S_i \times n)$), each reward (of which there are $O(S_i \times A_i \times S_i \times n)$), imparted behaviors (of which there are $O(A_i^{S_i{}^n})$), etc. Thus, rather than simply providing the agents with all of the organizational expectations, and ODP should limit the second-order information it provides to only that which is useful for the agents in determining how they should adapt their organization. In the final aspect of my dissertation, I plan to characterize which expectations are important for an ODP to supply alongside its design, so as to allow the agents to intelligently adapt their organization in response to the environment.

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