Policies for common awareness in organized settings

Ioannis Partsakoulakis and George Vouros

Department of Information and Communication Systems Engineering
83200 Karlovassi, Samos, Greece
{jpar,georgev}@aegean.gr

Abstract. Groups of collaborative agents need to create group beliefs (*acceptances*) in order to act as a single entity. The notion of mutual or collective belief, which has been used extensively to cope with group belief, is not appropriate in organized settings where group members exploit shared policies to *accept* that certain states hold, even if some members of the group do not believe them. This paper distinguishes between beliefs and acceptances, introduces policies for acceptances, and investigates communication requirements towards forming acceptances.

1 Introduction

The objective of this research is to build multi-agent systems that form the digital analogues of human organizations and help humans to fulfil their responsibilities individually or in collaboration with other colleagues in well-organized settings [8, 6]. Investigating the capabilities of agents to fulfill collaborative responsibilities in organized settings, this paper focuses on the formation of acceptances. Acceptance is an important concept that is being studied in the context of philosophy [7, 10]; however, until now it has not been given much attention in the context of multi-agent systems.

Participating in a group, agents must reconcile their individual beliefs and reach group beliefs (*acceptances*) independently of their perceptual and cognitive abilities, permissions to access information sources, knowledge that they posses, preferences etc. Theoretical models of collaborative decision making [1, 2, 4, 9] adopt the notion of collective or mutual belief to cope with group belief. However, in settings where information is inherently distributed and access restrictions to information sources apply, the group belief cannot be based on the individual beliefs of all group members.

The above introduce the problem of representing and exploiting policies for building and maintaining group beliefs. For instance, in certain settings, group members must be able to exploit policies that state that the group shall accept something only if the majority of the group members believe it, although there may be group members with a different opinion. More than policies, the above example

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reveals the necessity for agents to clearly distinguish between their individual beliefs and their acceptances as group members.

This paper distinguishes between acceptances and beliefs, and proposes state recognition recipes for the specification of group policies towards forming acceptances. Based on this distinction, we assume that group members form beliefs using *primitive* state recognition actions (r-actions) and acceptances using state recognition recipes (r-recipes).

Dealing with acceptances in organized settings, this paper deals with groups of agents that follow a pre-specified organizational model specified in terms of roles, as Fig. 1 shows. A role serves as a prototype that specifies the behavior of an individual or of a set of individuals that form a group. In this paper, we assume that each role comprises *responsibilities* and *recipes*, and that roles are interrelated via the transitive relation "*contains*". A position is a formally specified role-assignment [3]. Each role can be associated with one or more positions. We assume that agents under a composite role must act as a single entity by forming acceptances and by managing shared plans [2].

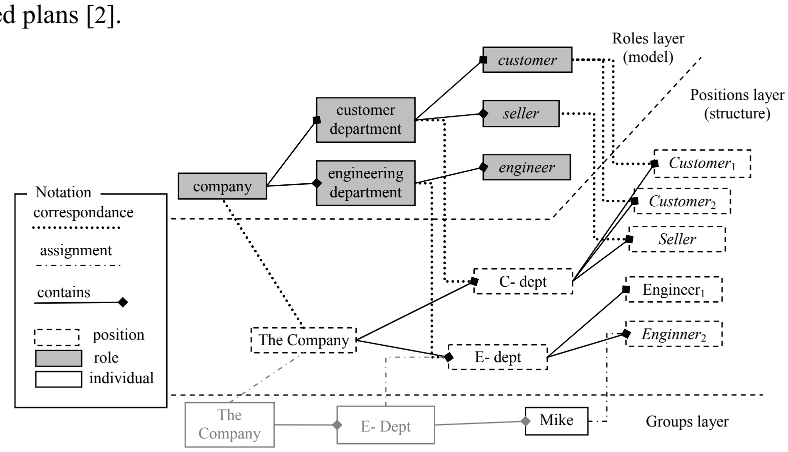

Fig. 1. Part of the organization that represents a company.

A policy about a state *s* is a tree-like structure in which nodes are states and each arc is labelled with an element of the form ρ_{ind} where ρ is a role and *ind* an indicator that can take the value *all*, *most*, or *one*, indicating *all* the players of ρ, *most* of them, or at least *one* of them is required for the formation of an acceptance for the state *s*. A policy for the acceptance of a state is not represented explicitly, but it is constructed gradually by combining r-recipes towards the recognition of states.

For example, the policy in Fig. 2 has been constructed by the two recipes in the corresponding rectangles and specifies that a company shall accept that there is a pending order of a customer *c* about product *p* (i.e. pending-order(*p*,*c*)) when it is known that (a) all sellers believe the fact that the order is pending and (b) customer *p* wants product *c*. Sharing the above policy, each agent in a company is aware of the information needed towards accepting a state and proactively communicates this information.

Given a policy for a state *s*, a *potential* (or *required) contribution* of an agent to the state *s* is a path from *s* to a leaf node in the policy, if the edge leading to this node corresponds to an atomic role played by the agent. Each agent computes all its *personal contributions* by identifying its potential contributions and by unifying the leaf states with its beliefs. In other words, personal contributions are instantiated potential contributions identified by individuals.

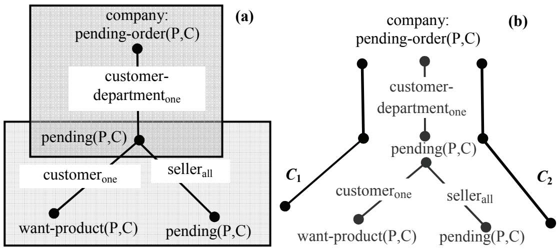

Fig. 2. A policy and group contributions C_1 and C_2 that match potential (required) contributions.

Personal contributions are communicated between agents that play the same atomic role (e.g. between sellers). Personal contributions that are identified by a sufficient number of agents (according to policy indicators) are called *group contributions* because they can affect the acceptances of a group. Group contributions are communicated between the agents that share the same policy (e.g. between sellers and customers). This makes possible for the agents to check whether for each of the potential (required) contributions of a policy there is a corresponding group contribution (as Figure 3(b) shows). When this condition holds, then the state *s* is considered to be a state that must be accepted by all group members that share the policy. Therefore, the state *s* is communicated to all group members (including those not sharing the recipe) as an acceptance.

3. Communication requirements

To study communication requirements for the formation of acceptances, let us assume that a group has *n* agents each playing one of *m* primitive roles and that each role has *k* players, therefore $n = k \cdot m$. Given a group policy with a required contribution for *each* primitive role we can distinguish between two extreme cases: (a) the policy requires the contribution of *all* the agents that play the corresponding primitive roles and (b) the policy requires the contribution of *one* of the agents that play the corresponding primitive roles.

In the first case, each agent must send its personal contribution to each of the k–1 agents that play the same role. This requires $n(k–1)$ messages. Then, each group contribution identified by each agent must be sent to the rest n–1 of the agents. In the worst case this requires $n(n–1)$ messages. The same number of messages is required for the formation of the acceptance. So, there is a total of $n(k–1)+2n(n–1)$ messages which results to $3n(n–1)$ messages, given that $k = n$. In the best case, only one agent for each primitive role will communicate the group contribution to the other agents (requiring $m(n–1)$ messages) and one agent will communicate the acceptance to the others (requiring n–1 messages). So, in the best case the formation of an acceptance requires $(k+m)n-m-1$ messages. Since the product $k \cdot m = n$ is constant, the quantity $k+m$ is minimized when $k = m = n^{1/2}$; therefore, the minimum total number of messages is of magnitude of $n^{3/2}$.

In the second case, agents do not need to communicate their personal contributions since each personal contribution is a group contribution. In this case, the worst case scenario requires $2n(n-1)$ messages while the best case scenario requires $2(n-1)$ messages for the formation of an acceptance.

To achieve the best-case in both of the above cases, agents may need to delay sending the recognition of group contributions. In this case, we can achieve lower communication overhead, although we cannot guarantee that we will always achieve the number of messages encountered in the best-cases.

Counting the number of messages required we have assumed a totally distributed setting: There is not a specific agent (e.g. a special seller or the manager of the selling department) that gathers all personal/group contributions, decides and communicates the formed acceptances. Given such a setting, then the required messages in the first case (where the contributions of all agents are needed), for the worst and the best scenario, drops to $2(n-1)$. In the second case (where only one agent is needed), the worst scenario (that results for $m = n$) requires $2(n-1)$ messages, while the best scenario (that results for $m = 1$) requires $n-1$ messages.

Currently, we have implemented a prototype system in which agents can reason about and pursue their responsibilities and we are also experimenting with different algorithms for creating acceptances and for pursuing responsibilities [5, 6].

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