Computational Theories of Collaboration

PH.D. COMPREHENSIVE EXAM

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1 Introduction to Collaboration Theories

To be collaborative, partners, e.g., a robot and a human, need to meet the specifications stipulated by some theories that we review in this document. As we discuss in Section 2.2, collborators need to commit to the group activity and to their role in it; they need to divide the task load according to their capabilities so they can carry out the individual plans that constitute the group activity; and they need to commit to the success of others. Collaborators also need to be able to communicate with others effectively, and to interpret others' actions and utterances in the collaboration context. Furthermore, collaborators need to be willing to help others in doing their own tasks, and to reconcile between commitments to existing collabortion and their other activities [11].

Collaboration is a special type of coordinated activity in which the participants work jointly, together performing a task or carrying out the activities needed to satisfy a shared goal [14].

Existing collaboration theories (including SharedPlans) consider the nature of a collaboration to be more than a set of individual acts. These theories argue for an essential distinction between a collaboration and a simple interaction or even a coordination in terms of commitments [9, 20].

2 Computational Theories of Collaboration

There are prominent collaboration theories that are mostly based on plans and often analysis of the discourse between collaborators revolving around these plans [16, 19]. In these theories the discourse analysis is based on search over these tree plans [27].

2.1 Theory of Joint Intentions/Teamwork

There are also some other theories with similarities and contrasts conveying collaboration concepts including Cohen and Levesque's work describing the concept of *joint intentions* in [5, 18].

2.2 SharedPlans Theory

2.2.1 Communicating Intentions

Using discourse plans can help to encode the knowledge about conversation.

The SharedPlans theory recognises three interrelated levels of discourse structure.

In [16], Grosz and Sidner argue that the components of the discourse structure are a trichotomy of linguistic structure, intentions structure and the attention state. In their work, the linguistic structure of a discourse is a sequence of utterances aggregating into discourse segments just as the words in a single sentence form constituent phrases. They also discuss the idea of the discourse purpose as the intention that underlies engagement in the particular discourse. They believe this intention is the reason behind performing a discourse rather than some other actions, and also the reason behind conveying a particular content of the discourse rather than some other contents. They describe mechanisms for plan analysis looking at Discourse Segment Purposes (DSPs). In fact, the DSPs specify how the discourse segments contribute to achieving the overall discourse purpose. Finally, the third component in their theory, the attentional state, provides an abstraction of the agent's focus of attention as the discourse unfolds. The focusing structure contains DSPs and the stacking of focus spaces reflects the relative salience of the entities in each space during the discourse. In short, the focusing structure is the central repository for the contextual content required for processing utterances during the discourse [16].

2.2.2 Collaboration Vs. Sum of Coordinate Actions

[10]

2.2.3 SharedPlans

Grosz and Sidner [16] Grosz and Kraus [14]

The SharedPlans model of collaborative action [13] [14] [16] aims to provide the theoretical foundations needed for building collaborative robots/ agents [10]. It specifies four key characteristics for participants in a group activity to be collaborative partners, and thus for their joint activity to be collaborative. The SharedPlans definition states that for a group activity to be collaborative, the collaborators must have:

a) intentions that the group perform the group activity;

b) mutual belief of a (partial or complete) recipe;

c) individual or group plans for the constituent subactions of the recipe;

d) intentions that their collaborators succeed in doing the constituent subactions.

In other words, to successfully complete a plan the collaborators must mutually believe that they have a common goal and have agreed on a sequence of actions for achieving that goal. They should believe that they are both capable of performing their own actions and intend to perform those actions while they are committed to the success of their plans.

The intentions that this definition specifies constitute different kinds of commitments required of the collaborators.

2.2.4 Intention-to and Intention-that

Intention to ...

In contrast with *intention to*, an *intention that* does not directly connote an action. Rather it implies that agents will behave in a manner consistent with a collaborative effort: they won't adopt intentions that conflict with the joint activity, and they will adopt intentions to communicate about the plan [14]. Communication requirements are derived from any intention that's, as opposed to being "hard-wired" in Joint Intentions.

2.2.5 Recipes

The SharedPlans definition of mutual beliefs states that when agents have a shared plan for doing some act, they must hold mutual beliefs about the way in which to perform that act. Following Pollack [25], the term recipe refers to what collaborators know when they know a way of doing something. Recipes are specified at a particular level of detail. Hence, the agents need to have mutual beliefs about acts specified at the particular level of detail of the recipe, and they do not to have mutual beliefs about all levels of acts that each agent will perform. Mutual belief of the recipe essentially means that all the collaborators hold the same beliefs about the way in which the activity will be accomplished. Therefore, the collaborators must agree on how to do the activity. Grosaz and Sidner in their earlier work [16] have considered only simple recipes in which each recipe consisted of only a single act-type relation [21]. Recipes are aggregations of act-types and relations among them. Act-types, rather than actions, are the main elements in recipes.

Finally, the definition of the overall plan in terms of constituent plans of individuals or groups is recursive, with the recursion ending at the level of basic, individual actions [11].

Grosz, Sidner and Lochbaum in [16] and [21] present a model of plans to account for how agents with partial knowledge collaborate in the construction of a domain plan. Agents have a library of partially speci ed plan schemas (recipes). These recipes might be underspeci ed as to how an action is executed or how an action contributes to a goal. Agents then collaborate in constructing a shared plan by uttering statements about their beliefs and intentions about the plan. This collaboration will terminate with each agent mutually believing that each act in the plan can be executed by one of the agents, that that agent intends to perform the act, and that each act in the plan contributes to the goal.

Shared plan is another essential concept in the collaboration context. The definition of the shared plan is derived from the definition of plans Pollack introduced in [24, 25] since it rests on a detailed treatment of the relations among actions and it distinguishes the intentions and beliefs of an agent about those actions. However, since Pollack's plan model is just a simple plan of a single agent, Grosz and Sidner extended that to plans of two or more collaborative agents. The concept of the shared plan provides a framework in which to further evaluate and explore the roles that particular beliefs and intentions play in collaborative activity [21]. However, this formulation of shared plans (a) could only deal with activities that directly decomposed into single-agent actions, (b) did not address the requirement for the commitment of the agents to their joint activities, and (c) did not adequately deal with agents having partial recipes [14]. Grosz and Kraus in [14], reformulate Pollack's definition of the individual plans [25], and also revise and expand the SharedPlans to address these shortcomings.

2.3 "Hybrid" Collaboration Approaches

Tambe's work on *STEAM teamwork model* [31].

3 Relation to Psychology and Sociology

Referring expressions [17]

4 Similarities and Differences

1. None of SHaredPlans' four components (see Section 2.2) has the notion of a joint intention. This is a significant difference between SharedPlans and Joint Intentions theories, since the notion of joint intention is an integral part of Cohen and Levesque's theory. In particular, SharedPLans theories emphesizes on the agents individually intending that the joint action be done successfully as well as the agents individually intending the success of their collaborators' actions which is introduced in [14] by Grosz and Kraus as the notion of *intention-that*.

5 Application in Human-Computer Collaboration

In [17] Heeman presents a computational model of how a conversational participant collaborates in order to make a referring action successful. The model is based on the view of language as goal-directed behaviour, and in his work, he refers to SharedPlans as part of the planning and conversation literature.

In [21], Lochbaum and Sidner modify and expand the SharedPlan model of collaborative behavior [16]. They present an algorithm for updating an agents beliefs about a partial SharedPlan and describe an initial implementation of this algorithm in the domain of network management.

There are many research focusing on different aspects of collaboration each of which are different than my own work. In my thesis, I focus on emotion functions and how they impact collaboration's structure and processes, and how the dynamics of the collaboration structure influences emotion-regulated processes. Some of the other works focus on the concepts of robot assistants [4], or teamwork and its challenges in cognitive and behavioral levels [5, 23, 28, 31]. Some researchers have an overall look at a collaboration concept at the architectural level. In [7] authors present a collaborative architecture, COCHI, to support the concept of emotional awareness. In [6] authors present the integration of emotional competence into a cognitive architecture which runs on a robot, MEXI. In [30] authors discuss the challenges of integrating natural language, gesture understanding and spatial reasoning of a collaborative humanoid robot situated in the space. The importance of communication during collaboration has been considered by some researchers from human-computer interaction and human-robot collaboration [3, 22, 27] to theories describing collaborative negotiation, and discourse planning and structures [1, 15, 29]. There are other concepts such

as joint actions and commitments [12], dynamics of intentions during collaboration [18], and task-based planning providing more depth in the context of collaboration [2, 26].

The concept of collaboration has also received attention in the industry and in research in robotic laboratories [8].

6 Conclusion

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