RESEARCH STATEMENT

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My current research span the areas of computational collaboration theories, affective computing, human-robot collaboraiton, and cognitive robotics. A common thread in my research is in developing a theory (Affective Motivational Collaboration Theory), design of a domain-independent architecture, and the framework which uses this architecture to provide a collabortive behavior for robots or vritual agents. I have resorted to prominent computational collaboration theories, i.e., SharedPlans theory, and computaitonal models of emotions, i.e., cognitive appraisal theory to develop my own theory. Broadly speaking, my research belongs to the area of human-robot collaboration and its underlyign processes, a growing field which has influence on different leading industries such as autonomous vehicles, space exploration, manufacturing, and any industry including situation inwhich human-robot teamwork is required.

Background - Collaboration Theories

The construction of robots that are intelligent, collaborative problem-solving partners is important in robotics and applications of Artificial Intelligence. It has always been important for us to make robots better at helping us to do whatever they are designed for. To build collaborative robots, we need to identify the capabilities that must be added to them so that they can work with us or other agents. As Grosz says, collaboration must be designed into systems from the start; it cannot be patched on [12]. Collaboration is a special type of coordinated activity in which the participants work together performing a task or carrying out the activities needed to satisfy a shared goal [15].

Collaboration involves several key properties both in structural and functional levels. For instance, most collaborative situations involve participants who have different beliefs and capabilities; most of the time collaborators only have partial knowledge of the process of accomplishing the collaborative activities; collaborative plans are more than the sum of individual plans; collaborators are required to maintain mutual beliefs about their shared goal throughout the collaboration; they need to be able to communicate with others effectively; they need to commit to the group activities and to their role in it; collaborators need to commit to the success of others; they need to reconcile between commitments to the existing collaboration and their other activities; and they need to interpret others' actions and utterances in the collaboration context [13]. These collaboration properties are captured by the existing computational collaboration theories.

As I mentioned, to be collaborative, partners, e.g., a robot and a human, need to meet the specifications stipulated by collaboration theories. These theories argue for an essential distinction between a collaboration and a simple interaction or even a coordination in terms of commitments [11, 20]. The prominent collaboration theories are mostly based on plans and joint intentions [4, 16, 19], and they were derived from the BDI paradigm developed by Bratman [2] which is fundamentally reliant on folk psychology [22]. The two theories, Joint Intentions [4] and SharedPlans [16], have been extensively used to examine and describe teamwork and collaboration.

SharedPlans theory - The SharedPlans model of collaborative action, presented by Grosz and Sidner [14, 15, 16], aims to provide the theoretical foundations needed for building collaborative robots/agents [12]. SharedPlans is a general theory of collaborative planning that requires no notion of joint intentions, accommodates multi-level action decomposition hierarchies and allows the process of expanding and elaborating partial plans into full plans. SharedPlans theory explains how a group of agents can incrementally form and execute a shared plan that then guides and coordinates their activity towards the accomplishment of a shared goal. SharedPlans is rooted in the observation that collaborative plans are not simply a collection of individual plans, but rather a tight interleaving of mutual beliefs and intentions of different team members.

Joint Intentions theory - Following Bratman's guidelines, Cohen and Levesque propose a formal approach to building artificial collaborative agents. The Joint Intentions theory of Cohen and Levesque [4, 5, 6, 7, 18] represents one of the first attempts to establish a formal theory of collaboration, and due to its clarity and expression, is a widely used teamwork theory. The basic idea of Joint Intentions theory is based on individual and joint intentions (as well as commitments) to act as a team member. Their notion of joint intention is viewed not only as a persistent commitment of the team to a shared goal, but also implies a commitment on part of all its members to a mutual belief about the state of the goal. In other words, Joint Intentions theory describes how a team of agents can jointly act together by sharing mental states about their actions while an intention is viewed as a commitment to perform an action. A joint intention is a shared commitment to perform an action while in a group mental state [5].

STEAM - Tambe in [29] argues that teamwork in complex, dynamic, multi-agent domains requires the agents to obtain flexibility and reusability by using integrated capabilities. Tambe created STEAM (simply, a **S**hell **TEAM**work) based on this idea. STEAM's operationalization in complex, real-world domains is the key in its development to addressing important teamwork issues. STEAM is founded on the Joint Intentions theory and it uses joint intentions as the basic building block of teamwork while it is informed by key concepts from SharedPlans theory.

I believe the SharedPlans and Joint Intentions collaboration theories are the most well-defined and well-established theories in computer science. I found SharedPlans theory more convincing than the other major and subordinate approaches, with respect to its inclusive explanation of the collaboration structure and its association to discourse analysis which directly improves the communicative aspects of a collaboration theory. I also understand the value of Joint Intentions theory due to its clarity and closeness to the foundations of collaboration concepts. These specifications of the Joint Intentions theory can make it applicable in multi-agent system designs and human-robot collaboration. I also consider hybrid approaches valuable, such as STEAM, if they clearly understand drawbacks with existing theories and successfully achieve better collaborative agents by infusing different concepts from different theories.

Background - Cognitive Appraisal Theory

According to Picard [21], the term affective computing encapsulates a new approach in Artificial Intelligence, to build computers that show human affection. Studies show that the decision making of humans is not always logical [10], and in fact, not only is pure logic not enough to model human intelligence, but it also shows failures when applied in artificial intelligence systems [8]. Emotions impact fundamental parts of cognition including perception, memory, attention and reasoning [3]. This impact is caused by the information emotions carry about the environment and event values. If we want robots and virtual agents to be more believable and efficient partners for humans, we must consider the personal and social functionalities and characteristics of emotions; this will enable our robots to coexist with humans, who are emotional beings.

Cognitive Appraisal Theory - There are different types of computational theories of emotion. These theories differ in the type of relationships between their components and whether a particular component plays a crucial role in an individual emotion. Appraisal theories of emotion were first formulated by Arnold [1] and Lazarus [17] and then were actively developed in the early 80s by Ellsworth and Scherer and their students [23, 24, 25, 27, 28]. The emotional experience is the experience of a particular situation [9]. Appraisal theory describes the cognitive process by which an individual evaluates the situation in the environment with respect to the individual's well-being and triggers emotions to control internal changes and external actions. According to this theory, appraisals are separable antecedents of emotion, that is, the individual first evaluates the environment and then feels an appropriate emotion [28]. The appraisal procedure begins with the evaluation of the environment according to the internalized goals and is based on systematic assessment of several elements [26]. The outcome of this process triggers the appropriate emotions.

In my Ph.D thesis, I attempt to lay a computational framework for the theory I have developed based on SharedPlans and Cognitive Appraisal theories. A great deal of my work has benefited from the integration of these well-established theories and their underlying structure.

Limitations

Although all the existing collaboration theories are well-defined and properly introduce collaboration concepts, they mostly explain the structure of a collaboration and they lack the underlying domain-independent processes with which collaborative procedures could be defined more systematically and effectively in different applications.

3. Introduce topic and research question

I believe that the evaluative role of emotions as a part of cognitive processes helps an agent to perform appropriate behaviors during a collaboration. It is important to think about the underlying cognitive processes of the collaborators in order to have a better understanding of the role of emotions. To work jointly in a coordinated activity, participants (collaborators) act based on their own understanding of the world and the anticipated mental states of the counterpart; this understanding is reflected in their collaborative behaviors. Emotions are pivotal in the collaboration context, since their regulatory and motivative roles enhance an individual's autonomy and adaptation as well as his/her coordination and communication competencies in a dynamic, uncertain and resource-limited environment. The collaborative behavior of the individuals can also be influenced by the tasks contributing towards a shared goal. Some tasks may be inherently insignificant, boring, unpleasant or arduous for a collaborator. Thus, knowing how to externally motivate other collaborator to perform such tasks becomes an essential skill for a participant in a successful collaboration. Such knowledge enables an individual to lead his collaborator to internalize the responsibility and sense of value for an externally motivated task.

Current Research

In my Ph.D. thesis, I have developed the Affective Motivational Collaboration Theory and the associated computational model that will enhance the performance and effectiveness of collaboration between robots and humans. This theory explains the functions of emotions in a dyadic collaboration and shows how affective mechanisms can coordinate social interactions by anticipating other's emotions, beliefs and intentions. This theory also specifies the influence of the underlying collaboration processes on appraisals. Affective Motivational Collaboration Theory elucidates the role of motives as goal-driven emotion-regulated constructs with which an agent can form new beliefs and intentions to cope with internal and external events. An important contribution of this work is to elucidate how motives are involved not only in the appraisal and coping processes, but how they also serve as a bridge between appraisal processes and the collaboration structure. I will validate my theory using my computational framework in the context of a human-robot collaboration.

5. Synopsis of second part of my work

6. Overview of human study at the end

7. Verification method

8. Say how current research can apply to their research

9. Exaplain why the research is valuable

A Research Agenda

In the course of my research, I have noticed that ...

In the near future, I am interested in the principles involved in the design of basic networking components. These include hardware components (e.g. scalable memories, network processor and co-processor architectures) and software techniques (e.g. network algorithms, packet processing techniques). Simultaneously, I intend to understand how large components, which use the above building blocks can be architected. My research will focus on how these basic and large components can be built in a scalable manner while maintaining performance guarantees. In particular, examples of large components that I have a keen interest in are switches (e.g. packet and circuit switches, multi-service routers etc.), security devices (e.g. firewalls and intrusion detection systems), network maintenance devices (e.g. measurement, management infrastructure) and application aware devices (e.g. web server load balancers, proxies) etc.

In the future, though performance and scalability will remain key, I also intend to look at issues such as *fault tolerance, graceful degradation, reliability and uptime* of networking systems, which will become more relevant. I also believe that as systems become increasingly large and inter-dependent, *simplicity in design and component re-use* will be major factors. Parallelism can play a key role here.

Indeed, many of our proposed solutions, involve component re-use and parallelism, which can aid and abet the above.

My research will involve a good mix of futuristic and present day research. One part of my work will focus on fundamentally different proposals and radical solutions. As an example — can we finally achieve real-time streaming over the Internet, assuming that the various network components give performance guarantees? In contrast, I intend to devote the other part of my work on practical systems, which have immediate relevance and impact in Industry. I intend to work closely with a number of researchers in related fields. Similarly, I intend to collaborate with Industry in understanding and developing solutions for practical problems. I believe my past experience of research work done jointly with a number of of colleagues as well as my prior record of participation with Industry will help me achieve this. I am excited at the prospect of learning, contributing, giving shape and making an impact in this upcoming and challenging field.

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