

# Expectedness in human-robot collaboration

## (Extended Abstract)

Mahni Shayganfar, Charles Rich, Candace L. Sidner  
Worcester Polytechnic Institute  
100 Institute Road  
Worcester, Massachusetts  
mshayganfar, rich, sidner@wpi.edu

### ABSTRACT

We have investigated the mutual influences of affective and collaborative processes in a cognitive theory to support interaction between humans and robots or virtual agents. We build primarily on the *cognitive appraisal* theory of emotions and the *SharedPlans* theory of collaboration to investigate the structure, fundamental processes and functions of emotions in a collaboration. We have developed new algorithms for appraisal processes as part of a new overall computational model. In this paper, we provide the *expectedness* appraisal algorithm for collaboration context. We have evaluated our implemented algorithm by conducting an online user study.

### Keywords

Algorithms; Appraisal; Human-Robot Collaboration

## 1. INTRODUCTION

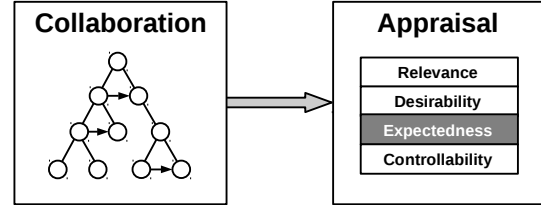
Collaborative robots are expected to become an integral part of humans' environment to accomplish their industrial and household tasks. In these environments, humans will be involved in robots' operations and decision-making processes. The involvement of humans requires the robots to evaluate the collaborative environments and maintain the collaboration respectively.

This work is implemented as part of a larger effort to build robots capable of generating and recognizing emotions in order to be better collaborators. In this paper, we report on the specific problem of appraising the expectedness of events within a collaborative interaction. Our contribution is to ground general appraisal concepts in the specific context and structure of collaboration. This work is part of the development of *Affective Motivational Collaboration Theory* [6] which is built on the foundations of the *SharedPlans* theory of collaboration [3] and the *cognitive appraisal* theory of emotions [2].

There are several appraisal models (e.g., EMA [5]) contributing in different applications such as social sciences, virtual agents, and robotics. However, none of these models have focused on the appraisal processes during collaboration. We believe appraisal plays a key role in collaboration

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**Figure 1: Influence of Collaboration on Appraisal (mechanisms in our framework).**

due to its regulatory and evaluative nature. Also, collaboration induces some changes to underlying appraisal processes due to its unique nature.

The computational collaboration model in our work is strongly influenced by the *SharedPlans* theory [3]. However, our algorithms are also compatible with other collaboration theories, e.g., Joint Intentions theory [1]. These theories have been extensively used to examine and describe teamwork and collaboration. Yet, collaboration and emotion theories have never been combined, as they are in our work. We believe a systematic integration of collaboration theories and appraisal theory can help explain the underlying processes of collaboration structure.

## 2. COLLABORATION

The Collaboration mechanism constructs a hierarchy of goals associated with tasks in a hierarchical task network (see Figure 2), and also maintains the constraints and other required details of the collaboration including the inputs and outputs of individual tasks, the *preconditions* (specifying whether it is appropriate to perform a task), and the *postconditions* (specifying whether a just-completed task was successful). Collaboration also monitors the focus of attention, which determines the salient objects, properties and relations at each point, and shifts the focus of attention during the interaction.

- *recognizeGoal( $\epsilon_t$ )* returns the unique goal to which the given event (action, utterance, or emotional expression) directly contributes; it is only one goal since the robot can only do one primitive action at a time in our collaboration model, i.e., in the goal tree, a given primitive action can only directly contribute to one parent goal. The method returns *ambiguous* if it does not recognize a goal in the plan<sup>1</sup>.
- *getTopLevelGoal( $g_t$ )* returns  $g_t$ 's top level goal.

<sup>1</sup>Ambiguity introduces some extra complexities which are beyond scope of this paper.

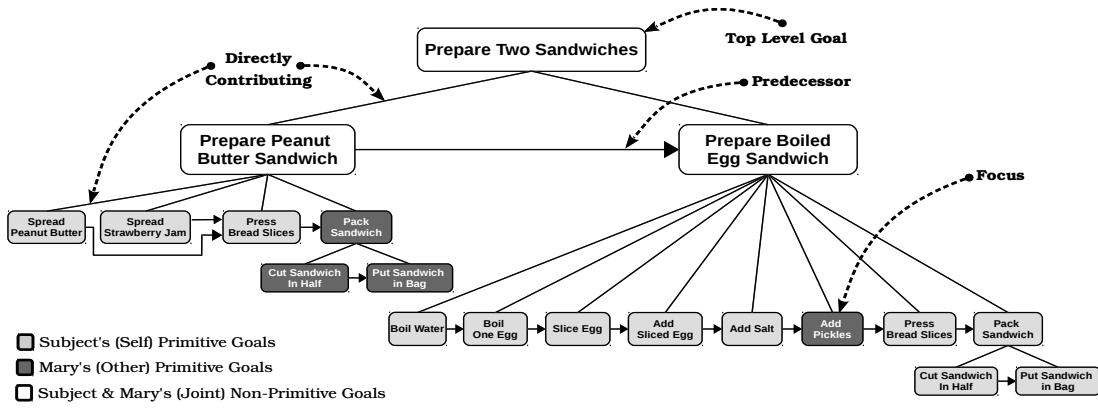


Figure 2: Example of collaboration structure (also used as task model for the evaluation).

- $isLive(g_t)$  returns *true* if all the predecessors of  $g_t$  are ACHIEVED and all the preconditions are SATISFIED, i.e., PENDING or IN PROGRESS goals; otherwise returns *false*.
- $isFocusShift(g_t)$  returns *true* if the given goal is not the previous focus (top of the stack); otherwise returns *false*.
- $isNecessaryFocusShift(g_t)$  returns *true* if the status of the previous focus was ACHIEVED; otherwise returns *false* [4].
- $isPath(g_1, g_2)$  returns *true* if there is a path between  $g_1$  and  $g_2$  in a plan tree structure; otherwise returns *false*.

### 3. EXPECTEDNESS IN COLLABORATION

Expectedness is the extent to which the truth value of a state could have been predicted from causal interpretation of an event [5]. In the collaboration context the expectedness of an event evaluates the congruency of the event with respect to the existing knowledge about the shared goal. Thus, expectedness underlies a collaborative robot's attention. Congruent beliefs in a robot's mental state will lead to more consistent and effective outcomes of the processes in the overall architecture. The collaboration mechanism uses expectedness to maintain the robot's attention and subsequently its mental state with respect to the shared goal. Reciprocally, the appraisal mechanism uses the underlying information of the collaboration structure to evaluate the expectedness of an event. Therefore, a collaborative robot uses expectedness to maintain its own mental state towards the shared goal. The robot will also be able to respond to unexpected but relevant events.

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#### Algorithm 1 (Expectedness)

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1: function ISEVENTEXPECTED(Event  $\varepsilon_t$ )
2:    $g_t \leftarrow recognizeGoal(\varepsilon_t)$ 
3:    $g_{top} \leftarrow getTopLevelGoal(g_t)$ 
4:   if ( $isLive(g_t)$ ) then
5:     if ( $\neg isFocusShift(g_t)$ 
6:        $isNecessaryFocusShift(g_t)$ ) then
7:       return MOST-EXPECTED
8:     else
9:       return EXPECTED
10:  else
11:    if ( $isPath(g_t, g_{top})$ ) then
12:      return UNEXPECTED
13:    else
14:      return MOST-UNEXPECTED

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In Algorithm 1 we provide the process of computing the expectedness based on the shared plan and status of the shared goal. The key point in this algorithm is the status of the current shared goal ( $g_t$ ) that is associated with the event  $\varepsilon_t$  and its relationship with the top level goal ( $g_{top}$ ).

The intuition captured here is that one expects the current goal to be finished before undertaking another activity, but the goals that are the next focus of attention are also to be expected [4]. Therefore, if the goal is live, the algorithm checks whether the goal has not changed, or the interpretation of the last event results in a necessary focus shift. Shifting the focus to a new goal is necessary when the former goal is achieved and a new goal is required. Consequently the new event is the MOST-EXPECTED one. However, even if the focus shift is not necessary, the new event can be considered as EXPECTED, since the corresponding goal is already live. For goals that have not yet been started (that is, are not live), the algorithm must determine how unexpected it would be to pursue one now; if the goal is at least in the plan, i.e., on the path to the top level goal, it is just UNEXPECTED while any others are MOST-UNEXPECTED.

### 4. EVALUATION

### 5. CONCLUSION

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#### REFERENCES

- [1] P. Cohen and H. J. Levesque. *Teamwork*. SRI International, 1991.
- [2] J. Gratch and S. C. Marsella. A domain-independent framework for modeling emotion. *Cognitive Systems Research*, 5(4):269–306, 2004.
- [3] B. J. Grosz and C. L. Sidner. Plans for discourse. In P. R. Cohen, J. Morgan, and M. E. Pollack, editors, *Intentions in Communication*, pages 417–444. MIT Press, Cambridge, MA, 1990.
- [4] N. Lesh, C. Rich, and C. L. Sidner. Collaborating with focused and unfocused users under imperfect communication. In M. Bauer, P. J. Gmytrasiewicz, and

- J. Vassileva, editors, *User Modeling 2001*, volume 2109, pages 64–73. Springer Berlin Heidelberg, 2001.
- [5] S. C. Marsella and J. Gratch. EMA: A process model of appraisal dynamics. *Cognitive Systems Research*, 10(1):70–90, March 2009.
- [6] M. Shayganfar, C. Rich, and C. L. Sidner. An overview of affective motivational collaboration theory. In *Proceedings of AAAI Workshop on Symbiotic Cognitive Systems, Phoenix, Arizona*, 2016.