Impact of Affective Appraisal on Collaborative Goal Management: How My Robot Shares My Worries

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***Abstract*—A collaborative robot needs to be able to regulate and manage shared goals during collaboration. Emotions has crucial influence on goal management process. In this paper, we provide a cost function that we use to choose a goal in the shared plan with the lowest cost value in a set of alternative goals. This cost function provides the cost value a) based on the goal attributes we consider in our framework, b) with respect to the reverse appraisal of the percived emotion, and c) the appraisal of the collaborative environment.**

I. Introduction

Goals represent an important part of the context information during collaboration. However, not all goals are appropriate to pursue in different conditions. In fact, it can be distructive and noncollaborative to pursue a good goal in a wrong context. Therefore, a collaborative robot needs to be able to regulate and manage shared goals during collaboration. Goal management process provides a diverse influence on a collaborative robot's behavior, such as choosing the right goal between available alternatives with respect to the collaboration status, or changing the focus of attention to a different goal at the right time.

Changes in a dynamic collaboration environment alter the balance of alternative goals. These changes can occur as the reflection of collaborators' internal changes, the influence of their actions, or in general, the occurance of any change in the collaborative environment. Most of the times, emotions are the repercussions of the changes in the environment. Emotions have different functions [1]. These functions, e.g., *goal management*, help one to communicate and/or regulate their internal changes as well as changes in their environment. In a collaborative environment, emotions represent the outcome of underlying internal mental processes of the collaborators. Goal-oriented emotions such as anger, frustration and worriedness, constitute the same representation of the mental processes specifically influenced by one's internal goals. Therefore, the reverse appraisal [2] of the collaborator's perceived emotion can impact regulation of the robot's active goals during collaboration. Furthermore, the appraisal of the individual alternative goals provides a better context-dependant assessment of these goals. Hence, we use both appraisal and reverse appraisal in our goal management process.

II. Contribution

In this paper, we focus on small part of a larger architecture framework built based on our *Affective Motivational Collaboration Theory* [3]. We introduce our goal management process based on a cost function including the influence of affective appraisal and reverse appraisal processes. Goal management is a crucial part of our investigation of the reciprocal influence of appraisal on collaboration structure (see Figure 1).

We have investigated the influence of a collaboration structure on appraisal processes, and implemented distinct algorithms for different appraisal processes for a collaborative robot [4]. According to the appraisal theory, the outcome of these processes are separable antecedents of emotion with which the robot evaluates the environment. Our appraisal variables included: a) *relevance* used to measure the significance of an event for the robot, b) *desirability* to characterize the value of an event to the robot in terms of whether the event facilitates or thwarts the collaboration goal, c) *expectedness* and d) *controllability*. The last two appraisal variables are beyond the scope of this paper.

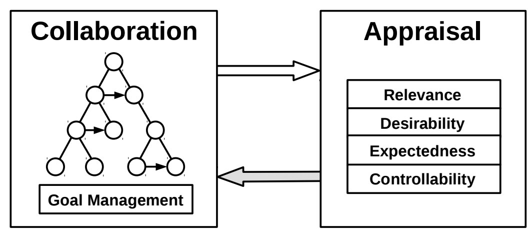

Fig. 1. Reciprocal influence of Collaboration and Appraisal mechanisms in our framework.

The outcome of each appraisal process is a specific value for the corresponding appraisal variable. The vector containing these appraisal variables can be mapped to a particular emotion instance at each point in time. For instance, a *relevant, undesirable, expected*, and *uncontrollable* event can elicit *anger* in an individual. However, it is not the actual emotion instance that is important for us. In fact, it is a) the functions of emotions in a social setting, i.e., *goal management*, and b) the meaning of the collabrator's perceived emotion in collaboration context.

A collaboration structure provides a hierarchy and the constraints of the shared goals in the form of a shared plan (Figure 2) which contains both the robot and human collaborator's goals. The robot pursue's the goal in which the robot is responsible for in the shared plan. However, there can be several goals available for the robot to pursue at each point in time during collaboration. In other words, any "live" goal can be pursued by the robot. A goal is live if all of its *predecessors* are achieved and all of its *preconditions* are satisfied. Therefore, a collaborative robot requires a mechanism to choose between a set of live goals. We believe appraisal processes are crucial to choose between the available live goals; since the appraisals are the immediate outcome of the robot's assessment of the collaboration environment.

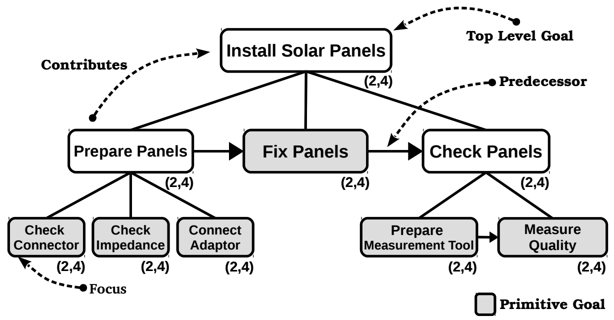

Fig. 2. Astronaut-robot collaboraiton structure (shared plan).

For instance, Figure 2 shows a nonprimitive "Prepare Panels" goal which contains three primitive goals. These primitive goals do not have any temporal constraint between them. Therefore, if the "Prepare Panels" is live, its primitive goals can be pursued by the responsible agent. In this example, the astronaut is responsible for the first primitive goal "Check Connector", and the robot is responsible for the next two primitive goals. According to the collaboration mechanism in our overall framework, the "Check Connector" primitive is in focus, and the astronaut is pursuing this goal. Suddenly, the astronaut tells the robot that the connector is broken and she is *worried* about the failure of the overall goal. The robot perceives and interprets astronaut's negative emotion using reverse appraisal (the details about reverse appraisal process in our framework is beyond the scope of this paper). Then, the robot evaluates the cost function for the current and the live goals. The astronaut's negative emotion increases the cost of pursuing the current goal, and also affects two other primitive live goals under the same parent. Therefore, the robot instead of insisting on pursuing the same blocked goal which has caused the astronaut's negative emotion, acknowledges the astronaut's emotion to be able to choose one of the live goals later at the right time. Robot's behavior mitigates the astronaut negative emotion helping the robot to pursue another live goal "Coonect Adaptor" which has a lower cost with respect to the collaboration status. The details about the robot's behavior is beyond the scope of this paper.

Equation 1 shows our general cost function we use to calculate the cost of each individual potential goal. The base in the equation is considered to calculate the cost of pursuing any given goal. There are three different functions used to calculate the cost, including *proximity* of a goal $P(g)$, *difficulty* of a goal $D(g)$, and *specificity* of a goal $S(g)$. The details about these functions are provided in equations 2 to 4. The exponent part of our cost function is considered to capture a) influence of human's emotional instance on the cost, and b) the influece of self appraisal of any given goal. The $R_h \in [0,1]$ and $D_h \in [-1,1]$ are the *relevance* and *desirability* values respectively, which will be attained based on the reverse appraisal of the human's perceived emotion. For instance, if the astronaut is frustrated the D_h obtains a negative value (depending on how undesirable is the event according to reverse appraisal), and R_h will be 1 for the active goal and its value descends to 0 for other live goals depending on their distance to the active goal in the shared plan. The $R_r \in [0,1]$ and $D_r \in [-1,1]$ are also the *relevance* and *desirability* values. However, the self appraisal functions provide these values for all of the live goals. For instance, for the active goal that the astronuat was frustrated for, the D_r can be a positive value (depending on the self's desirability appraisal function), and R_r can be 1, since the active goal is *relevant* for the robot. These values will change for the other live goals depending on how *relevant* they are with respect to the collaboration status. Finally, $C \in [1,\infty]$ is a constant used to control the influence of affect on cost value and it has negative sign since the *undesirablity* (negative values) should increase the cost, and $\alpha \in [1,\infty]$ is also another constant to control the importance of reverse appraisal for the cost function.

$$Cost(g) = \left(\frac{P(g) \times D(g)}{S(g)+1}\right)^{-C[(R_r+1)D_r + \alpha(R_h+1)D_h]} \tag{1}$$

The *proximity* of a goal indicates how far the goal is from the current active goal in the shared plan. It is calculated by the distance function (Equation 2) which returns the number of edges between the current active goal $g_{_{act}}$, and the given goal g in the shared plan.

$$P(g) = distance(g_{_{act}}, g) \tag{2}$$

The *difficulty* of a goal is a function of three parameters (Equation 3) which consider the difficulty based on a) topology of the shared plan tree (domain independent), and b) the amount of effort required to pursue a given goal (domain dependent). The $\sum pred_e(g)$ is the sum of efforts that all the *predecessors* of a given goal g require to be achieved. The $\sum desc_e(g)$ is the sum of efforts that all the *descendants* of a given goal g require to be achieved. The effort values represent the amount of effort for the goals with respect to the domain. The $H(g)$ is the height of the given goal g and it is important since a goal with higher height value (longest path from the goal to a leaf; a primitive goal) makes the collaboration more difficult than the goal with shorter height.

$$D(g) = \Big(H(g)+1\Big) \times \left[\sum_{m=0}^{M} pred_e(g) + \sum_{n=0}^{N} desc_e(g)\right] \tag{3}$$

The *specificity* of a goal is the function of *depth* (distcance from the root) and *degree* (number of children) of a given goal g. The first number primitive goal (root) is the least specific goal, and the primitives (leaves) are the most specific goals.

$$S(g) = \frac{depth(g)}{degree(g)+1} \tag{4}$$

The tuples below the goals in Figure 2 indicate the cost value of each goal. The first number in each tuple is the cost value without the influence of the affetive part of the cost function, i.e., the exponent is equal to 1 in Equation 1. The second number of each tuple indicates the value of the cost including the influence of affetive appraisal and the astronaut's perceived emotion.

III. CONCLUSION

We use our proposed cost function in our goal management algorithm to be able to integrate affective appraisal into the collaboration mechanism in our framework. We will continue to implement other parts of our framework, including action selection and motivation processes.

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