Emotionally Modulated Time Perception for Prioritized Robot Assistance*

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ABSTRACT

This work aims at improving the global HRI experience in setups involving several humans interacting with a single service robot. This is accomplished by enabling the robot to (i) exploit information about the emotional state of individual humans (ii) predict how each human experiences the flow of time and (iii) serve with priority the persons under time pressure, after considering the expected completion time of the relevant tasks. An empirical study with humans competing to get robot assistance shows superior performance for our method in comparison to ordinary approaches.

1. INTRODUCTION

In order to produce robotic systems seamlessly integrated into human societies, it is essential that an understanding of not only robotics but also human psychology be brought to bear [1]. For example, in the field of domestic service robots it may be often the case that two inhabitants ask help from the (single) robotic assistant that supports house activities. To decide which of the two help requests will be served first, the robot should ideally consider the emotional state of humans and the estimated completion time of the two individual requests.

Interestingly, it is well known that emotions affect human time perception. In particular, time seems to fly when we are happy or in a high arousal state, and to drag when we are sad or bored [2]. Considering the domestic robot example discussed above, the emotional effects on time perception imply that a happy person in high arousal state would only be satisfied with the direct realization of his request. In contrast, a person in low arousal or sad state would thoughtlessly accept being served second in the queue (given that the completion time of the other task is not very long).

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2. METHODOLOGY

The goal of the present work is to enable robots consider how individual humans experience the flow of time and adapt their planning strategy accordingly. To this end, we exploit available data collected addressing the effect of emotions on human time perception [3]. Using these data it is possible to predict how fast humans experience the flow of time, given their current emotional state. The estimated speeds of time experience for the individual humans are fed to the Daisy Planner (DP) [4, 5] that has been particularly designed to implement time-informed planning, in order to prioritize human requests in a way that improves the composite level of satisfaction for the interacting humans.

Emotion-Time Interaction. To develop a quantitative association on the effect of emotions on time perception, we exploit collected data addressing the experience of time passage in the life of young and elderly people [3]. In short, 29 participants received in their smartphones 8 random alerts per day for 5 days, requesting them to fill questionnaires asking about their current experience of time passage, their affective state and their arousal level, among others.

We exploit these data to learn how emotional state affects time perception. In particular, we use an RBF neural network with four inputs: (i) the level of positive valence (happiness), (ii) the level of negative valence (sadness), (iii) the level of positive/high arousal, (iv) the level of negative/low arousal, all of them in a 1 to 7 Likert scale. The output of the network is an estimate of time passage experience for humans in a 1 to 7 scale (slow to fast). We use standard pack-propagation to learn the input-output association filtering out the noise existing in the original daily life human data. Results are shown in Fig 1.

Prioritized Planning. The Daisy Planner (DP) [4, 5] is enhanced with the ability to prioritize robot activities according to the emotional state of interacting humans. DP assumes that tasks (consisting of action sequences) are represented as petals on a daisy-like graph to facilitate immediate, locally optimal task selection. A unique feature of the DP regards its ability to fuse temporal information with other quantitative HRI features (efficiency, emotions, fatigue, etc.). This is accomplished by adopting a fuzzy number representation of time intervals, which enables examining the current HRI state by writing down time-informed, fuzzy calculus equations. In the current work, task allocation aims to predict and minimize the average delay on human request completion, considering how it is individually experienced by the participants.

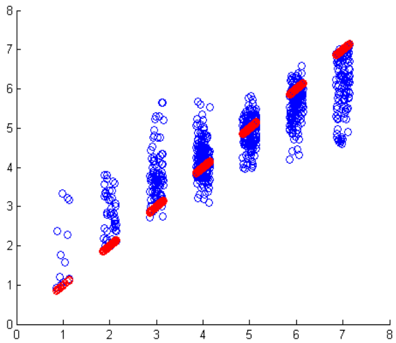

Figure 1: The results of RBF learning on how emotions affect time perception.

Let us assume that two spouses are served by a single domestic robot. The husband had a good day, sitting relaxed in sofa. He asks robot to prepare for him a sandwich. The estimated time for sandwich preparation is 3 to 5 minutes (in the form of triangular fuzzy numbers this is represented by $FT_{san} = (3, 4, 5)$). At the same time, wife has just arrived home. She had a hard day and she needs to work overnight to prepare a complicated company report. The wife asks robot to prepare for her a salad. The estimated time for salad preparation is 4 to 7 minutes (represented as a triangular fuzzy number by $FT_{sal} = (4, 5.5, 7)$).

The robot considers the emotional state of the two spouses and predicts that the husband is experiencing time flow in normal speed ($s_h = 1.1$), while the wife, being under work pressure, is experiencing time flowing fast ($s_w = 1.6$). The robot considers how humans will experience delay in the completion of their requests, in order to decide whether it should first prepare the sandwich or the salad.

Case A - Prepare sandwich first. The husband is experiencing sandwich preparation to take $FT_{san} \cdot s_h$ moments. The experienced delay for him will be $FT_{san} \cdot s_h - FT_{san}$ which results to the fuzzy number $(-1.7, 0.4, 2.5)$. At the same time, wife will experience salad preparation to take $(FT_{san} + FT_{sal}) \cdot s_w$. The experienced delay for the wife will be $(FT_{san} + FT_{sal}) \cdot s_w - FT_{sal}$. This results to the fuzzy number $(4.2, 9.7, 15.2)$. Overall, the average experienced delay for the spouses will be $(1.25, 5.05, 8.85)$.

Case B - Prepare salad first. The wife is experiencing salad preparation to take $FT_{sal} \cdot s_w$ moments. The experienced delay for her will be $FT_{sal} \cdot s_w - FT_{sal}$ which results into the fuzzy number $(-0.6, 3.3, 7.2)$. At the same time, the husband will experience sandwich preparation to take $(FT_{sal} + FT_{san}) \cdot s_h$. The experienced delay for him will be $(FT_{sal} + FT_{san}) \cdot s_h - FT_{san}$. This results to the fuzzy number $(2.7, 6.45, 10.2)$. Therefore, the average experienced delay for the spouses is now estimated to $(1.05, 4.875, 8.7)$.

Clearly, giving priority to sandwich preparation (case A) results into higher experience of delay for the couple, in comparison to starting with the salad preparation (case B). As a result, the planner directs robot to first work for the wife's meal and then prepare husband's meal.

3. RESULTS

To evaluate the proposed planner, we consider 10 randomly paired couples consisting of 8 male and 7 female lab members. The experiments were conducted close to an important lab deadline which means part of the participants have been in a stressful emotional state. Participants fulfilled questionnaires providing information about their current positive/negative valence, positive/negative arousal, in a 1-7 scale. Similar to the scenario described above, the participants are told that the robot will prepare for them a meal of their choice, either sandwich or salad. Participants have no visual access to the actual preparation procedure.

Table 1: Summary of DP vs SJF Comparison

	Score Average	Score Variance	Intra-Distance Average	Intra-Distance Variance
DP	4.32	1.75	1.83	0.61
SJF	3.78	2.21	2.67	0.58

The ability of the DP to consider the emotional state of humans and properly adapt planning decisions is contrasted to the classic shortest job first planner. Each planner is used to serve 5 couples. Participants are asked to evaluate robot serving quality, in a 1-10 scale. The obtained results are summarized in Table 1. The second and third columns show the score average and variance for the two planners. DP is rated higher, mainly because some users that have been served second consider that they have been considerably delayed with SJF. Lower DP variance indicates it is rather consistently evaluated higher than SJF. The last two columns consider intra-distance in the scores provided by the given couples (i.e. the level of disagreement in each pair of scores). Interestingly, the average disagreement between users is lower for DP. The variance in user disagreement is nearly the same for the two planners indicating a frequent imbalance between coupled user ratings.

4. CONCLUSIONS

The present work demonstrates that considering the emotional state of humans and how they experience the flow of time may provide a stable means to improve the HRI experience of humans in setups where many persons are served by a single robot.

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