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Emotion-Awareness Improves Human-Robot Collaboration

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Abstract ...

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1 Introduction

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2 Related Work

2.1 Emotions in Social Context

2.2 Social Functions of Emotions

2.3 Affect and Motives

2.4 Collaboration Theory

3 Example Scenario

3.1 The Backstory

The scenario transpires in a NASA's research center. Light, temperature and other environmental factors are simulated based on conditions on the surface of the moon. The mission is to finish installing the required solar panels to provide energy for the operation of NASA's science lab on the moon. Ninety percent of these panels have already been installed. However, the operation is now faced with low batteries which forces everyone to be cautious about consuming energy. The astronaut is inspecting the working conditions in the field and planning the installation of the remaining panels in collaboration with the robot. He determines that the sun will cast shadows over the installation structure, leading to potential difficulties. The astronaut asks control base to go through the final checks of the robot and prepare it for the operation.

3.2 Astronaut-Robot Interaction

The robot and the astronaut will collaborate with each other to achieve their shared goal, which is to install two solar panels. They will face various difficulties, ranging from the task being unpleasant and challenging to conflicts of their private and/or shared goals occurring because of a blocked or a protracted sub-task. The robot and the astronaut will go through a series of assessment processes to figure out a) how did the current blocking happen? b) why is the current task is blocked? and c) what is the next action they are going to take? The robot uses its cognitive abilities and its communication skills to overcome these problems and to motivate the astronaut to propose alternative tasks. The following is part of an interaction between the astronaut and the robot during their collaboration on installing solar panels.

3.3 Agreeing on Shared Goal (Emotion-Awareness)

A1. Astronaut: Oh no! Finishing the quality check of our installation with this measurement problem is so frustrating. I think we should stop now!
[*Astronaut is frustrated.*]

A2. Robot: I see. This is frustrating. But, I can help you with the measurement tool and we can finish the task as originally planned.
[*Robot perceives Astronaut's frustration and acknowledges that.*]

A3. Astronaut: Can you fix the measurement tool?
[*Astronaut's emotion is neutral.*]

A4. Robot: The next task is fixing the panel and it needs you to prepare and attach the welding rod to your welding tool. To save our time, I will fetch another measurement tool while you are preparing your welding tool.
[*Robot perceives Astronaut's neutral emotion, and tries to negotiate and provide a fair offer.*]

A5. Astronaut: That would be great!
[*Astronaut is content.*]

3.4 Agreeing on Shared Goal (Emotion-Ignorance)

B1. Astronaut: Oh no! Finishing the quality check of our installation with this measurement problem is so frustrating. I think we should stop now!
[*Astronaut is frustrated.*]

B2. Robot: I can help you with the measurement tool, or we can terminate this task. What do you want me to do?
[*Robot does not perceive Astronaut's frustration.*]

B3. Astronaut: As I said the measurement tool does not work properly. We can not continue!
[*Astronaut is frustrated.*]

B4. Robot: Okay. Do you want me to fix this problem or terminate the task?
[*Robot does not perceive Astronaut's frustration.*]

B5. Astronaut: Can you fix my measurement tool?
[*Astronaut is frustrated, even more.*]

B6. Robot: I cannot fix your measurement tool, but I can fetch another one for you if you want?
[*Despite Astronaut's strong frustration, Robot tries to negotiate.*]

B7. Astronaut: No, I don't want another measurement tool! We don't have time for that!
[*Astronaut is angry.*]

B8. Robot: Okay. You want me to terminate this task. Terminating this task can influence the quality of installing this solar panel which can cause the mission to fail. Or, do you want us to work on another task? This can help us to install the panel using your welding tool, but I do not know whether the quality of our installation will be acceptable.
[*Not only the Robot does not perceive Astronaut's anger, but also continues to negotiate the next step based on the shared plan to select proper action.*]

B9. Astronaut: I told you we have this problem and we should terminate the mission! We cannot continue without the measurement tool!
[*Astronaut is angry.*]

3.5 Delegation of a Task (Emotion-Awareness)

A1. Astronaut: I still have some problems with attaching the first panel! We do not have enough time. You should begin to install the second panel.
[*Astronaut is worried.*]

A2. Robot: Okay. Don't worry. I can handle that.
[*Robot perceives Astronaut's worriedness and acknowledges that. Also, it doesn't ask the Astronaut (because of perceiving worriedness) if it is okay to leave the current task which was helping the Astronaut to install the first panel.*]

[*Robot perceives the Astronaut's request as on open planning (as oppose to specific executive) task delegation.*]

A3. Astronaut: I will try to fix it asap.
[*Astronaut's is still worried.*]

A4. Robot: I might need to ask some questions while I am installing the second panel.
[*Robot perceives Astronaut's worriedness.*]

[*Robot checks a) dependencies of the task (a sub-task might need to be done by both parties), b) preconditions, c) required resources, d) possible future conflicts.*]

[*Robot needs to ask several questions to remove uncertainties, but because of the Astronaut's emotion, Robot decided to postpone questions about the details to when the Astronaut's answers are necessary to make progress. Robot modifies its utterance in a proper way.*]

A5. Astronaut: That's fine. Just let me know.
[*Astronaut is neutral.*]

3.6 Delegation of a Task (Emotion-Ignorance)

B1. Astronaut: I still have some problems with attaching the first panel! We do not have enough time. You should begin to install the second panel.
[*Astronaut is worried.*]

B2. Robot: Okay. I can handle that. Is it okay if I leave the current task though?
[*Robot does not perceive Astronaut's worriedness.*]

[*Robot perceives the Astronaut's request as on open planning (as oppose to specific executive) task delegation.*]

B3. Astronaut: Yes, that's fine. I can finish it by my own.
[*Astronaut is still worried.*]

B4. Robot: Okay. But according to the plan, I need your help when we need to weld the panel. Will you be able to help me?
[*Robot does not perceive Astronaut's worriedness.*]

[*Robot checks a) dependencies of the task (a sub-task might need to be done by both parties), b) preconditions, c) required resources, d) possible future conflicts.*]

[*Robot needs to ask several questions to remove uncertainties, so it does, since it misses the Astronaut's negative emotion.*]

B5. Astronaut: Yes, I will.
[*Astronaut is more worried about finishing the first panel.*]

B6. Robot: We also need your welding tool and supplies as well as the measuring tool to install the second panel.
[*Robot does not perceive Astronaut's worriedness. So, it continues to ask question.*]

B7. Astronaut: Just let me know whenever you need something!
[*Astronaut becomes frustrated, since he thinks the Robot's questions are killing time.*]

B8. Robot: Thanks. I will. How about the conflict that might occur while I am trying to fix the second panel? You are going to need my help at the same time. Last time this issue terminated our mission.
[*Not only the Robot does not perceive Astronaut's frustration, but also asks about some possible future problems based on reflection of the same tasks in the past.*]

B9. Astronaut: Robot, I really don't understand what you are talking about!
[*Astronaut becomes more frustrated.*]

B10. Robot: Do you want me to provide some examples?
[*Robot does not perceive Astronaut's strong frustration. So, it doesn't stop asking questions.*]

B11. Astronaut: We don't have time for this anymore!
[*Astronaut becomes angry.*]

4 Affective Motivational Collaboration Theory

5 Computational Framework

6 Walk Through Computational Examples

6.1 Agreeing on Shared Goal (Emotion-Awareness)

6.2 Agreeing on Shared Goal (Emotion-Ignorance)

6.3 Delegation of a Task (Emotion-Awareness)

6.4 Delegation of a Task (Emotion-Ignorance)

7 Conclusion and Future Work

References

1. Author, Article title, Journal, Volume, page numbers (year)
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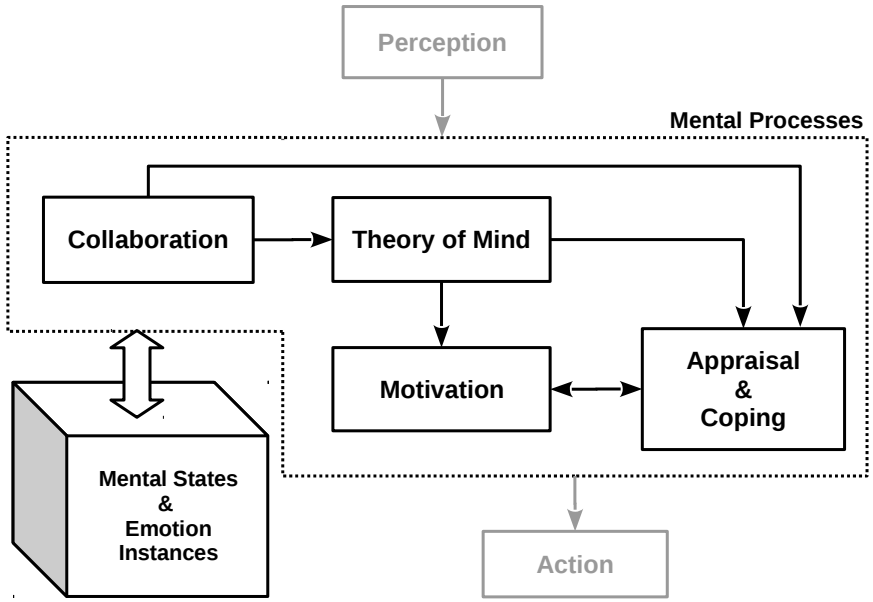

Fig. 1 Roadmap of *Affective Motivational Collaboration Theory* showing primary influences between processes.