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Enabling robust robotics through human-robot behaviour coordination

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ABSTRACT

When a service robot performs a complex, multi-staged task for a human, the human is actually taking part in the task. So this becomes a shared task, a fact of which the human is often not consciously aware. The more complex a task, the more likely the robot will encounter failure situations, leading to annoying overall task failure. Many of these failure cases are seemingly trivial to the user, making it even more annoying in terms of user experience. In this paper we propose an architecture for behaviour coordination that detects such failure cases and directs the user's attention to the underlying problem. The robot explains the problem, asks for the user's assistance and guides the user through the process of overcoming the problem. We will give a short outline about the mechanisms of joint actions between robot and user. Next, the conceptual idea how the user can be put into the control-and-action loop is given, followed by a description of an example scenario and the specific solution mechanisms.

Categories and Subject Descriptors

I.2 [**ARTIFICIAL INTELLIGENCE**]: Robotics

General Terms

Human Factors, Reliability, Design

Keywords

Robustness, Safety, Robotics, Joint action

1. INTRODUCTION

The ability that a robot autonomously interacts with a human requires sophisticated cognitive abilities including perception, navigation, decision making, and learning. Impressive achievements have already been made in the research field of HRI considering robots as tour guides in museums and shopping malls and for assistive robots in the care and domestic context.

However, robotic systems are still in a stage where we have to accept that failures do occur, especially in unstructured and dynamic environments. For successful long-term HRI it will thus not only be necessary that robotic behaviour becomes more flexible and adapts to previously unknown situations, but also that it deals with remaining failure situations in a manner that does not negatively impact on user acceptance.

We thus propose an architecture that detects such failure cases and efficiently communicates the event, the problem situation and potential solutions to the user, inviting the user to help the robot overcome its problem. This approach follows the 'mutual care' paradigm [2] where, apart from the robot's standard job to care for the user, the user is also invited to care for the robot in order to increase the user's self efficacy.

This increases user acceptance significantly, as the user does not feel helpless in case of failure, but maintains a feeling of control over the situation. One specific problem that occurs in unstructured dynamic environments is that the robot misses events outside its limited sensor range, making it difficult to maintain a valid world model, e.g., for collision avoidance. Therefore, next to sensors, we propose to use the user as a source of valid world knowledge.

In this position paper we present our concept for a robotic behaviour coordination framework that uses joint action mechanisms between the user and the robot to perform complex tasks.

2. CONCEPT

Based on the notion of joint actions between humans [5], and humans and robots [4] we will focus on the usage of the following mechanisms to accomplish a task at hand (in our first example a collision free movement close to a user).

Joint attention as the ability to direct the attention of an interaction partner to create a common ground for the joint action. Usual methods to achieve this is by the possibly combined use of gaze cues, pointing and gestures, demonstration of a task, and language.

Task sharing establishes a shared task representation and models how the partner will react to a certain event as well as which action they will engage in.

Action coordination as the planning of the achievements that each participant in a joint action has to reach.

In the first stage of our approach the robot will actively try to adapt these mechanisms to convince the user to fulfil a part of the shared task. This concept will be part of a framework that is designed to identify the abilities (e.g. able to rotate on the spot?) and limitations (e.g. field of view of a camera) of the robot, recognise the task that has to be performed, as well as the problems that can arise during the task (e.g. too close to a wall for collision free movement). Based on these findings a method to bring the user's attention to the task and provide the user with the information on how the robot can be supported is selected. Furthermore, the ability of the robot to reason about its embodiment and the dynamic environment is required to actually be able to recognize a problem and therefore the need to seek the user to recover from the problematic situation.

3. SCENARIO

Let the preconditions of the scenario be that the robot should autonomously move to a fixed position next to the user, where the user can interact with its touchscreen which is mounted on its upper body. The robot at hand is the HOBBIT PT2 [1], a mobile platform with a head on a pan-tilt unit with two displays to show eyes, one RGB-D camera (i.e. Asus Xtion) mounted inside the head (user detection, obstacle detection, and object recognition), another one inside the body at the front (localisation), and a IGUS Robolink 6-DOF arm as pictured in Fig. 1. Our robot suffers from a reduced field of view and a blind spot of up to 80 cm of the RGB-D camera which presents the challenge of finding a safe path to navigate away from the user. Therefore we will focus on this challenge for now. As the user in our scenario has not been made aware that any user input is needed the first step our framework has to focus on how to steer the attention of the user to the possible problems of the task. For our *approach-the-user* scenario we observed the following potential problems and come up with ideas how the user can support the robot to increase the chance of a successful detection and approach to the user.

Figure 1: HOBBIT

- During the approach to the user obstacles in the blind spot of the lower camera are only partly observed and can lead to a collision.

  The movement will be in straight line to the user if possible to detect obstacles at a greater distance and the robot stops 1 m in front of the user. From there the user can either close the gap or instruct the robot manually (e.g. voice or gesture) to come closer.

- Navigation stacks tend to consider obstacles only for a certain amount of time after their last detection. If the robot is close to the user or obstacle, the robot forgets that the path might be blocked when it starts moving again. Remembering them indefinite would block navigation after a certain amount of time as the blind spot makes it impossible to clear close obstacles from the map.

  Temporal and spatial reasoning will save the detected obstacles and their trajectory during the approach, and calculate with the help of a solving constraint satisfaction problems [3] if there is the risk that they can block the path at a later time. If this risk exists the user will be asked to confirm this assessment.

- The limited field of view affects the self localisation of the robot and with this the accuracy during navigation, which increases the chance of a collision as well and hinders the ability to reach a position close to the user.

  To overcome the reduced accuracy in self localisation, which can be recognized by an increase of uncertainty of the robots position, we use a fixed landmark in the environment, at which the robot will trigger a reset of its current position and uncertainty. The landmark we use is the docking station to which the user can push the robot into to start this procedure.

- False positive or false negative user detections are still quite common within 2D and 3D person detection algorithms. In the case of 2-dimensions pictures of people on the wall are enough to trigger a false positive, for 3-dimensions a doll or puppet results in similar error case.

  The combination of 2D- and 3D-detection techniques as well as improvements with thermal sensors will reduce the false positives in a first step. Further we assume that the user is willing to interact with the robot, so that we can argue that any detected user who is not reacting to multiple attempts to initiate a dialogue by the robot is in fact no user. Also the user is able to inform the robot about a false positive via multi-modal input to stop the interaction attempts.

3.1 Framework design

Even though the example focuses on Hobbit, our framework is not designed for only one specific robot model in mind. There is a need to support the mechanisms of joint actions via different modalities of interaction such as speech output, gaze control or pointing gestures with an arm. This multi-platform design guarantees that a certain interaction pattern will only be selected if applicable (e.g. head or eye movement is possible). As stated before the robot needs to be able to reason about the situation and context it is in at the moment, how the environment changed during the unfolding of the situation and what regions of the environment are observable. Only if this reasoning suggests that the user is needed it will change its planning to seek a joint action with its user, otherwise the autonomous behaviour is used.

3.2 Joint actions

As we see the basis of our framework in joint actions between robot and user our implementation heavily relies on the previously mentioned mechanisms of *Joint attention*, *Action coordination*, and *Task sharing*.

Joint attention will be accomplished by the robot through the combination of gaze cues that are executed by the head movement, pointing gestures with the arm, and speech output. The speech output is set to be performed either after or during the movement, depending if the attention should be driven to an area or a specific point in the room. In our scenario the arm would point to the area in front of the robot, and the head would do a panning motion while tilted down and simultaneously ask the user if the space is clear at the location it is pointing and looking at.

Action coordination will be done by our framework as we do not expect the untrained user to be able to coordinate the possible solution methods. Therefore from a set of pre-defined strategies for the task one that matches the recognized context best will be chosen and executed in the fashion of turn taking.

Task sharing is then the execution of the selected strategy. To be on the safe side the robot will try to get the user's confirmation before risking a possible damage or collision. The robot will guide the user through the tasks in the fashion of an instructor for the execution steps that it is not able to perform on its own, like checking if the space directly in front of the robot is empty.

4. CONCLUSIONS

In this position paper we proposed a situation aware behaviour coordination framework that lets a robot engage the user if it is not able to accomplish a task without external help. We explained how we plan to focus the attention of the user to the location of a possible problem and how the robot creates the environment for a joint action if needed. We are confident that a robotic system that is able to seek support from the user will improve the robustness of the robot and increase the acceptance by the user as it gives the user the feeling of a certain degree of control and influence on the robot.

5. ACKNOWLEDGMENTS

This work has been partially funded by the European Commission under grant agreements FP7-IST-288146 HOBBIT and FP7-ICT-610532 SQUIRREL.

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