Exploration of Intention Expression for Robots

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ABSTRACT

This paper presents a novel exploration on how to enable a robot to express its intention so that the humans and robot can form a synergic relationship. A systematic design approach is proposed to obtain a set of possible intentions for a given robot from three levels of intentions. A visual intention expression system approach is developed to visualize the intentions and implemented on a mobile robot and a manipulator to demonstrate the intention expression concept.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Interaction styles

General Terms

Human Factors

Keywords

Robot, intention expression, augmented reality

1. INTRODUCTION

When people meet a robot, they may be excited and curious, but those who are not experts in robotics usually have no idea what the robot can and will do. For example, when a mobile robot moves around in a human living environment, we act cautiously and nervously around it mostly because we do not know what it will do next and we need to prepare ourselves for its sudden and unexpected movements. We try to observe the robot carefully and use our cognition system to make sense of its motions and predict its intentions. Unfortunately, there typically is not a clear indication of the robot's next move, and the programming built into the robot is not observable by people who co-live with it. If, at all times, we could know the intention of the robot and its next move, we would feel much more comfortable and at ease around them.

A human not only has to understand the current motion of the robot but also must perceive the robot's intention in order to predict its next move(s) so as to actively collaborate with the robot and create synergy. To achieve this, one approach is to design robots that can express themselves as humans do - allow humans to identify the robot's intentions as we observe them in action (as humans do with other humans). A number of researchers in socially interactive robotics have suggested that in order to interact socially with humans, a software agent must be believable and life-like, must have behavioral consistency, and must have ways of expressing its internal states [1, 2]. However, it is unrealistic to require all the robots coexisting with humans to have human-like appearance, kinematics, and dynamics. A robot's motion, by nature, is far different from regular human motion we observe every day. The motions we consider to be unnatural are rooted in the physical properties and configurations of robots. A robot's material, actuators, and sensors are fundamentally different from humans, which yield rather different patterns of acceleration, deceleration, and the like. A robot is designed to amplify its strength and be efficient for certain tasks. The differences give it abilities that humans do not have, such as super speed and extreme precision.

To enable a robot to express its intention, we have developed an intention expression framework that allows the robot to derive its intention sets from its models and programmed tasks and select an optimal intention representation and expression with our study results on intention perception.

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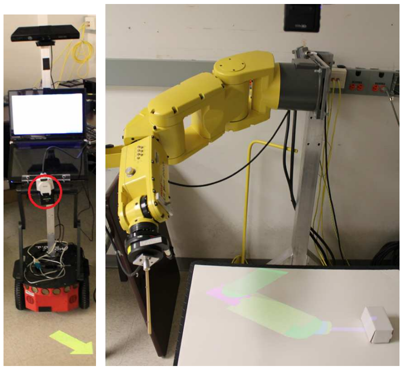
2. INTENTION EXPRESSION SYSTEMS

2.1 Mobile Robot

We have constructed an autonomous mobile system based on an Adept MobileRobots Pioneer 3-DX differential drive robot. A particle filter-based simultaneous localization and mapping (SLAM) algorithm and path planning algorithm were developed and integrated into the Robot Operating System (ROS). The software runs on an Acer Iconia duel-touchscreen laptop equipped with a Microsoft Kinect for 3D perception. The mobile robot can navigate fully autonomously with the Kinect sensor data, and it also can be tele-operated through wireless Internet. For intention expression, the system is equipped a Microvision SHOWWX+ 848 x 480 Scanning LASER projector for visual expression. The projector is rigidly mounted on the frame and pointing to the floor to render the robot's intention (Figure 1A).

After analyzing the tasks of the mobile robot, we can clearly derive its long-term intention, which is to reach a goal position defined in a task, while its mid-term intention can be an intermediate target such as avoiding an immediate obstacle. The long-term intention can be represented with



(A) (B)

Figure 1: Telemedicine mobile robot with intention displayed on the floor (A), manipulator with intention displayed with a LASER projector (B).

the trajectory generated by the robot's path planner, and the mid-term intention can be represented with a short and more-detailed path that the robot will take to get around the obstacle. The mobile robot's short-term intention could be its next motion, such as moving 30-degrees left with a 0.3 meter-per-second speed. It can be represented with a motion vector.

As the robot moves, the long-term and mid-term intentions can change if the robot computes a new path and trajectory with new perception data. For our studies, we displayed the intention on the ground and aligned the direction of the displayed map with a real-world environment to require less mental computation from human coworkers compared to displaying on a monitor (Figure 1A).

2.2 Robot Manipulator

We also have designed and implemented a visual expression system on our robotic manipulator - a 6-DOF Fanuc L200IC robotic arm. The same visual display element - a Microvision LASER projector - is attached to a stationary camera to form a camera-projector system (as shown in Figure 1B). The camera was originally setup for the manipulator as a part of a hand-eye system to automate manipulation tasks. One of the tasks is to flip a box with its stick. The location of the box is obtained from the camera, and then a sequence of motions is generated to carry out the flipping task. The intended pose is directly rendered on the workbench and superimposed onto the object. To accurately align the projection with the real-world objects the manipulator intends to handle, the poses and shapes of the objects are obtained from a camera, and the intrinsic and extrinsic parameters of the projector are calibrated relative to the robot coordinate system and the camera [3, 4, 5].

After a sequence of motions is planned, the projector displays the intended motion on the workbench and overlays the simulated intended target position with the box that should be flipped. The person supervising the task can easily judge if the planned motion is likely to be successful or not by simply glancing at the display. Figure 1B shows one example of the longer-term intention visual expression.

3. EVALUATION

A study was conducted with the mobile robot intention expression system to examine human understanding of directional information if the robot communicated information regarding its future direction by projecting. Participants in the study interacted with the robot in real time. The robot was moving and projecting arrows on the ground in front of it (Figure 1A). Two types of tests were performed: congruent (the projected arrows reflected the robot's movements) and non-congruent (the projected arrows were random and did not reflect the robot's movement). After each intention expression, the participants rated their confidence in the robot's upcoming movement on a scale of 1 (not at all confident) to 7 (completely confident). Each participant made a total of 10 ratings (4 congruent and 6 non-congruent). Data were collected from five young adults. The means for the congruent items ($M = 6.8$-7) greatly exceeded the means for non-congruent items ($M = 1$-1.2), $t(4) = 72.06$, $p<0.001$. The study showed that projecting arrows that represent the robot's current and future motion provide information with a high level of confidence to individuals approaching a robot, as opposed to not having the correct motion projected or not having a projection at all.

4. CONCLUSIONS

We have successfully implemented intention expression systems on two robotic systems - a mobile telemedicine robot and an industry robotic manipulator. The novel robot intention expression concept has the potential to allow people to perceive the robots' intention at all time when they are living with us, which will instill trust in regular people toward robots and significantly broaden the acceptance of robots in our lives. Equipped with a well-designed intention expression component, a robot will be viewed as reliable, truthful, and transparent, since people will be able to foresee and control its next motion at ease.

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