Exploratory Studies of a Robot Approaching a Person in the Context of Handing Over an Object

K.L. Koay[♦], E.A. Sisbot[+], D.S. Syrdal[♦], M.L. Walters[♦], K. Dautenhahn[♦] and R. Alami[+]

Extended Abstract

1 Introduction

This is a three page extended abstract for review and consideration for submitting a full paper.

Research for this study was conducted under the EU Integrated Project COGNIRON [COGNIRON, 2006], which aims to develop robots with the ability to perceive, decide, communicate and learn in an open-ended way, for interacting with humans. In order to interact with humans under the robot companion scenario, robots not only need to be able to perform useful tasks and have adequate safety but also need to engage in social interactions and behave in a socially acceptable manner [Dautenhahn, 2005][Fong et al. 2003]. Hall [Hall, 1966] in his work on social spaces between humans demonstrated that social spaces play an important role in human-human relationships, and that the distance between two people does reflects their relationship. This has raised new issues regarding robot motion planning (i.e. for navigation and manipulation) in the presence of humans which is our long-term goal.

The first step towards reaching this long-term goal and to develop a Human Aware Navigation Planner was addressed in our previous paper [Sisbot et al. 2005] that integrates human preferences results from user studies on social spaces and robot to human approach directions [Koay et al. 2006] [Walters et al. 2005] [Dautenhahn et al 2006]. The Human Aware Navigation Planner planner was later implemented into a real robotic system [Sisbot et al. 2006].

In this paper we will address the next step of our long-term goal of developing a human aware 3D *manipulation* planner that will complement the navigation planner. We present an interactive exploratory study conducted to understand how a robot should approach, and hand over an object (i.e. a can of soft drink) to a seated person. We hope to show the 3D manipulation planner that takes into account these social interaction aspects in our final paper.

2 Research Methodology

Results from the trials are presented in three categories: direction of approach, distance of approach and robot handing over behaviour. Twelve subjects took part in the study (4 females), with an age range between 21-41. The study took place in the University of Hertfordshire "Robot House" dedicated to Human-Robot Interaction Studies in a domestic environment relevant for the Cogniron project. We used a commercially available Peoplebot robot modified in order to give it a humanoid appearance, including a head and two humanoid arms.

The first stage of the trials involved the subjects interacting actively with the experimenters and the robot, regarding their preferences of how the robot should approach and hand them an object. The purpose of this approach was to actively involve the subject in the study, in contrast to our previous experiments where the subjects passively experienced and later chose from a set of pre-programmed robot approach behaviours. For the current trials, subjects guided the creation of a handing over gesture for the robot arm at their preferred position for handing over a can of soft drink. This gesture was then coordinated with the approach movements of the robot's base in four different ways:

I. Robot starts moving towards the subject only after it completed its handing over gesture.

II. Robot starts moving towards the subject but only executes its handing over gesture coordinated from point B to point D.

III. Robot starts moving towards the subject but only executes its handing over gesture coordinated from point C to point D.

IV. Robot starts executing its handing over gesture after it has stopped at point D.

The subjects experienced each of the four predefined robot arm-base coordination styles, tailored to their preferences, and to select the one they most preferred in the second stage of the trials.

---

* Adaptive Systems Research Group, School of Computer Science, University of Hertfordshire, College Lane, Hatfield, AL10 9AB, UK (phone: +44-1707-281026; fax: +44-1707-284303; e-mail: K.L.Koay@herts.ac.uk).

+ LAAS-CNRS, 7 Avenue de Colonel Roche, 31077 Toulouse, FRANCE (phone: +33 (0)5 61 33 79 11; e-mail: Emrah.Akin.Sisbot@laas.fr).

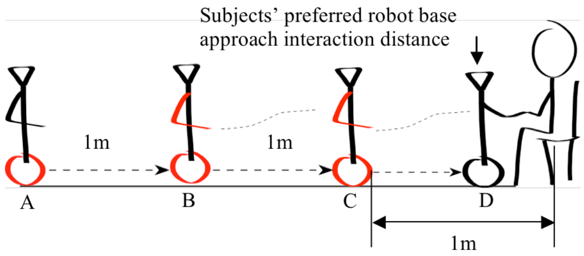


Figure 1. The four different arm-base approach coordination styles.

3 Results

3.1 Direction

The results show that 58.3% of the subjects prefer the robot to approach from the subject's front, 25% prefer the robot to approach from the subject's right front and 8.3% for each robot approach from subject's right and subject's left front. We found that 75% of the subjects prefer the robot to hand them the object from directly in front, 17% prefer the robot to hand the object at their right front and 8% prefer the robot to hand them the object to their left front. The summary of these two results shows that the direction where the robot should hand over an object has most influence on determining where the robot should approach. The robot base approach interaction position and its handing over hand position are likely to be in the same region (i.e. at 36 degree interval starting from subject' right to subject's left) during the handing over process (Pearson's r=19.111, p=.004).

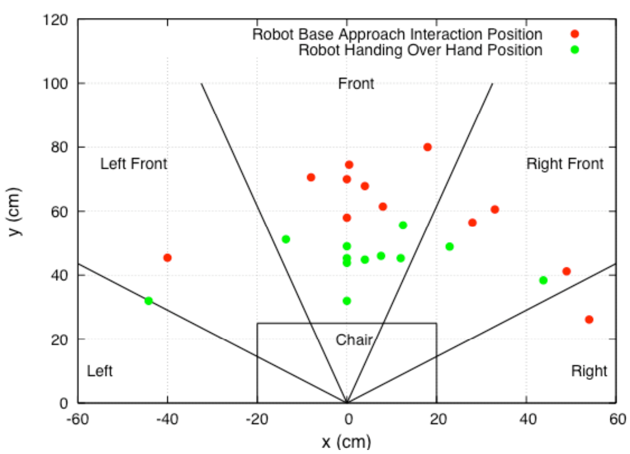


Figure 2. Subjects' preferred robot base approach interaction and robot handing over hand direction and position.

3.2 Distances

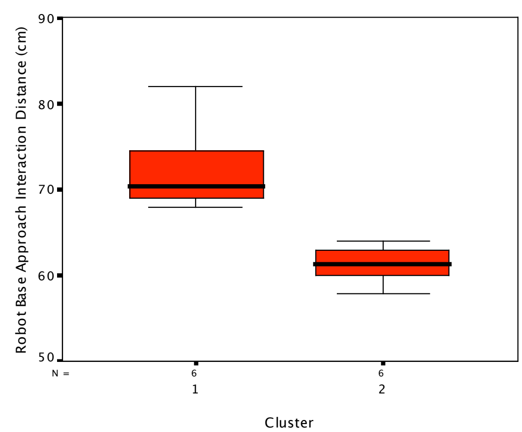
The mean preferred robot base approach interaction distance for the whole sample was 66.8cm (SD=6.96cm). The minimum distance was 58cm, and the maximum distance was 82cm. Assuming the distances between the subjects and the robot should be measured from subjects' chest (i.e. centre of the chair), the results show that the subjects prefer to interact with the robot within their personal zone [Hall, 1966].

Two clusters of the preferred robot base approach interaction distances were found which centred at 72.42cm and 61.25cm, and were significantly different from each other (F(1,10) = 23.515, p = .001).

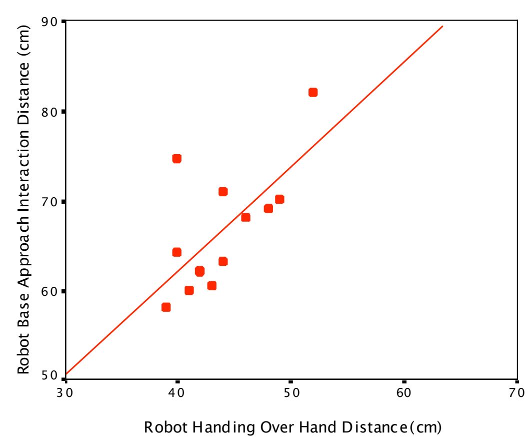
The results also show that the subjects preferred robot base approach interaction distances were positively correlated with subjects preferred robot handing over distances (Spearman's rho=.568, p=.027). This may imply that subjects who were comfortable with the robot being physically close to them prefer to interact closely, while subjects whom prefer to interact with the robot at a larger distance, prefer the robot to stay further away.

No correlations were found between subjects' height and preferred robot base approach interaction distances (Spearman's rho =- .375, p = .127), subjects preferred robot handing over hand distances (Spearman's rho = .046, p = .444) and subjects preferred robot handing over hand heights (Spearman's rho = .134,p = .339).

Most of the subjects (i.e. 10 were right handed, 1 was ambidextrous) preferred the robot to hand them the object with its right hand (92%). Only one subject (right handed) preferred the robot to use its left arm.



(a)



(b)

Figure 3. These graphs show (a) Two clusters of the subjects preferred robot base approach interaction distances, and (b) Positive correlation of robot base approach interaction distances and robot handing over hand distances.

3.3 Robot Arm-Base Approach Coordination

The results show that the majority of the subjects preferred the robot arm-base approach coordination type III, followed by type IV and lastly type II with 58.3%, 33.3% and 8.3% respectively. None of our subjects preferred robot arm-base approach coordination type I.

4 Human Aware Manipulation Planner

Current robot manipulation systems deal only with the feasibility and the goal of the motions without taking into account their effects on the human partner and thus minimizing the richness of an interaction.

In the planner, new concepts and protocols include reasoning about the human's field of view, attention, preferences (left/right handed, etc), current state (sleeping, sitting, working, etc.) and the robot's field of view, kinematics and dynamics.

Our aim is to build a generic (applicable to various robot structures) 3D manipulation planner which:

- is able to work with a model of the human that can be quite complex (kinematic structure with head, body and limbs).
- is able to include computation on the visibility of the human and its readability (geometric reasoning based on kinematic representation of the human).
- introduces costs, protocols and preferences in terms of motion of the platform, the arm and the head based on the user studies.

There are 2 key concepts that must be considered when planning a human-friendly manipulation:

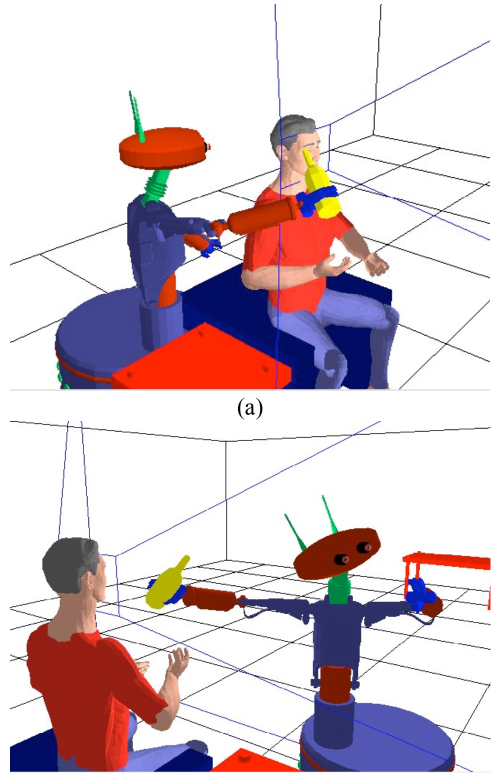
1) Visibility of the motion:

- The robot must move in a way that guarantees its visibility from the human (see figure 4a).
- In a real manipulator robot, one must consider the correct targeting of its cameras to ensure the correctness of the motion. For example, an object carried by the robot must not be hidden of the camera by its arm. Although it may appear that this property serves only the functioning of the robot, maintaining a look at the object during the interaction helps the human to understand and predict the robot's attention.

2) The posture of the motion:

The motion should reflect the intention of the robot in a step by step manner by controlling the type of the motion, the orientation of the robot head and visibility of the object and of the human (Figure 4-b).

Currently, only the navigation planner is implemented. We hope to show the 3D manipulation planner that is able to automatically produce human friendly motions in our final paper, implemented based on results from our user studies described above.



(a)

(b)

Figure 4. (a). Even though the object is visible, if the robot is hidden to the human partner, the interaction is uncomfortable, (b). The robot's motion must be predictable. In this figure we see that even though the robot and the object are visible to the human, this unusual motion during the interaction causes uncomfortable interaction.

Acknowledgments

The work described in this paper was conducted within the EU Integrated Project COGNIRON ("The Cognitive Robot Companion") and was funded by the European Commission Division FP6-IST Future and Emerging Technologies under Contract FP6-002020.

References

[Alami et al., 2006]R. Alami, A. Clodic, V. Montreuil, E. A.Sisbot and R. Chatila. Toward Human-Aware Robot Task Planning. *AAAI Spring Symposia* (AAAI 06), California, USA, *2006*.

[Cogniron, 2006] COGNIRON. Website available at http://www.cogniron.org, 2006.

[Dario et al., 2001] P. Dario, E. Guglieimelli, and C. Laschi. Humanoids and personal robots: Design and experiments. *Journal of Robotic Systems*, 18: 673-690, 2001.

[Dautenhahn et al, 2006] K. Dautenhahn, M. Walters, S. Woods, K. Lee Koay, E. A. Sisbot, R. Alami, T. Siméon. How may I serve you?. A robot companion approaching a seated person in a helping context. *HRI Human Robot Interaction*, Salt Lake City, Utah, USA, 2006.

[Dautenhahn et al, 2005] K. Dautenhahn, S. Woods, C. Kaouri, M. Walters, K. L. Koay, I. Werry. What is a Robot Companion - Friend, Assistant or Butler?, *Proc. IEEE IROS*, 2005.

[Fong et al., 2003] Fong, T., I. Nourbakhsh, and K. Dautenhahn, A survey of socially interactive robots. *Robotics and Autonomous Systems*. 42(3-4): p. 143-166, 2003.

[Hall, 1966] Hall, E.T. The Hidden Dimension, New York: Doubleday, 1966.

[Koay et al., 2006] K.L. Koay, K. Dautenhahn, S.N. Woods and M.L. Walters. Empirical Results from Using a Comfort Level Device in Human-Robot Interaction Studies. *Proceeding of 1st Annual Conference on Human-Robot Interaction* (Salt Lake City, Utah), 194-201, March 2006.

[Sisbot et al., 2005] E. A. Sisbot, R. Alami and T. Siméon, K. Dautenhahn, M. Walters, S. Woods, K. L. Koay and C. Nehaniv. Navigation in the Presence of Humans. *IEEE-RAS International Conference on Humanoid Robots (Humanoids 05)*, Tsukuba Japan, December 5-7, 2005

[Sisbot et al., 2006] E.A. Sisbot, A. Clodic, L.F. Marin Urias, M. Fontmarty, L. Brèthes and R. Alami. Implementing a Human-Aware Robot System. *Proc. IEEE RO-MAN*, 727-732, 2006.

[Walters et al, 2005] M.L. Walters, K. Dautenhahn, K.L. Koay, C. Kaouri, R. te Boekhorst, C.L. Nehaniv, I. Werry and D. Lee (2005). Close encounters: Spatial distances between people and a robot of mechanistic appearance. *Proceedings of 5th IEEE-RAS International Conference on Humanoid Robots* (Tsukuba, Japan), 450-455, December 2005.