Human-Robot Interaction by Motion Analysis and A Robot at large in Public

Mikael Svenstrup *

* *Department of Electronic Systems, Aalborg University, Denmark (e-mail: ms@es.aau.dk) .*

Abstract: In recent years, robots have started to move from the factories and out into the real world in human environments. The research in this Ph.D. project aims to enable robots with capabilities, that makes them better at being a part of the everyday human environment. Specifically the project is about making the robot interpret human intentions, and make the robot move around in a comfortable manner. A pilot study, which is presented in this paper, of a robot driving around in a public transit space, has shown that people are willing to accept robots in their daily environment. Hereafter, a method for making the robot move in a comfortable way, depending on what the intentions of a person in interaction wants, has been developed. Concurrently a method to identify the intentions, in terms of being interested or not interested in interaction, of persons has been devised. Experiments have demonstrated the applicability of the combined methods in a controlled real world test.

1. INTRODUCTION

In the later years there have been larger and larger public focus on elder care. The problem is that the old population is growing larger, and the workforce to take care of the old people is getting smaller. This generates a desire for "extra hands", and a potential solution for this is to develop robots [1] , which are able to help doing the work. Furthermore science fiction movies have shown robots as a natural part of the everyday environment, and most of us expect robots to become more and more visible in future years. Bill Gates has recently stated that "we may be at the verge of a new era, in which future robotic devices will become a nearly ubiquitous part of our day-to-day lives" [Gates, 2007].

When robots come into the real world, they will no longer be alone with their tasks. They will have to learn behave and interact with humans, and accordingly human-robot interaction is a novel and growing research field Dautenhahn [2007]. For robots to be accepted in human environments, they will have to be safe, reliable and behave in a social way that will be acceptable, as perceived by humans. This Ph.D. work focuses on the motion of robots, and there will be two main focus areas described in this paper. The two focus areas are introduced in the following two paragraphs.

First a pilot study, where an autonomous robot is let loose in a public transit area, is described. This is done to see how people react to robots in their natural environment. Experiments like this have been done before, but only with almost stationary robots (see Hayashi et al. [2007]). This robot follows persons around.

After this a theory and experiment about, how robots should move and interpret human intentions, is described. A method called Case Based Reasoning (CBR) (see Kolodner [1993]) is utilized to determine a person's willingness in engaging in interaction with the robot. From psychology within human-human interaction, we know how people move relative to others. This motion is divided into zones relative to the person Hall [1963]. It has been showed that these zones also apply to human-human interaction (see e.g. [Walters et al., 2005]). From the zones and the interest in interaction information a motion strategy for the robot is generated using potential functions inspired by Sisbot et al. [2008].

[1] The word robot originates from the Czech word robota, which means labor or hard work. This means that the a robot is meant to work (hard) for humans.

2. METHODS AND MATERIALS

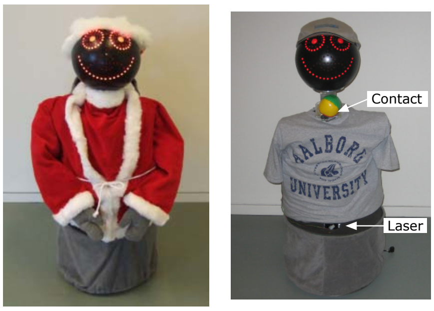
First this section describes the robot platform (Robotino), which is used for all the experiments. Hereafter the other experiments and algorithms are described.

2.1 Hardware Platform

The robot is based on a FESTO Robotino robot platform, which is a small wheeled robotic platform. In addition the robot is equipped with a head with 126 red diodes, which makes the robot able to show different facial expressions. The robot is shown in Figs.1(a),1(b). The robot gets sensory input from an laser-range finder, which provides a map of the distances to all object within a distance 4 meter and a 270° degree view. There is also a switch, which can sense if the robot has a ball or not.

2.2 Experiment in a public transit space

This experiment was done for two purposes. First we wanted to get some knowledge about what humans think of robots entering into the everyday environment, and how they react to them. Second we wanted to get some hands on experience about the challenges putting a robot into this everyday environment. The following describes the setup for the experiment in the public transit space.



(a) Robotino dressed as Santa Claus (b) Robotino in normal dress

Fig. 1. Images of the robot used in the experiments in different outfits. In the right figure the laser-range finder used for detecting persons can be seen. Furthermore the ball and contact used for interaction is shown.

Location: The experiment was performed in the combined central bus station and shopping mall the *Kennedy Arkaden* in Aalborg, Denmark, on 13th of December 2007 from 9am to 1pm.

Robotic Platform. To facilitate interaction the robot, as seen in Fig. 1(a), was dressed as Santa Claus (the experiment was carried out just before Christmas) and equipped with a loudspeaker playing the well known Christmas jingle "Jingle Bells" when a person was detected and the robot tried to initiate interaction.

Person Detection. To enable detection of persons in the environment, a method relying on a laser range finder was employed. An algorithm for detecting legs of persons and converting these to persons described in Xavier et al. [2005], was implemented on the robot platform.

Control of the Robot. The robot behavior is inspired by the spatial relation between humans (proxemics) as described in Hall [1963]. Hall divides the zone around a person into to four categories, 1) the public zone $> 3.6m$, 2) the social zone $> 1.2m$, the personal zone $> 0.45m$, and the intimate zone $< 0.45m$. The following behavior scheme was implemented on the robot:

(1) Roam randomly around until a person is detected.
(2) Start smiling and play a jingle.
(3) Follow that person keeping a specific distance, until the person is lost, or a certain time interval has elapsed.
(4) Change facial expression and start roaming again.

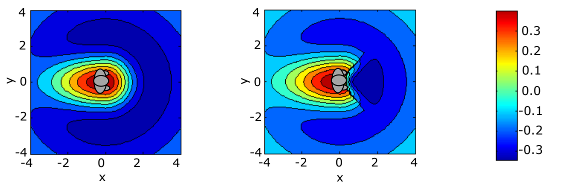
Evaluation The outcome of the experiment was evaluated by, questionnaires, video recordings, and in situ observations. The questionnaires were done by interviews of the persons that were in interaction with the robot. The questionnaires were about how people felt about the robot driving around in their presence, and if in their opinion robots have a future as an integrated part of everyday life.

The observations and the video analysis was used to gain knowledge about the reactions of people and positive and negative aspects of the procedure of the experiment.

2.3 Algorithms for intention recognition and motion pattern

After the above described experiment, the motion strategy for the robot, and the intelligence was further developed. The central matter is a variable PI called the person indication. It ranges from 0 to 1 on a continuous scale, and tells if a person is interested in interaction, or not. 1 means that the person is interested in interacting with the robot, and 0 means that the person is not interested. So first of all the task of the robot is to estimate the PI value of a person who is detected. It has been chosen to use a method called Case Based Reasoning (CBR). It consists of a database, where the robot stores previous experiences (cases) - in this context previous encounters with persons. To keep it simple, only the motion of the person is stored together with the final result of an encounter (interested/not interested). The final result is given to the robot by handing over or take the small ball seen on Fig. 1(b).

During an encounter, the PI value of the person is continuously estimated, and the motion strategy is changed according to the believed PI value. The motion strategy is based on the previous described Hall zones. So if $PI = 1$ (i.e. the person is interested), then the robot moves in front of the person and into the personal zone. But if e.g. $PI = 0$, then the robot moves away out into the social or public zone, and also to a 45° degree, so the robot is not directly in front of the robot. The implementation of this behaviour is done using an adaptive potential function based on Gaussian distributions centered in the person (see e.g. Andersen et al. [2008] for the mathematical description). The potential function is shown in Fig. 2 for different PI values. It is implemented such that the robot always seeks towards the lowest level, which is the dark blue areas.



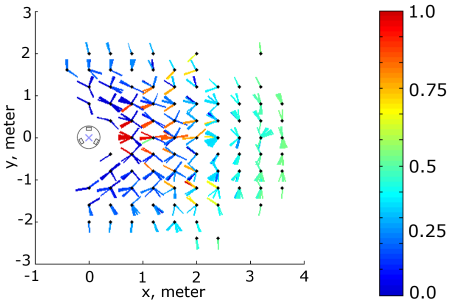
(a) PI=0 (b) PI=1 (c) Scale

Fig. 2. Shape of the potential function for (a) a person not interested in interaction, and (b) a person interested in interaction. It is the person wich is centered at the figures, and the value of the person interested indicator PI is denoted under each plot. The robot will seek towards the dark blue areas.

These algorithms has been tested in a real world setting, where the robot started with an untrained case database. Then a person would approach from different directions and sometimes interact with the robot, and sometimes walk past the robot. The experiment is able to demonstrate both if the robot after training is able to find out what the intentions of the person are, and verify that the robot has the correct movement strategy.

3. RESULTS AND DISCUSSION

First the results for the robot driving around in the Kennedy Arcade is described. Then the results for the



(a) The case database. (b) *PI*

Fig. 3. The figure shows the values stored in the CBR system after completion of 20 test runs. Each dot represents a position of the test person in the robot coordinate frame. The facing direction of the test person is shown by the extending line, while the level of interest (PI) is indicated by the color range of the line.

second experiment demonstrating the robot learning and movement abilities are summarized.

3.1 Public Transit Space

Generally the experiment showed, that the person detection algorithm was able to detect persons robustly, and that the robot was able to follow person in a real world scenario.

During the experiment 48 different persons were interviewed, and most of the them answered all the questions. Overall results was that most people felt comfortable with a robot being in the everyday environment, and that robots like this will fit well into places like the Kennedy Arcade in the future. A more thorough summary of the results can be found in Svenstrup et al. [2008].

3.2 Behaviour Experiment

The output of the test was a trained CBR database. The database can be seen in Fig. 3. The dots show recorded test person positions, which was rounded to a grid size of $40 \times 40cm$. Note that the positions are not global coordinates, but relative to the robot while it is moving. The extending lines, show the direction the person is facing, and the colour the corresponding PI value, where red indicates an interested person, and blue indicates a person which is not interested. The database shows that persons who is right in front of and facing the robot are typically interested in interaction, whereas when facing away from the robot indicates that the person is not interested.

4. CONCLUSIONS

This paper gives an overview over what have been done in this Ph.D. project within the first year. A pilot study with a robot driving around in a public transit space was done. This demonstrated a reliable algorithm for detecting and tracking persons. Luckily (for us robotic researchers) most people liked the idea of robots in their everyday environment.

This experiment served as a base for more theoretical investigation of the robot behaviour. More specifically about how the robot should estimate intentions of persons and how it should move relative to these persons. To estimate the intentions of persons a Case Based Reasoning Approach was used, and Gaussian potential functions was used to determine the motion of the robot.

There is still a lot of work to be done. The algorithms needs to be refined, and further tests have to be done.

An idea for future work is to make a robot, that is able to drive around in a supermarket and act as an interactive shopping basket. This will also require all the skills described above. So hopefully, by making robots better at understanding human intentions, we make a small step towards, some time in the future, having fully autonomous sociable robots assisting us in our daily lives. This is both within elder care, as described in the introduction, and in all other parts of everyday life.

ACKNOWLEDGEMENTS

Acknowledgements goes to Robotino, our energetic and hard-working little robot, who has not complained a single time. It has kept on doing what it was told to, even though we asked it to do many stupid things over and over again.

REFERENCES

Hans Jørgen Andersen, Thomas Bak, and Mikael Svenstrup. Adaptive robot to person encounter : by motion patterns. In *Proceedings of the International Conference on Research and Education in Robotics*, 2008.

Kerstin Dautenhahn. Methodology & themes of human-robot interaction: A growing research field. *International Journal of Advanced Robotic Systems*, 4(1):103–108, 2007.

B. Gates. A robot in every home. *Scientific American*, 296(1):58–65, 2007.

Edward T. Hall. A system for the notation of proxemic behavior. *American anthropologist*, 65(5):1003–1026, 1963.

Kotaro Hayashi, Daisuke Sakamoto, Takayuki Kanda, Masahiro Shiomi, Satoshi Koizumi, Hiroshi Ishiguro, Tsukasa Ogasawara, and Norihiro Hagita. Humanoid robots as a passive-social medium: A field experiment at a train station. In *Proceedings of the 2007 ACM/IEEE Conference on Human-Robot Interaction*, 2007.

Janet Kolodner. *Case-based reasoning*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 1993. ISBN 1-55860-237-2.

Emrah Akin Sisbot, Aurelie Clodic, Rachid Alami, and Maxime Ransan. Supervision and motion planning for a mobile manipulator interacting with humans. In *HRI '08: Proceedings of the 3rd ACM/IEEE international conference on Human robot interaction*, 2008. ISBN 978-1-60558-017-3.

Mikael Svenstrup, Thomas Bak, Ouri Maler, Hans Jørgen Andersen, and Ole B. Jensen. Pilot study of person robot interaction in a public transit space. In *Proceedings of the International Conference on Research and Education in Robotics - EUROBOT 2008*, 2008.

M. L. Walters, K. Dautenhahn, R. te Boekhorst, K. L. Koay, C. Kaouri, S. Woods, C. Nehaniv, D. Lee, and I. Werry. The influence of subjects personality traits on personal spatial zones in a human-robot interaction experiment. In *Proc. IEEE Ro-man*, pages 347–352, Hashville, August 2005.

J. Xavier, M. Pacheco, D. Castro, A. Ruano, and U. Nunes. Fast line, arc/circle and leg detection from laser scan data in a player driver. In *Proceedings of the 2005 IEEE International Conference on Robotics and Automation, 2005. ICRA 2005.*, 2005.