Pilot Study of Person Robot Interaction in a Public Transit Space

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Abstract. This paper describes a study of the effect of a human interactive robot placed in an urban transit space. The underlying hypothesis is that it is possible to create interesting new living spaces and induce value in terms of experiences, information or economics, by putting socially interactive mobile agents into public urban transit area. To investigate the hypothesis, an experiment was carried out at a bus terminal serving both as a transit space and a shopping mall, where an autonomous robot were to detect and follow random people. The people that were followed were asked to fill out a questionnaire for quantitative analysis of the experiment. In addition video documentation of the experiment was used in the evaluation. The results showed that people were generally positive towards having mobile robots in this type of environment where shopping is combined with transit. However, it also showed harder than expected to start interaction with commuters due to their determination and speed towards their goal. Further it was demonstrated that it was possible to track and follow people, who were not beforehand informed on the experiment. The evaluation indicated, that the distance to initiate interaction was shorter than initially expected, but complies with the distance for normal human to human interaction.

Keywords: Human-Robot Interaction, Transit Space, Pilot Study.

1 Introduction

When robots move from the laboratory or factory, and out into the everyday human environments, they will have to interact with humans, and accordingly human-robot interaction is a novel and growing research field [1,2,3]. For robots

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to be able to behave appropriately in human environments, they will have to possess skills to interact with, and learn from people as well as behave in a social way that will be acceptable, as perceived by humans. Experiments with robot motion and people's perception of robots have been investigated by several authors. For example, the level of comfort for the test subjects are investigated in [4,5,6] through wizard-of-oz experiments.

Interaction between a robot and a human not only rely on the ability to input, output, and process information, but to move socially around, it is also necessary to know something about the spatial relationship between the two actors. In [7] human-human proxemics, i.e.the spatial distances between persons in interaction, were studied, and in [8] experiments were made, that support the division into these zones. [9] concerns models describing social engagement based on spatial relationships, and this is also investigated in [10], where a robot system is implemented to learn, perceive and understand the spatial dimension of an indoor human made environment. This calls not only for skills for interacting with humans, but also for navigating in populated public areas. In [11] an approach for coordinating motion of a robot in a crowded human environment with moving obstacles is described, and an experiment with a robot at a train station is done in [12]. In [13], a navigation strategy enabling a robot to join a group of persons engaged in a conversation is developed. The above research concerns how to implement a robot in public spaces, but where are the actual potential of mobile agents in public spaces?

The global transportation activity and congestion has increased the time we spend in transit [14], and thus *transit spaces* opens new opportunities for human interactive robots. The spaces of transit are seen as sites of interaction where people meet and thus (potentially) engage [15]. In Denmark for example there is a clear correlation between GNP and Mobility during the period 1994-2004 [16]. Mobility thus makes up an increasing proportion of contemporary everyday life ([17]). Much mobility is done in transit and in designated *transit spaces* such as airports terminals and shopping centers.

Focus in this paper is on the willingness of people to interact with a robot, and how people reacts when robots suddenly is a part of their daily environments.

The general hypothesis is that it is possible to add value, both in terms of experience, information and economics, to urban transit spaces by inducing socially intelligent robots. This is supported by the assumption that, by putting interactive social robots into a transit space, interesting interaction will arise.

To be able to verify this hypothesis and create robots suitable for these public spaces, it is necessary to conduct experiments investigating how robots are perceived by humans in the public space. It is also necessary to find out how the robot should be designed and what behavior algorithms should be used to get into interaction with humans. The effect of placing a robot in a human environment is analyzed through an experiment where a robot is placed in a transit space and shopping center, and tries to start interaction by following people it detects.

2 Methods

The experiment documented in this paper is designed to give some indication to the validity of the hypothesis as outlined in the introduction. To do this two experimental elements have been explored: 1) demonstration of the ability of a robot to detect, track and follow people in a natural way, 2) investigation of peoples perception of the robot, the space and the interaction. So both the technical aspects of placing mobile robots in complex open-ended environments are investigated, and so is the understanding of the nature and potential of robotic agents in public urban transit spaces.

2.1 Experimental Setup

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. The space is characterized by being used both by commuters and shoppers having patterns of motion ranging from very determined to wandering behavior. Hence, the space may be categorized a combined public and urban transit space giving a very dynamic and diverse experimental environment. In the setup there was no primarily information about the experiment for the persons involved.

Robotic Platform. The basis for the experiment was a robotic platform, Robotino, from FESTO. To facilitate interaction the robot 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. In addition the robot was equipped with a head with 126 red diodes which enables it to to express emotions like happy, sad, surprised or confused or even showing a question mark. Expressing emotions, is an important feature for robot-human interaction as indicated in [18,19].

Person Detection. To enable detection of persons in the environment, a simple method relying on a laser range finder was employed. An algorithm for detecting legs of persons and converting these to persons described in [20], was implemented on the platform. This algorithm provides a list of persons within the range of the laser, and the algorithm was modified to keep track of the individual persons in the list, so that a specific person can be chosen as the target for interaction.

Control of the Robot. The robot behavior is inspired by the spatial relation between humans (proxemics) as described in [7]. 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 $< 0.45m$. Social spaces between robots and humans were studied in [8] supporting the use of

Hall's proxemics distances and the human robot interaction is therefore designed to be able to experiment with different distances.

For control the robot programming framework Player [21] was installed on the Robotino platform and the following behavior scheme was developed (see Fig. 1):

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.

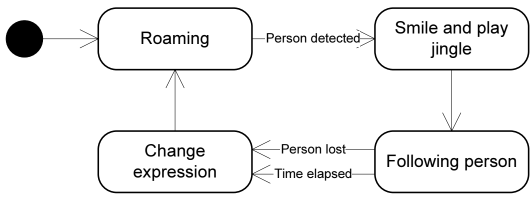

Fig. 1. The state diagram, which was implemented on the robot for the experiment

To keep the desired distance to the person being followed, two decoupled PID controllers, one for velocity and one for rotation, was used. The desired distance was initially set to 1,4 meters to make the robot stay in the social zone of the persons. Later in the experiment, the distance was decreased to 1 meter to investigate if it has any effect on the initiation of interaction.

2.2 Evaluation Methods

The outcome of the experiment was evaluated by, questionnaires, video recordings, and in situ observations. The questionnaire was done by interviews of the persons that were in interaction with the robot. All interviews were done immediately after the interaction.

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.

Questionnaire. The interviewed persons were asked about age, sex, occupation, business at the location, and the frequency of their visits to this specific transit space. The interviewed persons were then asked to rate the following questions on a five point Likert scale from good to bad. How would you describe the arcade as a public space in terms of

– What is your impression of this transit space?
– Is it a good place for social networking?

These questions were followed by questions about the experience with the robot:

- How did you experience the robot when you first noticed it?
- How did you feel when it followed you?
- How do you think a robot like this fits into a place like this?
- How do you think robots in 20 years will be a part of transit spaces? (assistants - as entertainment - surveillance - there will be no robots)
- How many robots do you think will be present in future transit spaces? (few - as today - they will be everywhere)

All answers were recorded for future analysis.

3 Results and Observations

During the experiment 48 different persons were interviewed, and most of the them answered all the questions. Only two persons answered too few questions to be used in the evaluation.

3.1 Person Detection and Robot Controller

A typical scenario from the experiment is seen in Fig. 2, where a mother and a child interact with the robot. The output from the laser range finder from that same scene is shown in Fig. 1.

Fig. 2. A mother and a child interacting with the robot, a typical situation from the experiment

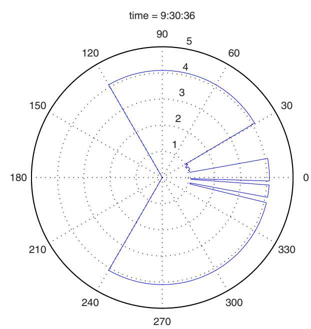

Fig. 3. Typical readings from the laser rangefinder. The laser image corresponds to the scenario in Fig. 2. The radial scale on the polar plot is in meters.

The experiment showed that the algorithm was able to detect the persons in the area. However, due to persons generally moving faster than expected, and only 4 meters of laser vision, the control loop for caching up with persons to be followed, sometimes reacted too slow, and people were lost on that behalf. Because of this, some parameters of the controller were tuned during the experiment to make the robot move faster. This increased the ability to follow

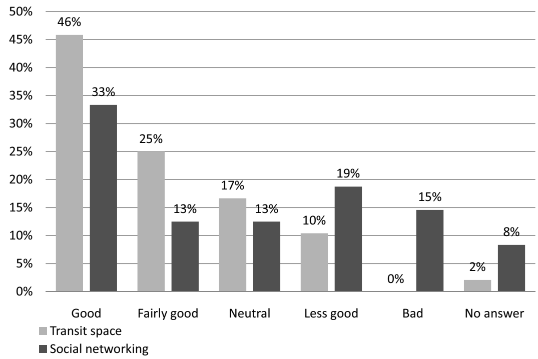

Fig. 4. Answers from questions on peoples overall experience of the space as a transit space and as a place for social networking

people, but the robot still did not move fast enough for following all people. The controller could be tuned to make the robot move even faster, but this is also a compromise between fulfilling the desire to make the robot move in a slow, smooth and comfortable way.

3.2 Answers to Questionnaire

Of the 48 respondents, 47% were commuters, while 29% were shoppers, reflecting the combined transit and shopping space. The average age of the respondents was 45 years and 65% were women. A summary of the answers to a selection of the questionnaire are displayed in the three histograms in Fig. 4-6.

88% of the questioned people think of the transit/shopping space the "Kennedy Arkaden" as Neutral to Good place. So people in general experience the space as a comfortable not hostile environment - a good basis for interacting with the robot (see Fig. 4). 58% rate the space as Neutral to Good as a space for social networking.

Regarding questions about how people experienced the robot the majority (92%) answered that they were positive towards (Neutral to Good) when they first noticed it and it started to approach them. Further, in general people (67% Neutral to Good) did not feel uncomfortable when the robot followed them, though a few persons answered that did not like the robot following them (see Fig. 5).

Of the people questioned 90% found that a robot would fit Neural to Good into a transit space like the "Kennedy Arkaden", see Fig. 6.

When asked if they expect robots and what role they would have in transit space in 20 years, 23% expect robots to have a role in entertainment, 40% see robots as assistants, helpers or guides when used in transit spaces and 6% expect them to have a role in surveillance. 50% expect robots to be everywhere in 20 years, 29% only expect a few and 8% expect a situation as today.

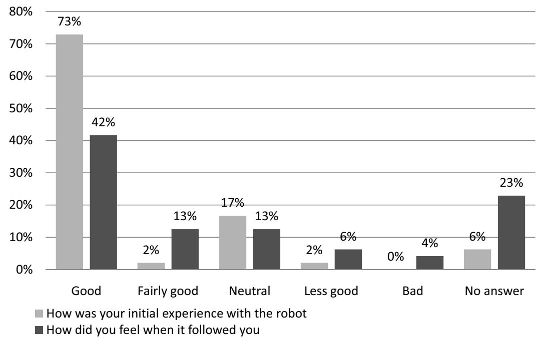

Fig. 5. Answers from questions on peoples experience with the robot, initially and after the robot started following them

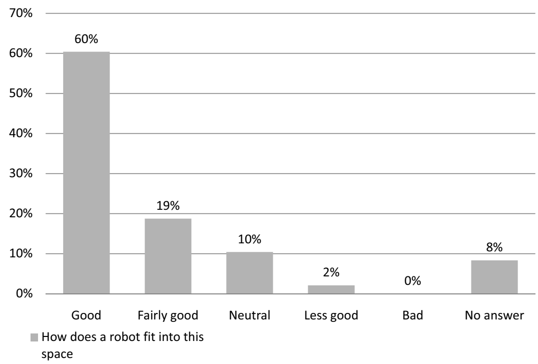

Fig. 6. Answers from question on peoples opinion regarding the use of robots in transit spaces

3.3 Observations

During the experiment and by video analysis the following were noted:

- When individual persons were near the robot, they either did not notice it, give it a curious look and then go, or, in a few cases they played with it a bit. However, when larger crowds formed around it, they seemed to get bolder; there was much more playing with the robot then, essentially turning it into an attraction of the arcade. This actually contradicts the results found in [22], where an experiment shows that if a person is close to the robot, other people tend not to get close to the robot also.
- People in transit like e.g. commuters (who knew exactly where to go) tend to completely ignore the robot even when it followed them. It was more people who had time to stop, people with children, or people who just liked the entertainment, who reciprocated the interaction.
- When changing the desired distance from 1,4 meters to 1 meter, i.e. moving into the personal zone, people tended to start interaction much more often.

– A lot of the time the robot was roaming around in one end of the transit space having nothing to do. But at the same time, there might be people in the other end of the environment, who the robot could not see and who were potential subjects for interaction.

4 Discussion

4.1 People Detection

The detection of persons seemed to work very well, but the persons are modelled with no dynamics, which means that persons should be close to where they were before to be certain to detect that it is the same person in the next iteration of the algorithm. When e.g. the robot is turning, the person positions as seen from the laser changes rapidly, and this can sometimes be a problem for the laser. It is therefore suggested to improve the person detection algorithm with information about the movement of the persons and the robot itself, or a range finder with a longer field of vision.

Instead of trying to make the robot better at following people, this could also be interpreted in an other way; the robot should not try to start an interaction when a person does not show the slightest interest in the robot. If for example you each day passed through the transit space to get to the office or home, then you would not be interested in, or even be annoyed when, robots try to interact with you all the time. Therefore research should focus on the persons who have interest in interaction, either when they want information, help, experience or other things. In this context it would be of great benefit if the robot were able to learn to see, what the intentions of each person are. This could for example be done using Case Base Reasoning, which is used in [23] and [24].

Sometimes during the experiment, some people were standing and looking at other persons who were interacting, or several persons tried to get in contact with the robot at the same time. At these times it was the robot who needed assistance. Therefore it could be interesting to investigate the possibility of multiple cooperating robots, who helps each other in completing the tasks in transit spaces. This could enable robot A to call for help, or informing robot B that at some place, there is a person who needs assistance, but robot A is already occupied. Sharing information would also enable the robots to get a better overview over the whole situation, and e.g. make an adaptive map over the environment. Such a system could also be supported by other sensors, like surveillance cameras or sensors detecting people moving into or out of the area. This could also eliminate or reduce the cases, where the robot roams around in one end, and therefore does not observe interesting persons in other ends of the transit space.

4.2 Quantitative Evaluation

Generally the people questioned were positive towards the "Kennedy Arkaden" as a place for transit and shopping (see Fig. 4). Of the respondents most were commuters. The observation was that commuters were more difficult for the robot to follow, and the overall number of commuters in the space is hence higher than indicated in the numbers. The high number of commuters may also influence the attitude towards the "Kennedy Arkaden" as a place for social networking. The people positive towards the space as a place for social networking was lower than the people positive towards the space in general. The response to the two questions as outlined in Fig. 4 indicate a positive attitude towards the transit space, which is the basis for the experiment. Introducing a robot in an environment where the general attitude is hostile, may be much more difficult.

The majority of the respondents where were positive towards having a robot entering the transit space (see Fig. 5). This supports the hypothesis that it is possible to add value to urban transit spaces by putting interacting robots into them. Furthermore, most people feels comfortable towards having the robot in the environment, even when the robot were following them, though it was slightly less in this case. As the interaction interface was very simple (sound and motion), it may not have been clear, what was the purpose of the interaction.

People started to interact more when the interaction distance was set to be closer, probably due to the robot getting into the personal zone, where it can not just be ignored. This result complies with logic, since when we are moving normally around in public spaces, we pass a lot of people within the social zone. But unless it is very crowded, we try go stay out of the personal zone of people we do not interact with. In this context, it is also important for the robot to stay out of the intimate zone, which according to [25] is uncomfortable for test persons passing a robot.

Also supporting the hypothesis is the fact that 90% (Neutral to Good) found that robots could be used in transit spaces. The questionnaire also gave some idea of the potential use of robotics as seen by the respondents, where the majority (40%) sees robots as assistants. 50% expect robots to be everywhere in 20 years, which given the relative high average age (45 years) of the respondents is interesting and provides a very good basis for the extension of robotics into peoples everyday lives.

5 Conclusion

This paper has described an experiment with an autonomous robot, driving around and following random people in an urban transit space. The results show that people are generally very positive towards the idea of having more robots assisting or entertaining persons in public spaces. About interaction it was found that initiating interaction, is much easier, if the robot comes into the personal zone of the persons. It was also demonstrated that the algorithm for detecting, tracking and following persons worked, if the persons did not move too fast (below approximately 1,5 m/s), though it was possible to tune the controller for better behaviour during the experiment.

The purpose of the experiment was to get some indication of the hypothesis that it is possible to add value to urban transit spaces by putting social robotic agents into them. The experiment supports the hypothesis in terms of most persons being positive and interested in the robots existence in the public space.

However, there is still a long way to go before we see sociable robots naturally integrated into everyday human environments.

In this experiment essential knowledge have also been gained about making experiments in an open-ended environment, where you are not able to know all factors beforehand as opposed to laboratory experiments.

An interesting prospect for future work is to actually try to detect if people is interested in interaction from their movement pattern, and only try to start interaction if that is the case. Additional it can be concluded that it would be of great benefit if several robots were able to cooperate about solving the tasks for mobile robots in urban transit spaces.

The robot described in this paper is the relatively "dumb" first generation mobile agent in a transit space. Taking small steps towards the final goal of a human interactive robot in a public space, the next generation could be overlayered with one-way information technologies (e.g. traffic information). Third generation robots could be added interactive technologies (e.g. games and interactive communication) and thus become the "digital passenger" of the future.

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