Contents

Decoding Human Intentions

- by Mobile Robot Interaction

1 Project Summary

In recent years robots have started to move from the factories, and out into our society to become a more integrated part of our daily life. The research in this Ph.D. project aims to enable robots with capabilities, that enhance their ability to be a part of everyday human environments. This means that robots in a natural way must be able to coexist and interact with humans. To do this, the robots must act in a way that feels comfortable for humans, i.e. act in compliance with the unwritten context dependent rules of appropriate social behaviour. More specific this Ph.D. project concerns the motion of robots in relation to the interaction. This includes how robots should interpret the intentions of humans, i.e. are the persons talking each other, do they want to interact with the robot, or do the persons only want to go around the robot.

2 Project Description

This section elaborates the Ph.D. project.

Background and State-of-the-art

For many years robots have been an ubiquitous part of science fiction movies, but have until now not succeeded to enter into the everyday human environment, in the same way. The fact is that we have a long way to go before real robots can catch up with their science-fiction counterparts. Robots in human interaction is a research field which is yet only in its infancy Dautenhahn [2007]. In recent years researchers have begun to focus, on how the future generation of robots may become a part of human environments. It has been much harder than expected to enable computers and robots to exhibit social behaviour and communicate at the appropriate level of abstraction. One of the inventors of the PC-revolution, Bill Gates, states that we may be on 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].

Robots will enter our daily lives to do floor cleaning, logistics, surveillance, entertainment, rehabilitation training, playing, assisted living, learning and more.

This Ph.D. project aims at trying to combine capabilities of movement, human state estimation, interaction and path planning, in a way which makes intelligent robotic devices capable of being a more natural and sociable player in a human environment.

There have been some recent research about Human Interactive Robots. For example the large project COGNIRON [COGNIRON, 2007], whose vision is to develop robots which are able to serve humans in their daily life. In Sverre Syrdal et al. [2006], it is investigated how people feel about approach directions for robots, and in Pacchierotti et al. [2005] the comfort level for a robot passing in a hallway is measured. Also Kismet (and its successor Leonardo), a robotic head designed for social interaction with humans, has been subject to recent research [Breazeal, 2002]. In Michalowski et al. [2007] the robot GRACE is navigating around among persons in a conference area. In Prassler et al. [2002] an approach for coordinating motion of a robot in a crowded human environment with moving obstacles. The robot is supposed to follow a human target, in this case it is a wheelchair accompanying a person.

However, none of this research concerns how a robot should plan its motion, such that it feels comfortable for humans. To do that, it is also necessary to know the state of the human - is (s)he for example talking to another person or trying to get into interaction with the robot. This state estimation has been considered in Kelley et al. [2008], but only using a stationary robot, so this could just as well be a surveillance camera. What is missing, is a robot, which is able to estimate how people will move, and then safely, naturally and comfortably move around in the human environment.

So in short, the Ph.D. project concerns the state of the art development of the next generation of intelligent robotic devices entering and moving around in the day-to-day human environments.

Hypothesis

From the above background, the hypothesis of the project can be formulated:

It is possible to enable robots in an everyday environment with capabilities, such that they are capable, in a natural way, of moving around, estimating human intentions and interacting with humans or other robots.

Methodology

It has been chosen to split the project up into five subsequent steps:

1. To move around in a populated area, the robot must first of all be able to see persons and estimate their motion direction, velocity etc.
2. People moving around can be treated as dynamic moving obstacles. Therefore the robot must learn to navigate through an area where these are moving around.
3. Since people interacts with each other, the robot must also take this into consideration when moving around. For example, it is not natural to move in between to persons talking together. So the robot must estimate the internal state of the persons.
4. When unsure about which current state the person has, the robot must do something to optimize the estimate.
5. Last the robot must also take into consideration that the person might want to interact with the robot itself, or that the robot want to get into contact with the person.

Figure 1: The robot to be used in this phd project.

The results from the five steps will each be tested both in simulation and on a real world robotic demonstrator. The demonstrator used on the project can be seen in Figure 1. The above described steps will now be further elaborated.

Step 1: Human Motion Analysis To navigate safely around in a human environment, it is necessary for robots to detect and estimate the motion states of human beings. An algorithm for human detection using a laser range finder [Xavier et al., 2005], has been implemented on the robotic demonstrator shown in Figure 1. The algorithm has been tested and verified in a real world scenario in Svenstrup et al. [2008]. The information of the person position can be used to estimate the trajectory, direction of motion and the velocity of the person. The motion of the person relative to the robot can then be used to generate a trajectory for the robot. In Sisbot et al. [2006]; Shiomi et al. [2008]; Althaus et al. [2004] it is considered how the robot should move relative to humans. Together with knowledge of different psychological zones (Hall zones [Hall, 1963]), the approach in Sisbot et al. [2006] is used to make a motion algorithm for the robot. The motion algorithm is primarily developed in Kracht and Nielsen [2007]; Andersen et al. [2008]. The motion strategy together with the estimation of the human motion is developed in "paper 1" described in the Publication Strategy in Section 4.

Step 2: Dynamic Obstacle Avoidance The above described movement strategy only applies for one person. But in a real world, for example on a pedestrian street, there are most likely more persons moving around. The robot must be able to dynamically plan its way through the area. This includes continuously estimating the motion model of each person, such it is possible to plan in advance where they will move. The route planning must be done so that it is safe and natural to the humans. This means that it is not only a collision avoidance task, but also a question about how robot motion patterns should be in a human environment.

Step 3: Human State Estimation People are not just moving randomly around. Maybe they are talking together, standing still and watching something, strolling around or moving determined towards a goal. This means that they act different in different states, and consequently the robot must also move different accordingly. This step looks at a human as a hybrid system, which can take different motion states. The task is to use system identification techniques to estimate the state, or the internal parameters of the persons, from the observed motion. This also means trying to estimate if the motion of two persons are correlated, i.e. they are doing something together. In Figure 2 two persons are moving along together - maybe talking to each other. At first glance they are moving away from each other towards point 1. This means that there is a path between them, but this is not necessarily a good path. Because you might estimate that their states are correlated, i.e. they are talking together, and thus they tend to move towards each other again. The robot should be able to estimate this, and therefore make a path around the persons.

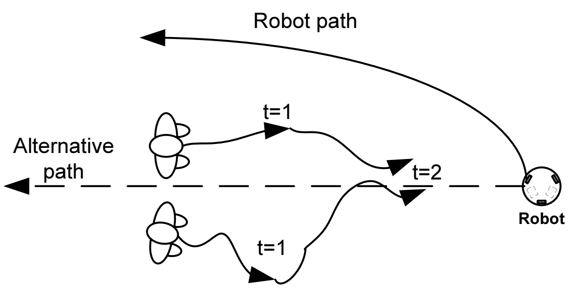

Figure 2: This is a figure of a robot trying find out how to move when two people are coming towards the robot. There could be several possibilities. For example, if the persons are talking, they might stay close, and the "correct" path will be around the persons. But if they are not interacting, a better trajectory might be in between the persons.

Step 4: Active Optimization of State Estimate In the previous step, the robot might be uncertain about what the intentions (state) of the persons are. For example if two persons are standing and talking far away from each other - are the really talking then? The purpose of this step is to find principles about how to interact to get better system identification. That means that if the robot is not sure enough, it can do something to become more certain. An idea is to use methods from game theory, which is to apply a "winning strategy" to optimize the observability of the system (person), and from this generate trajectories. Winning, in this perspective, means that the robot finds out what the person is doing.

Step 5: Interacting with Persons In the previous steps, it has been chosen to use the robot as just an other person moving around in the area. But it might also be that the robot is some kind of service mechanism. This could for example be a robot driving around a hospital with medicine. Then people also sometimes want to interact with the robot to maybe exchange something. This step considers the person state estimation and motion of the robot, when the interaction also might occur.

Preliminary Findings

Until now a pilot study with a robot driving around in a public space has been conducted. The study was primarily to gain knowledge about putting robots in public spaces, and to find out if in general people were interested in robots. The experiment is described in Svenstrup et al. [2008] and it have shown that people are willing to accept robots in their daily environment. This experiment has also been documented and accepted for a video session on the Human Robot Interaction 2009 - conference.

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. This is described in the publication Andersen et al. [2008].

Expected Results

To the best of my knowledge, there is currently no research about how robots should interpret human motions, and from this devise a motion strategy around in everyday environments. Therefore it is expected that the work will serve as a building block for future research within robot motion for Human-Robot Interaction. Eventually the algorithms will be an integrated part of future robotic devices driving around and helping us in our daily lives.

3 Time Schedule

The time schedule is based on the five project steps listed in Section 2. A milestone is associated with each step. Furthermore a last milestone, which is the completion of the thesis, is added .

	Deadline Dates					
Step 1	Jan.'09					
Step 2		Mar. '09				
Step 3			Sep. '09			
Step 4				Feb. '10		
Step 5					May '10	
Step 6						Aug. '10
Milestone	Paper submission	Paper submission	Paper submission	Paper submission	Journal submission	Hand in thesis

Table 1: Timetable

4 Publication Strategy

The Ph.D. thesis will be organized as a plurality of papers. The tentative list of papers and their current status are presented below. The list of papers is derived from the project description in Section 2. Each paper relates to the equally numbered step.

Paper 1:	*Pose Estimation and Adaptive Robot Behaviour for Human-Robot Interaction*
Abstract:	This paper introduces a new method to determine a person's pose based on laser range measurements. Such estimates are typically a prerequisite for any human-aware robot navigation, which is the basis for effective and time-extended interaction between a mobile robot and a human. The robot uses observed information from a laser range finder to detect persons and their position relative to the robot. This information together with the motion of the robot itself is fed through a Kalman filter, which utilizes a model of the human kinematic movement to produce an estimate of the person's pose. The resulting pose estimates are used to identify humans who wish to be approached and interacted with. The interaction motion of the robot is based on adaptive potential functions centered around the person that respect the persons social spaces. The method is tested in experiments that demonstrate the potential of the combined pose estimation and adaptive potential function approach.
Outlet:	International Conference on Robotics and Automation 2009 (ICRA2009)
Status:	Submitted
Coauthors:	Søren Tranberg Hansen, Hans Jørgen Andersen, Thomas Bak

Paper 2:	*Route Planning with Dynamic Moving Human Obstacles*
Abstract:	When robots move around in populated human spaces, they will need to plan their way according to the dynamic movement of the persons in the area. This requires a model of the human motion, and a strategy for how to navigate in a comfortable way. The model and motion strategy is developed and simulated in this paper.
Outlet:	Conference: IROS 2009 (March 2009)
Status:	Planned
Coauthors:	Hans Jørgen Andersen, Thomas Bak

Paper 3:	*Robot Motion in a Dynamic Environment with Interacting Humans*
Abstract:	When robots move around in human spaces, they have to move in a natural an safe way. This paper addresses how robots should move when meeting people, who are interacting. This includes estimating if two persons interact by observing the correlation of their respective dynamic model. If for example two persons are talking to each other, the robot should not move in between them.
Outlet:	Conference: ICRA2010 (September 2009)
Status:	Planned
Coauthors:	Søren Tranberg Hansen, Hans Jørgen Andersen, Thomas Bak

Paper 4:	*Injection of Motion Effect to Optimize Estimation of Human Intentions*
Abstract:	When humans move around, they can be in different states. The states can for example be interacting with other humans, moving towards an other destination or avoiding the robot. The robot have to adapt the motion pattern to this human state. The paper concerns estimating the human state. If the state can not be established with a given certainty, the robot tries to inject motion in such a way that, the state estimate is optimized. The brutal way is to drive into a person, but also other motion patterns can be used to increase the certainty of the estimate (e.g. moving in front of the person).
Outlet:	Conference: IROS2010 (February 2010)
Status:	Planned
Coauthors:	Hans Jørgen Andersen, Thomas Bak

Paper 5:	*Adapting Robot Motion Trajectories when Meeting Interacting Humans*
Abstract:	In the previous papers, it has been considered how a robot should estimate the human state, and how the robot should move accordingly. Until now it has not been considered a possibility that the person would like to interact with the robot, or the robot would like to interact with the person. This paper considers the estimation and motion when moving around in a human world, where people sometimes tries to get into interaction with the robot, or the robot desires to get into interaction with the human. Furthermore the results from the previous papers are described to cover most of the Ph.D. project.
Outlet:	International Journal of Social Robotics (May 2010)
Status:	Planned
Coauthors:	Søren Tranberg Hansen, Hans Jørgen Andersen, Thomas Bak

Note: Other possible outlets are the conferences ROMAN, HRI and ICAR.

Thesis:	*Decoding Human Intentions by Mobile Robot Interaction*
Synopsis:	This is a tentative table of contents for the thesis: - Introduction - Background and State-of-the-art within HRI - Methods for motion and intention decoding wihtin HRI - Contributions - Connection between papers - Paper 1 - Paper 2 - Paper 3 - Paper 4 - Paper 5
Deadline:	August 2010
Status:	Planned
Coauthors:	None

5 Courses

This section contains a list of completed and planned courses. The list is split into two tables, one with joint courses and one with project related courses.

Project Related Courses

Title	Date	Location	Organizer	ECTS	Status
Machine Learning	Dec. 2007	AAU	Zheng-Hua Tan	3	Completed
Workshop: Metrics in HRI	March 2008	Amsterdam	Catherina R. Burghart	0.5	Completed
Tutorial: Experimental Design	March 2008	Amsterdam	Greg Trafton	0.5	Completed
Studygroup: Structurally Constrained Control	Spring 2008	AAU	Klaus Trangbæk	2	Completed
Robot Motion	Apr.+ May 2008	AAU	Anders la-Cour Harbo	3	Completed
Control and Optimization	March 2008	AAU	Rafael Wisniewski	3	Planned
Problems of Advanced Optimization	April. 2009	AAU	Horia Cornean	3	Planned
Total				15	

Table 2: Project Courses

Joint Courses

Title	Date	Location	Organizer	ECTS	Status
PBL	Jan. + Apr. 2008	AAU	Lars Peter Jensen	1	Completed
Bayesian Statistics	May 2008	AAU	Kasper K. Berthelsen	4	Completed
Writing and Reviewing Scientific Papers	Sep. + Nov. 2008	AAU	Jakob Stoustrup	3.75	Completed
Professional Communication	March 2009	AAU	Anette Kolmos	2.5	Planned
Advanced mathematics for phd candidates in the engineering sciences: analysis and topology	Nov. 2009	AAU	Lisbet Fajstrup	4	Planned
Total				15.25	

Table 3: Joint Courses

6 Communication of Scientific Knowledge

This section lists the how the scientific knowledge until now has been communicated.

- December 2007: feature tv2nord (12.00 and 19.30 news programs)
- May 2008: Poster at the conference HRI08
- October 2008: article on videnskab.dk
- October 2008: follow up articles on jp.dk, newz.dk
- December 2008: interview to “journalisthøjskolen”
- Misc. demonstrations of Robotino at seminars and exhibitions
- Project supervision: 6th semester, 5th semester 7th semester, 3rd semsester Esbjerg
- Planned supervision: 8 semester and 10th semester related to the phd project
- Teaching: 3rd semester PE course in Datamaters Arkitektur og Programmering

7 International Activities

A 4-5 month external visit to University of Nevada in Reno is currently being planned. Their robotics research lab is headed by Monica Nicolescu. Mainly the research focuses on human behaviour modelling, human intend understanding and learning by demonstration (see e.g. Kelley et al. [2008]). The research interests is more elaborated on this website:
`http://www.cse.unr.edu/~monica/Research/res.html`

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