Distributed Collaborative Control of Sociable Mobile Robots

- in Human Interaction

Field of study

This PhD project concerns human-robot interaction (HRI) using multiple cooperating sociable mobile robots. Sociable robots in terms of this project means robots, which in a natural way are able to coexist and interact with humans in an everyday environment. To do this, the robots must act in a way that feels comfortable for humans in the environment, i.e. act in compliance whith the unwritten context dependent rules of appropriate social behaviour, a property that most humans possess.

To make robots (or agents) able to continuously evolve their social behaviour, cognitive skills should enable the robots to interpret the environment, reason about how to interact and react accordingly. Like humans gradually increase their social capabilities from when they are born, the robots are trained to make good decisions and thereby exhibit social and situational awareness.

It is expected that future public areas will virtually be swarming with robots. If all these robots must enter naturally in the environment, they must also learn to cooperate, which is also a topic in this phd 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]. Only in the recent years researchers have begun to focus on how the future generation of robots[1] are likely to be 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, recently wrote an article about robots in the future. He 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].

In the future years, such robots will enter our daily lives to do floor cleaning, logistics, surveillance, entertainment, rehabilitation training, playing, assisted living, learning and more.

This phd project will aim at trying to combine capabilities of movement, interaction, path planning, collaboration and not the least cognition, in a way which makes intelligent robotic devices capable of being a more natural and sociable player in a human environment, and not only able to perform specific pre-programmed tasks.

In short, the phd project concerns the state of the art development of the next generation of intelligent robotic devices entering the day-to-day human environments.

Motivation for problem and its scientific challenges

Imagine some time in the future entering the main hall of a huge office building. You have never been there before and need to find a specific conference room. Around you is a lot of busy business people rushing towards their destination. Intermingling with this crowd is a swarm of robotic agents; small mobile message carrying robots, larger human like robots, flying robots, medium

[1] The term robot in this context refers to a mobile robot, which are able to interact with humans due to its ability to move. The counterpart, human-machine interaction, has been a known research field for a long time.

sized wheeled robots, receptionist robots, and not the least visitor assisting robots. In this chaos the all the robots must be able to exhibit the same social accepted motion pattern as people. Otherwise the robots will be of annoyance to the people minding their own business, and they will never be accepted in a human environment. For the visitor assisting robots, it is even more difficult. They will have to identify you as a visitor needing help, and know how to approach you and help you. Even further they will have to agree which robot will help you or to hand you over from e.g. a welcoming robot to a guiding robot.

This is a scenario not far from what is seen in science fiction movies. But to enable the robots of today with the above mentioned capabilities requires a huge leap from today's technology. The robotic research society has of today only taken a small bite of the cake, but is progressing by taking small steps enhancing the capabilities of robots towards the goal of making robots a natural part of human everyday lives.

This future scenario is the motivation for this project, and thus the hypothesis of this project is therefore:
It is possible to enable robots with capabilities such that they are capable of moving, cooperating and interacting both with humans and other robots. These capabilities supports social behaviour, so that the robots become an integrated and natural part of future everyday human environments.

To get towards fulfilling this hypothesis, several different sub questions can be considered:

1. How should robots communicate, collaborate and agree on tasks?
2. How should control frameworks be designed to facilitate sociable and comfortable robot behaviour?
3. How should robots approach and interact with humans?
4. How should robots be able to learn from their common previous experiences like people do?
5. How are these abilities evaluated and tested on prototype robots?

Scientific methods

This section describes what research has previously been made within this field, and states how this phd project will contribute to current research.

Analysis and Potential Solutions

Human Interactive Robots A large ongoing research project is called COGNIRON, which is short for cognitive robot companion. Their vision is, according to [COGNIRON, 2007], to develop robots who are able to serve humans in the daily life. In Sverre Syrdal et al. [2006] it investigated how respectively seated and standing persons feel about approach directions compared to the personality of the test persons. In Sisbot et al. [2005]; Koay et al. [2005] it is tested how the robot should move, so it feels most comfortable for humans. Derivation of movement patterns for a robot in a human environment have also been investigated in Sisbot et al. [2005]. Here, a method for generation of a trajectory for a robot, which is supposed to avoid getting in the way of humans, is developed. For example if two persons are standing and talking together, the robot would avoid going in between them. The implementation of this system, including person detection, is described Sisbot et al. [2006]. The cognitive aspect has been investigated in Calinon and Billard [2007], where a robot learns skills by watching and mimicking movements performed by a person.

An other similar project is CoSy (Cognitive Systems for Cognitive Assistants) COSY [2007], which have the approximate same goal as COGNIRON, however with slightly more weight on the cognitive part. In Pacchierotti et al. [2005] they evaluate the comfort level of a robot passing in a hallway using the proxemics described in Hall [1963]. In Zender et al. [2007] a robot is designed to track and follow persons in a socially acceptable way, and in Mozos et al. [2007] a robot system is implemented to learn, perceive and understand the spatial dimension of an indoor human made environment.

Carnegie Mellon university also have several human interactive robots e.g. Tank, an immobile robot receptionist, and Grace who is a mobile robot. In Michalowski et al. [2007] Grace is programmed to try to find a person wearing a pink hat at a conference. This is done by approaching persons and asking if they can see the pink hat, and if so point to the right direction. Humans can also by themselves approach Grace to help her. In Gockley et al. [2007] she is used for testing natural, in the way of being a social robot, person following behaviour.

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.

What have not been investigated, is how and when to switch from avoiding getting in the way, to actually interact with a person. For this to be possible, it is necessary for the robot to know if a person is interested in interaction. One method to estimate the intention of a person is case based reasoning (CBR). In CBR the current situation is compared to previous experiences (cases), action is taken from this information, and a case database is updated according to the output of the current interaction. This is done in e.g. [Likhachev and Arkin, 2001; Likhachev et al., 2005]. Also work within the Section of Automation and Control at Aalborg University has been done within this area. In [Kracht and Nielsen, 2007] CBR has been used to find out if a person is interested in interaction, and adapting the motion according to this.

Decentralized Control of Multiagent Teams As stated in the Field of Study section, is wanted to have more than one robot cooperating about a task. Therefore it is also necessary to investigate methods for making multiple robots work together. Farinelli et al. [2004] presents a survey of recent research within multirobot systems, and analyzes the forms of coordination and cooperation. A new taxonomy for classification of different approaches is suggested, and around 80 research projects/articles are categorized.

Overall control of a swarm of robots with joint intentions is described in [Tan and Bishop, 2004] and Jennings [1995] and a system giving the diferent robots role assignments are investigated in McMillen and Veloso [2006].

Nair et al. [2005] studies the state of the art within multiagent teamwork and the effect of putting emotions into it. Both in combined human-agent teams and pure multiagent teams, it is argued that the robots need not to have emotions themselves, but they should display emotions to communicate their internal state to others (both agents and humans), and thus enabling better understanding of each others intentions. A belief-desire-intention (BDI)[2] model is used to enable the robot to perceive and affect the world. To control each robot the BDI model is combined with a distributed partially observable Markov decision processes (POMDP) to enable the robot to find out what to do. These (Distributed) POMDP's for robot team coordination and its optimality and complexity are studied in [Xu et al., 2005; Emery-Montemerlo et al., 2004; Pynadath and Tambe, 2002; Bernstein et al., 2002].

[2] Belief is the robots beliefs of how the world is looking, the desire is how the robot desires the world to be, and intention is how the robot will react to obtain the desired world.

Human detection and tracking All this interaction described above is not possible without robots being able to detect and identify humans. In Xavier et al. [2005] they use a fast line arch detection algorithm on laser range data. Persons are detected by analyzing the geometric characteristics of the lines and arches (if e.g. two arches, resembling legs in size, are beside each other, it could be a person). In Kleinehagenbrock et al. [2002] and Michalowski and Simmons [2006] a combination of vision and laser range data is used to track objects. In Schulz et al. [2001] a motion model of the objects being tracked is used in a particle filter to generate a probabilistic Bayesian estimate of the position of multiple objects being tracked. In Zivkovic and Krose [2007] legs are detected by a laser range finder, and this is combined with vision information of the upper body to reliably detect people.

What is missing As established above, there have been done research about robot movement behaviour in a human environment, behaviour when interacting, cognition in human-robot interaction and collaborating robots. However these four areas have not been combined in one robot yet. For example there is no research in interacting robots which are also collaborating with other robots. Furthermore there are no robots which can switch between interaction and non interaction modes. Only few public experiments, which are not restricted to confined static laboratory environments, have been done, and these are also necessary to find out how humans will react to different robotic behaviours.

The research in this phd project will mainly consider collaboration and behaviour patterns of the robot. The other tasks will be solved using knowledge from other research and simplified solutions if necessary. For example the person detection will utilize previous research [Xavier et al., 2005]. Psychological experiments have been done in the COGNIRON project, and the results from this will be utilized. For localization and navigation (obstacle avoidance), already existing implementations will be used [Ulrich and Borenstein, 2000; Collett et al., 2005].

Solution verification and Test The developed algorithms will be tested on robot demonstrators, one already available at the department. The current robot (see Figure 1) is based on the FESTO Robotino® platform. The robot is further equipped with a head, which makes it able to perform expressions like happy, sad, confused, etc.

The Playerstage robotic software framework [Collett et al., 2005; Rusu et al., 2007] will be used to control the robot.

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

Expected Outcome

It will be showed that it is possible to use modified robot cooperation methods in a context where robots interact with humans. Furthermore a novel robot control framework, which gathers capabilities such as cognition, cooperation, interaction, and socially acceptable motion, will be developed.

Potential Significance and Applications(s)

It is expected that this phd project will help to develop a small part of a robot framework, on which future generations of socially intelligent robots can be based on.

Rough Time Schedule

Month 1 - Month 12: Literature study identifying the background on previous and potential solutions. Pilot test of an interactive robot inserted in a human environment.

Month 7 - Month 12: Literature study, analysis and identification of cooperative solutions.

Month 10 - Month 24: Literature study, analysis and identification of cognitive solutions and motion patterns.

Month 12 - Month 30: Analysis, development, implementation and validation of control, collaboration and behaviour strategies. This period might also encompass an external visit to another research institution.

Month 20 - Month 36: Experimentation and documentation of knowledge on the technical aspects of collaborative social robots in human interaction, as well as the influence on peoples behaviour. This last period will be used to gather the most notable research results in scientific papers for conferences and journals.

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Distributed artificial intelligence;Joint intentions;Multi agent systems;Cooperative problem solving;Electricity transportation management;.

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