Make room for me

A study on a spatial and situational movement concept in HRI

Annika PETERS a,1, Thorsten P. SPEXARD a, Marc HANHEIDE a and Petra WEISS b

a Applied Informatics Group, Bielefeld University, Germany
b Department of Linguistics and Literature, Bielefeld University, Germany

Abstract
Mobile robots are already applied in factories and hospitals, merely to do a distinct task. It is envisioned that robots assist in households, soon. Those service robots will have to cope with several situations and tasks and of course with sophisticated human-robot interaction (HRI). Therefore, a robot should not only consider social rules with respect to proxemics, it should detect in which (interaction) situation it is in and act accordingly. With respect to spatial HRI, our goal is to use non-verbal communication, namely implicit body and machine movements to make interaction simpler and smoother. A first study aims to acquire a concept of spatial prompting by a human and by the robot in a “passing by” scenario. The results will be used to enrich the existing system with an appropriate passing behaviour and to distinguish between passage situations and others.

Keywords. implicit HRI, implicit cues, movement concepts, situational interaction, spatial interaction, non-verbal communication

Introduction
Mobile robots are more and more leaving the labs and are applied in public places (hospitals, museums, factories). It is envisioned that soon robots assist in household as well. Therefore, robots should be designed for the average human, who has little to no technical understanding of a robot. This is why, Pacchierotti et al. suggest that designs should follow person-person interaction patterns initially, to have a basis from which to start [10]. In human-human interaction social signals or unconscious cues are sent and received by interaction partners. These signals and cues influence the interaction partner wanted and unwanted - sometimes to achieve a distinct goal. To be aware, of those to and fro sent signals and especially of implicit cues, is crucial, when interaction between a robot and a human is modelled.

Imagine you are walking through or towards a narrow place, e.g., a hallway, a door frame or a small kitchen. A service robot might block the way or drives towards you, pursuing its own goal like you. The service robot needs to decide, whether you just want to pass or if you like to start a conversation with it. Consider human-human interaction, humans would not even speak in order to pass by and avoid bumping into each other, even if the space is narrow. Some cues or signals must have been sent back and forth
between both interaction partners to decide that they are in a passing by situation. Body movements are one way to communicate with each other, sometimes in an implicit or unconscious way. According to this, spatial interaction with a robot should be that easy, either. Therefore, participants of the interaction should be taken into account as sender and receiver of signals. As a start in this direction of research, this paper focuses on non-verbal communication, especially on implicit body movements from the human and from a robot towards the other in a “passing by” scenario.

Although, robot movement in domestic environments has already been studied, it is not sufficient for a robot to avoid obstacles and navigate to metric positions to really share space with humans in a social and interactive fashion. A robot should not only consider social rules with respect to proxemics (e.g., defined by Hall [5]), orientations in communication (e.g., Kendon’s L-formation [7]) or in approaching people. It should also be able to signal and understand certain spatial constraints such as “passing by” or “making room for each other”. The complexity for a social robot comprises not only the detection of a particular situation but also the distinction between several situations. These could be for example, a “passing by” situation, an “approaching”- or a “giving information” situation. This is why, detection of humans and collision avoiding is necessary but not enough, when a robot is modelled for assistance in households.

1. Passing By

When modelling interaction behaviours, both sides of the interaction have to be taken into account. On the one hand, there is the side of the robot and how the movement of the robot is interpreted. On the other hand, there is the human side and how the human tries to communicate with the robot. Human-human communication is taken as an inspiring example in social robotics, therefore one should not forget the human interaction partner might display some human features of human-human communication, either.

Most research is primarily concerned with how the human perceives and is comfortable with the action of the robot. With respect to mobile robots, Butler et al. state that “body movements of the robot are one way for the robot to communicate with humans around it”, [1]. Therefore, they identified and evaluated two parameters, which influence the participant’s comfort level with the robot in an avoiding scenario: (a) speed of the robot and (b) distances of the robot towards a human. The results of the user study reveal that participants prefer a faster (0.38 m/s) and a flowing passing movement of the robot. Participants of the study thought this behaviour more ‘human-like’. The authors think that the speed of the robot should be between 0.3 m/s and 1 m/s to reach maximal comfort, depending on the familiarity of the user with the robot. Pacchierotti et al. evaluated a person passing model on a social robot in a hallway setting [9]. Three parameters were tested in a pilot study with four participants. The lateral distance towards a walking person (a), the distance of initiating the avoiding movement (b) and the speed of the robot (c) were varied and tested in different combinations. Results display a tendency that participants were more comfortable with a higher robot speed (0.6 m/s), a longer signalling of avoidance distance (6 m) and a lateral distance of 0.4 m. In a follow up study Pacchierotti et al. varied only the lateral distances and found that people do not perceive, lateral distances lower than 40 cm as reaction of the robot towards themselves. Furthermore, preliminary results suggest that social conventions of direction of travel play a role when passing a robot [10].
Green and Huettnerauch introduced the term *spatial prompting* [4]. This concept means that robots should actively and spatially influence humans to position themselves in a better way to make human-robot communication easier. As soon as the position of the user is detected, the robot could plan to position itself with respect to proxemics. Naturally, this should apply to the human, either. There is little research done on how exactly humans are spatially influenced (or prompted) by each other, but even less in human-robot interaction.

Hence, the concept of spatial prompting is taken further and considered from another point of view. Spatial prompting from the human side towards a robot is examined closer to analyse the implicit spatial signals, which are sent by the human towards a robot within interaction. Person-Person communication or interaction is very complex, various signals are sent by interaction partners back and forth. Therefore, the social robot should not only prompt a human, but also it is the goal that the robot is able to recognize social signals, especially, in the form of body expressions or movements, which the human sends, unconsciously and consciously, to make her/his intentions clear.

Those social signals could be helpful for the robot to be aware of situations in a spatial context and react in a social appropriate manner without the need for humans to explicitly explain her/his intentions. Naturally, if there are usable spatial - social signals of the human towards the robot, the interplay between spatial prompting from either side and the reaction towards those signals will be crucial to examine to make interaction as naturally as possible. This is why, an iterative approach, which comprises implementation and evaluation, is planned for the course of this research. “Making room for each other” in a “passing by” scenario is the situational and spatial concept, which is currently examined. The above mentioned parameters of passing strategies will be considered to make the robots overall behaviour more ‘human-like’ and consequently observe human prompting strategies.

In this context, the planned human-robot study in a hallway setting, will be outlined the section after the robot platform BIRON2 is presented and a software component necessary for this research is shortly introduced.

### 2. Person Representation

As a first step towards situation aware spatial prompting a robust tracking system for humans has to be established, for sure. Besides pure position estimation, which is often a tough task on its own, the actions of an interaction partner have to be provided for a situation aware system causing a more natural robot behaviour. By which means should a robot decide, whether to avoid an approaching person or to make contact when only position information is given? For this reason a person tracking approach based on the idea of Anchoring, suggested first by Coradeschi and Saffiotti [2], is used. The idea of Anchoring consists of applying real world sensor readings (Percepts) to a software model, the so called Symbol. Lang et al [8] extended the unimodal single object Anchoring to a multi-modal person tracking, considering several types of Percepts and Symbols as depicted in Figure 1.
Person Anchoring: For each modality, e.g., a face, a separate anchoring process is associating position information to the symbol. Tracking is achieved by applying a movement model evaluating position changes according to the time elapsed between two subsequent Percepts. Besides feasible movements a composition model limits the association of the different kinds of Symbols to one particular Person by maximum distances between, e.g., a face position and a pair of legs. By this Person Model the separate modalities are fused to a Multi-modal Anchor for Persons. Thus a Person is tracked as long as one Component Anchor exists.

Combining the different types of information, which are given from the several modalities, assumptions, according to the human’s current action, are drawn to enable the robot for situation aware interaction. Currently, information about the movement behaviour, the speech and gazing direction are evaluated. This information is, on the one hand, used to identify the most promising interaction partner, if multiple persons are in the vicinity of the demonstrator. On the other hand, the monitored person behaviour is provided to a central memory, enabling both flexible accesses by other software modules [11], and the monitoring of the development in time. This monitoring provides the system with information which can be used to decide situationwise, whether the robot should circumnavigate a person, who wants to pass by or approach a person since she/he wants to start an interaction. The exact heuristic will be modelled, based on the outcomes of the study with the demonstrator.

3. Platform

The demonstrator on which the person representation and monitoring is already implemented is BIRON2, see Fig. 3. It serves as a platform for the user study described in the following section. The demonstrator is based on the research platform GuiaBot™ by MobileRobots® customised and equipped with sensors that allow analysis of the current situation in a human-robot interaction. BIRON2 is a consequent advancement of the BIRON (BIlefeld Robot companiON) platform, which has been under continuous development since seven years. It comprises two piggyback laptops with Intel Core2Duo®, 2GB main memory, and Linux to provide the computational power and to achieve a system running autonomously and in real-time for HRI.

2www.mobilerobots.com
The robot base is a two-wheeled PatrolBot™, with two passive rear casters for balance. Its maximum motion speed is 1.7 meters per second translation and 300 degrees per second rotation. Inside the base front there is a 180 degree laser range finder (SICK LMS200). With a scanning height at 30 cm above the floor, the laser ranges are used both for navigation tasks and to detect pairs of legs for the previously mentioned person representation. The camera, for face detection and gaze estimation, is a Sony 12x zoom pan-/tilt camera. The camera is able to scan the area in front of the robot. For localisation of sound direction in the person tracking approach, two interfacial microphones are mounted on the top of the body of the robot. Additionally, the robot is equipped with a Pioneer 5 degrees-of-freedom arm for lightweight manipulation and referential gestures. With the upper part, BIRON2 has an overall size of approximately 60 cm x 50 cm x 130 cm. The body houses a touch screen as well as the system speaker, used for speech output in user interaction.

4. The Fieldstudy

To investigate both, the human side and the robot side of prompting during interaction, a study will be conducted, regarding the above mentioned parameters (speed, distances), (a) to provide data under the focus of proxemics and (b) to subsequently improve the system accordingly. The study take place in a corridor of the Bielefeld University. Students and employees of Bielefeld University use this hallway to reach other stories or lecture halls. A sign on the floor and hallway will inform them that a robot is currently working in this area. Unknowingly, some passerbys will take part in the field study. These will be informed shortly after they passed through. Of course, they will be asked if the data can be used for the study and if they would fill in a questionnaire. An experimenter will be always there, observing and stopping the experiment whenever she/he thinks it is necessary. This strategy is chosen to achieve a realistic situation, in which people have a realistic wish to pursue their own goal and are not in a lab environment.

The line of thought, which is approached within this study, is that humans prompt spatially, therefore the robot has to react adequately. This raises the questions, what reactions are appropriate and how people are communicating their wishes to pass by.

Consequently, a range of avoiding behaviours will be activated on BIRON2 in two slightly different experiment settings. There is a static setting and a dynamic setting in which the robot either stands in a door frame in the corridor or drives towards it to create a blocking situation for the approaching human, see Fig. 3. As soon as an approaching person is detected (about 7 m), randomly, an avoiding behaviour is initiated. The avoid-
ing/passing strategies can be divided into defensive, offensive and less prompting and more prompting, see Tab. 1. The categories less - and more prompting are behaviours in which BIRON2 either drives straight or turns to one side. These behaviours are displayed to examine if there are any differences in human spatial prompting. Furthermore, these behaviours can be divided into defensive and more offensive motions. Defensive behaviours are backward motions in a static setting. In a dynamic setting, defensive strategies are short forward movements, see circles 5, 6 in Fig. 3. Offensive passing strategies are movements towards the person with more or less prompting. The cases, in which BIRON2 displays forward motion, but no avoiding, are control cases. Participants have to find a solution to pass by. Especially, experiments with behaviour no.6 (dynamic, less prompting and offensive) will be interesting to observe, because BIRON2 will block the way completely. With the variety of tested behaviour we want to approach questions such as: in which situation does a human prompt spatially and which “avoiding behaviour” triggers most spatial prompting on human side?

Figure 3. Each experiment setting depicts four possible strategies to make room for each other, see numbered circles (orange). The square represents the robot, which is either standing in or moving towards the door frame in a corridor of the Bielefeld University (blue, letter R). The triangle (yellow, letter H) represents a human, who is approaching and wants to pass. The dotted line arrows depict the direction of movement. The circled letters a-d (skin coloured circles) represent passing behaviours, which are against the traffic rules of Germany, see Section 1 and [10]. They will be not considered in this study.
Table 1. These tables display the possible behaviours. BIRON2 exhibits these during the experiments. The numbers and letters correspond with the circled ones in Fig.3. More prompting means that the robot moves to right side in order to avoid an approaching person. These movements can be forward or backward. Less prompting stands for straight motions with no hint how the passing situation might be solved. Offensive motions are forward motions past the narrow space, see Fig.3 - frame of the firedoor. Defensive motions are mostly backward motions and motions in front of the narrowness.

4.1. Measurements

To analyse spatial prompting quantitatively, following parameters are measured to provide the data.

- The time of the participant’s interaction with BIRON2
  - start: when BIRON2 has detected a person
  - stop: when BIRON2 cannot detect the participant again or remote controlled by experimenter
- The interaction is audio- and video-taped with an external camera and with the on board camera and microphones of BIRON2
- The Person Tracking records, if a person is facing, moving, speaking, see Section 2
- The path, which the participant pursued is also provided by the Person Tracking
- The path, which BIRON2 pursued is provided by odometry data

4.2. Questionnaire

After the encounter with BIRON2, participants are asked to fill in a questionnaire. The questionnaire is designed to find out, if people related the displayed behaviour of the robot to their presence and their spatial prompting. We like to know, if the participant can guess the intention of BIRON2, and if the behaviours are good enough to work without the help of other modalities. In addition, the displayed strategy should be rated to find the behaviour which is appropriate for this situation. This includes questions concerning the reaction time or signalling distance of BIRON2, which we expect to be an important parameter to influence the comfort of the user with a robot [1, 10]. Furthermore, we would like to know, how the participant would have liked or expected, BIRON2 to have reacted.

5. Summary and Outlook

In this paper the hypothesis was presented that humans prompt in a spatial way towards a robot to make their intentions clear. Consequently, the robot has to react adequately. To
make human-robot interaction smoother, sent and received signals from both human and robot have to be taken into account. The paper focuses on non-verbal communication, namely, on the spatial movement of a human towards a robot. Interpreting the human spatial prompting makes the robot more situation aware and consequently let the robot act socially appropriate. A first study is presented and results will soon shed light on the spatial prompting situation. Thereafter, first models will be implemented under the same condition and subsequently evaluated in a home environment. A full furnished flat outside the University, which is rented for experiments, will be the next setting to acquire more data in a household environment. Moreover, in future research the question will be addressed, if less spatial prompting on human side is an indicator for a smoother interaction.

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