Hesitation Signals in Human-Robot Head-on Encounters

A Pilot Study

Christian Dondrup
University of Lincoln
Brayford Pool, LN6 7TS
Lincoln, UK
cdondrup@lincoln.ac.uk

Christina Lichtenthäler
TU München
Boltzmannstr. 3
85748 Garching, DE
lichtenc@in.tum.de

Marc Hanheide
University of Lincoln
Brayford Pool, LN6 7TS
Lincoln, UK
mhanheide@lincoln.ac.uk

ABSTRACT

We present a pilot study to identify hesitation signals in Human-Robot Spatial Interaction which we aim to employ to evaluate the quality of the robots executed behaviour. The presented study focuses on head-on encounters between a human and a robot in pass-by scenarios. Our results indicate that these hesitation signals can be found and therefore present a form a implicit feedback.

Categories and Subject Descriptors

I.2.9 [**Artificial Intelligence**]: Robotics; I.5.1 [**Pattern Recognition**]: Models

Keywords

Hesitation; Human-Robot Spatial Interaction

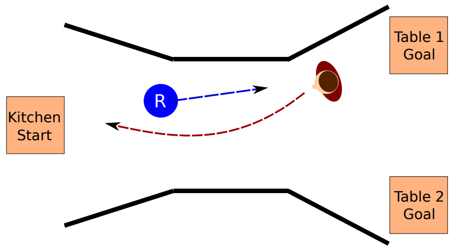
1. INTRODUCTION

Human-Robot Spatial Interaction (HRSI) is the study of joint movement of humans and robots through space. A large body of research is dedicated to answer arising questions like how to move in the close vicinity of humans given spatial constraints and how to effectively coordinate these movements [3].

In the early stages of mobile robotics research humans were only regarded as static obstacles which had to be avoided but in recent works the social and communicative character of spatial movement is also taken into account, e.g. [7]. This lead to the design of human-aware navigation approaches which try to increase the *comfort*, *naturalness*, and *sociability* (as defined by [3]) of the interaction, using mostly pre-learned or constraint based behaviours. Enabling a robot to learn from experience and shape its behaviour over time to adapt to the users personal preferences requires feedback on the quality of the executed behaviour. To this end, we conducted a pilot study to find signals which allow to evaluate the quality of such human-aware navigation approaches.

Using hesitation gestures as an implicit form of communication is a well established approach in Human-Robot Interaction (HRI). The study proposed in this paper was inspired by the work of AJung Moon *et al.* [5] in particular. They showed that using the acceleration profile of the wrist is sufficient to detect and convey hesitation in HRI manipulation tasks: "[...] *the* [hesitation] *gestures exhibit a characteristic acceleration profile in their principle axis.*" [5, p. 1998]. We aim to transfer these findings to spatial movement of the human body as a whole, to detect *hesitation signals*. Hesitation, caused by confusion due to unexpected behaviour, manifests itself as an abrupt stopping or deceleration. We therefore assume that *hesitation signals* in HRSI are an *abrupt stopping or sudden decrease in velocity of the whole body.*

(a) Robot



(b) Head-on encounter in study set-up.

Figure 1: *a)* Robot hight: 1.72m, diameter: $\sim 61cm$. *b)* The experimental set-up had a size of $5m^2$. The image is showing a typical head-on encounter.

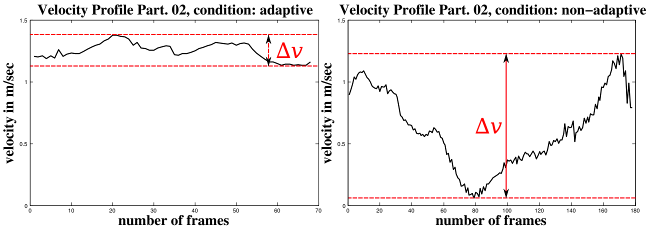
Previous work on head-on encounters in so-called *pass-by scenarios* (see Fig. 1b) used manual annotation of videos or sensor data to evaluate the quality of a chosen trajectory, e.g. [6]. Our study aims to enable a robot to autonomously infer the quality (regarding HRSI standards as described in [3]) of the interaction from sensor data, using hesitation signals. This evaluation would enable a robot to shape its behaviour "on-the-fly" using a shaping framework like TAMER [2], employing hesitation signals as negative reward.

So far, little work has been done to find hesitation signals in spatial movement. We therefore conducted a pilot study to find these hesitation signals in head-on encounters between human and robot during pass-by scenarios.

2. PILOT STUDY

A first within-subject (allowing further investigation if hesitation signals vary between individuals) pilot study was conducted using a motion capture system, tracking the movements of a robot and a human in a confined, shared space. The aim of this study was to find the mentioned hesitation signals in head-on encounters of human and robot.

HRI'14, March 3–6, 2014, Bielefeld, Germany.
ACM 978-1-4503-2658-2/14/03.
http://dx.doi.org/10.1145/2559636.2559817.



(a) Adaptive condition (b) Non-adaptive condition

Figure 2: Adaptive and non-adaptive velocity profile of two of the head-on encounters of one of the participants.

Study Design. In this study participants were put into a hypothetical restaurant scenario with a human-size robot (see Fig 1a). The experiment was conducted in a large motion capture lab with two tables and a kitchen counter in the middle. The tables and the kitchen counter were positioned as depicted in Fig. 1b and connected by an artificial corridor to elicit close encounters between human and robot while still being able to reliably track their positions. The motion capture system recorded x, y, z coordinates (at a rate of 50hz) of the robot and the participant during the whole interaction. We had 14 participants (10 male, 4 female) interacting with the robot for 6 minutes each.

Conditions. During the interaction the robot showed two different behaviours, i.e *adaptive* and *non-adaptive* velocity control, which was switched at random upon the robots arrival at the kitchen counter. When executing the adaptive behaviour the robot gradually slowed down while approaching the human and stopped before entering the personal zone [1] of the participant to let her/him pass (inspired by findings of [4]). In the non-adaptive behaviour the robot tried to reach the goal as efficient as possible regarding the human as a static obstacle. These behaviours were chosen because they mainly differ in the distance the robot keeps to the participant and the velocity of its approach, this should therefore allow to evaluate the quality of the navigation strategy while still enabling the human to reliably infer the goal of the robot.

Procedure. The robot was presented as a co-worker, establishing the same social status for robot and human. During the study, the robot autonomously moved between tables and kitchen counter, taking orders from the supposed guests, while the participants delivered drinks from the kitchen counter to the tables (see Fig. 1b). This task created a more natural type of pass-by scenarios where the robot and the participant would only occasionally and incidentally engage in head-on encounters while trying to achieve their goals most efficiently.

3. RESULTS

For our analysis, a head-on encounter was defined as human and robot approaching and passing-by each other (see Fig. 1b). Manual selection yielded 64 head-on encounters for the adaptive behaviour and 57 for the non-adaptive behaviour. The number of head-on encounters per participant varies between 4 and 14 with a mean of 8.71.

We created velocity profiles from the sequence of recorded x, y, z coordinates of the participants and computed the difference in velocity Δv between the highest and lowest speed during each encounter. Fig. 2 shows two example velocity profiles for different encounters between the robot and the same participant. Fig. 2a shows a small Δv (almost constant speed) for the adaptive behaviour and Fig. 2b shows a high Δv for the non-adaptive encounter which represents a distinct slowing down and therefore, according to our assumption, a hesitation signal. The mean values of all Δv for each condition: adaptive: $\mu_{\Delta v} = 439.78^{mm}/_{sec}$, $\sigma = 25.71$, non-adaptive: $\mu_{\Delta v} = 516.44^{mm}/_{sec}$, $\sigma = 65.84$, also show a difference between the two behaviours but it is not statistically significant.

4. DISCUSSION

The results show that hesitation signals can be found in head-on encounters during pass-by scenarios. Analysis of the velocity profiles resulted in differences between the adaptive and non-adaptive condition. The non-adaptive behaviour showed a larger deceleration of the participant during interaction than the adaptive behaviour which means that the robot interfered with the participant's goal in an unexpected way, therefore, causing annoyance and stress. This shows that the adaptive behaviour is better suited for this kind of head-on encounters and reveals that shaping the robots behaviour towards the more adaptive control would suite the needs of our participant group. This indicates that hesitation signals can be used as implicit feedback and should allow our mentioned shaping approach to work but this is still subject to further investigation.

The mentioned lack of statistical significance could have various reasons, e.g. the small number of samples. Since this paper describes a pilot study to find trends and evaluate if further investigation would be justified, we only had a small group of participants and a short interaction time for each individual. This yielded a very limited number of head-on encounters (see Sec. 3). A future study with prolonged interaction and more participants is believed to address this issue and allow us to use a shaping approach, employing hesitation signals as implicit feedback.

5. ACKNOWLEDGMENTS

The research leading to these results has received funding from the EC FP7; grant agreement No. 600623, STRANDS.

6. REFERENCES

[1] E. T. Hall. *The Hidden Dimension.* Doubleday, anchor books edition, 1966.

[2] W. B. Knox, P. Stone, and C. Breazeal. Training a robot via human feedback: A case study. In *Social Robotics*, pages 460–470. Springer, 2013.

[3] T. Kruse, A. K. Pandey, R. Alami, and A. Kirsch. Human-aware robot navigation: A survey. *Robotics and Autonomous Systems*, (0):–, 2013.

[4] C. Lichtenthäler, A. Peters, S. Griffiths, and A. Kirsch. Social navigation-identifying robot navigation patterns in a path crossing scenario. *ICSR. Springer*, 2013.

[5] A. Moon, C. A. C. Parker, E. A. Croft, and H. F. M. Van Der Loos. Did you see it hesitate? - Empirically Grounded Design of Hesitation Trajectories for Collaborative Robots. In *IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, pages 1994–1999, 2011.

[6] A. Peters, T. P. Spexard, M. Hanheide, and P. Weiss. Hey robot, get out of my way - A survey on a spatial and situational movement concept in HRI. In *BMI - Well-Being*, pages 147–165. 2011.

[7] E. Sisbot, L. Marin-Urias, R. Alami, and T. Simeon. A Human Aware Mobile Robot Motion Planner. *IEEE Transactions on Robotics*, 23(5):874–883, Oct. 2007.