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As Time Goes by: Representing and Reasoning Timing in the Human-Robot Interaction Studies

Hatice Kose-Bagci, Frank Broz, Qiming Shen, Kerstin Dautenhahn, Chrystopher L.Nehaniv
Adaptive Systems Research Group, University of Hertfordshire, School of Computer Science, Hatfield, Herts, AL 10 9AB, U.K.
{h.kose-bagci;f.broz;q.shen;k.dautenhahn;c.l.nehaniv}@herts.ac.uk

Abstract

We summarise the experimental design issues related to timing in three human-robot interaction studies investigating imitation and drumming experiences with child-sized humanoid robots and human participants. Our aim[1] is not to have the humanoid robots just replicate the human's behaviors (e.g. waving or drumming), but to engage in a 'social manner', i.e. in a call and response turn-taking interaction. This work is part of a research project on developmental robotics with a particular emphasis on imitation and gesture communication.

1. Introduction

Timing plays a fundamental role in the regulation of human-robot interaction and communication. We present the experimental design and analysis issues related to timing based on three exploratory studies investigating imitation based interaction games with child-sized humanoid robots and human participants. The primary goal of this work is to achieve (non-verbal) gesture communication and imitation between child-like humanoid robots and human beings, whereby interaction games including drumming and imitation served as a test bed to study key aspects of face-to-face interaction such as turn-taking, synchronisation and non-verbal gestures.

The first presented study is based on *drum-mate*, a drumming game where turn-taking is deterministic and head gestures of the child-sized robot KASPAR[1] accompany its drumming to assess the impact of non-verbal gestures on the interaction [2]. This paper will focus on a modified version based on emergent turn-taking dynamics; here our aim is to have turn-taking which is not deterministic but emerging from the social interaction between the human and the humanoid [2].

The second study focused on imitation. Unlike the first work, which concerns turn-taking, this work is based on synchronisation which introduces different issues related to timing. Here the robot makes simple body moves like waving its hand, and the human tries to imitate the robot whilst the robot evaluates how successful the imitation is [3]. Here the joint motion of the human and the robot should be tracked simultaneously and compared.

In a third study, our aim is to analyse and model the gaze behaviour of human-human and human-humanoid pairs. Therefore we need to track the gaze of the participants coming from different sources in real-time and compare them to detect joint and mutual gaze. Additionally, once the data is collected, a suitable representation for the time distribution of the periods of mutual gaze must be chosen.

3. Issues related to timing

A. Turn-taking issues

We implemented the human-robot drumming game as an example of a *call and response turn-taking interaction.* In the deterministic case, we used predefined fixed time duration heuristics for turn-taking . The human partner started by playing simple rhythms with a toy drum. KASPAR started playing if the human was silent for a few seconds. However, it was not always clear when the robot or human partner should initiate interaction in taking a turn. In the second version of the study (the emergent case), we instead used probability-based computational models to control timing and turn-taking. Three simple models (threshold, linear, hyperbolic) were used to control the starting and stopping of the robot's drumming beats. The temporal dynamics of turn-taking thus emerged from the interaction between the human and the humanoid. We studied how these models impacted the drumming performance of the human-robot pair and the participants' subjective evaluation of the drumming experience.

B. Synchronisation issues

Synchronisation is another vital issue in timing which we encounter during human-robot interaction

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experiments. Many interaction games, including physical imitation or music, are based on synchronisation. The second experiment we present was based on the synchronisation of the human and humanoid using a simple arm waving motion. We used magnetic motion trackers to detect humans' arm motion and compared with the position of the robot's arm joints, and tried to detect the synchronisation between them in different scenarios, i.e. waving hands totally in phase or out of phase [3]. We proposed a method based on *information distance* to detect the similarity and synchronisation between the motion of human and the humanoid robot KASPAR2 [3,4].

Fig. 1 A screen shot from the experiments

C. Issues related to measurement devices

In the third study, we analysed the gaze habits of two human subjects. Human-human pairs sat at each side of a table looking towards each other and had simple dialogues while their gazes were tracked by special eye-tracker devices to analyse their joint gaze habits.

Timing is a big issue in using cameras, eye-trackers and other devices to measure body motion, which are essential for human-robot interaction studies. The data coming from these devices should be time-stamped to use with data from other sources. If data is collected on different PCs/laptops, synchronizing time-stamps is not trivial. A Network Time Protocol (NTP) server/client setup should be able to maintain clock accuracy among machines within tens of milliseconds, a resolution which should be adequate for most sensors [5]. Better synchronization is commonly reported, especially across local networks, but may not be reliably achievable without specialized hardware or software [6].

D. Issues related to adaptation:

Adaptive behaviour is a very important part of our interactive studies and in the case of producing or detecting such behaviour, timing is very crucial. It is important to compare the real-time waving-motion data/ drumming performance/gaze direction of the robot and the human (or human-human pair) to get feedback which will be used in the adaptation. If the data from both participants can not be synchronized correctly this feedback can not be achieved.

Additionally, creating adaptive behaviour often relies upon designing or learning a computational model of the desired behaviour. This model may be, as in the case of the drumming study, quite simple, but the realism and interpretability of the behavior produced is likely to be highly dependent upon its internal representation. Because of the importance of timing in the interactions we've explored, models of these behaviours must explicitly represent timing relationships in order to capture their fundamental characteristics. What characteristics of timing (e.g, duration, periodicity, tempo) should be represented and how best to represent them (as values, distributions, or functions) is highly dependent on the nature of the interaction, and many have to be determined via trial-and-error or by examining data from humans performing the behaviour in question.

3. Conclusion

We presented the experimental design and the timing related issues resulting from three interaction studies with child-sized humanoid robots and human participants. Timing plays an important role in human-humanoid interaction, appearing in several different ways such as turn-taking, synchronization, real-time interaction and adaptation.

The methodologies and solutions to the related issues presented in this paper will be used for future studies related to social interaction between human and humanoid, and can possibly be extended for use in other robotic fields, e.g. entertainment, service, and educational/therapy robots.

Selected References

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