Towards the Measurement of Human-Robot Motion Imitation with Inertial Sensors

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ABSTRACT

In tasks like rehabilitation and dance-learning, imitating a master plays a key role. In this study, inertial sensors were attached to both NAO humanoid-robot, which plays the role of a master, and to individual user(s), in order to quantify the imitating phenomenon. Twelve healthy participants were invited to perform simple arm movements for which we applied our proposed framework based on non-linear dynamics to capture the nonlinear structure of the time-series. The results demonstrate that participants exhibit a range of imitating capabilities that can be efficiently captured by our develop metric.

CCS Concepts

•Computer systems organization → External interfaces for robotics;

Keywords

Human-Robot Motion Imitation, Movement Variability, Wearable sensors, Inertial sensors, Non-linear Dynamics

1. INTRODUCTION

Recently, NAO [3], a humanoid robot, has successfully been used both as a fitness coach for elderly and as a rehabilitation instructor for children. For instance, the work of Gorer *et al.* [2] takes advantage of an RGB-D camera to extract joint angles of a human demonstrator and participants in order to compute the vector of absolute differences between the two entities. The absolute difference vector is then used to create a corrective feedback for the movement of the elderly with regard to (i) speed adjustment, (ii) amplitude adjustment, (iii) mirroring detection , and (iv) motion. However, when participants are seated the RGB-D camera cannot provide correct skeleton information. Also there is room for implementation of a detailed scoring of human-robot motion imitation which can be used as a metric on how close the participant mimics the original movement of the robot. Similarly, Guneysu *et al.* [4] investigated the use of NAO as a instructor for children arm rehabilitation. In this case the work of Guneysu *et al.* takes advantage of Inertial sensors in order to avoid obstructions between the robot and the children. However, it turns out that each of the four physiotherapists has its own way to move which is reflected in the differences of frequency and amplitude of the movements as well as the initial positions of the hands of the therapists. Therefore, for this study, we advocate the use of inertial sensors to avoid the obstructions when using RGB-D cameras [2] and proposing a framework based on a non-linear dynamic technique in order to quantify human-robot motion imitation and to explore the similarity of movements across participants.

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2. METHODS

2.1 Research Questions

Can the use inertial sensors attached both to a humanoid-robot and to a human in order to quantify the human-robot motion imitation?

2.2 Hypotheses

With this preliminary study, we expect to generate an intuitive explanation of the problem of measurement of human-robot motion imitation in order to provide metrics reagarding the extend to which a participant can imitate the original movement.

2.3 Participants

Twelve healthy participants (two females and nine males) mean age 19.5±0.79 (from now on abbreviated as p01 to p12) were invited to participate in this study. All the participants were right handed. The design of the experiment was approved by University of XXX ethics approval process. All participants provided informed consent forms prior to participation.

2.4 Procedure

Participants were asked to imitate two simple arm movements: (i) horizontal movement and (ii) vertical movement; such simple movements were performed by NAO and each movement were repeated ten times for both the robot and the participant. Data were then collected at a sampling rate of 50Hz from two NeMEMSi inertial sensors which provide tri-axial data of accelerometer, gyroscope and magnetometer sensors and quaternions [1]. Inertial sensors were attached to the right hand of the robot and the right hand of the participant. Due to the simplicity of the proposed movements in this study, we focus our analysis on the z axis from the gyroscope sensor (g_z) which is mostly affected by the nature of the horizontal movement (Figure 1-A).

2.5 Framework for the study

Due to the non-linear structure of the time-series which creates different periods and amplitudes between repetitions of movements and also different time-series across participants (Figure 1-B,C), we use the time-delay embedding as our main method for this study in order to measure the human-robot motion imitation. The method of time-delay embedding is essentially an array of time delayed copies of the available time series $x(n)$ and is defined as $\overline{x}(n) = \{x(n), x(n-\tau), x(n-2\tau), \ldots, x(n-(m-1)\tau)\}$ where m is the embedding dimension and τ is the delay embedding [5]. We applied PCA ($PC_1, PC_2, \ldots, PC_m$) to $\overline{x}(n)$ in order to obtain the reconstructed state space using the first two principal components PC_1 and PC_2 (Figure 1-D,E and F). We then computed euclidean distances from (0,0) point to each point $(PC_1(i), PC_2(i))$ where $(1 \leq i \leq m)$ in order to obtain the box-and-whisker plots (Figure 1-G) for each participant.

3. PRELIMINARY RESULTS

On one hand, it is expect that the robot performs very similar repetitions of movements which are visualised in the orange time-series (Figure 1-B and C). Therefore, a tight circular shape of the reconstructed state space (Figure 1-D) is linked with little interquartile range of the respective box-and-whisker plot (Figure 1-G). On the other hand, the time-series of participant 05 shows (Figure 1-C) different amplitude and periods per repetitions which are related to the disjointed shape of the reconstructed state space (Figure 1-F) and therefore linked with a maximum interquartile range in the box-and-whisker plots (Figure 1-G). We also show that participant 01 is an example of a good imitator of the robot movement (Figure 1-B,E and G). It is important to note that due to the reduced space for the report, we are only presented the results for the horizontal arm movement.

4. FUTURE WORK

We can conclude that the proposed framework efficiently captured the imitating capabilities of the participants. However, our main concern when quantifying human-robot motion imitation is the lack of metrics to say who can be considered a bad, intermediate or good imitator. Therefore, there are four areas that we are going to investigate in the following year (i) data collection from a wider range of individuals (gender and age) and from additional inertial sensors attached to the body. (ii) explore complex movements which can be performed by both NAO and humans (iii) undertake a wider review of non-linear techniques that can be used for the assessment of human-robot motion imitation, and (iv) explore the use of convolutional neural networks for automatic classification of the levels of human-robot motion imitation.

5. REFERENCES

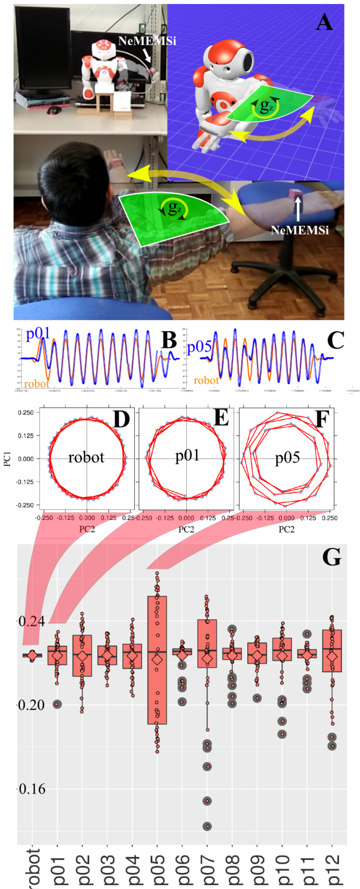

Figure 1: NAO and participant performing the horizontal movement (A). Smoothed angular acceleration g_z for participant 01 and robot (B) and for participant 05 and robot (C). Reconstructed state spaces (m = 40, τ = 10) for robot (D), participant 01 (E) and participant (F). Euclidean distances from the reconstructed state space for the robot and twelve participants (G).

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