Towards the Quantification of Human-Robot Imitation Using Wearable Inertial Sensors

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Objectives

For this study, we are proposing a framework based on Nonlinear Dynamics in order to explore a metric that can help us to determine how close humans mimic the movement of a robot with the use of wearable inertial sensors.

Background

NAO, a humanoid robot, has successfully been used both as a fitness coach for the elderly and as an instructor of rehabilitation for children.

For instance, Görer et al. [1] used NAO as an exercise tutor and an Asus Xtion RGB-D camera to get the absolute differences of the joint angles between the human demonstrator and the participants which were used to create a corrective feedback for the movement of the elderly. However, when participants are seated, the RGB-D camera cannot provide correct skeletal information of the participant.

Similarly, Guneysu et al. [2] used NAO and wearable inertial sensors to monitor the motions of arm rehabilitation of children. However, it was revealed that the four physiotherapists all moved in slightly different ways while performing the same arm motions; which is reflected in the differences of frequency and amplitude of the movements as well as in the initial positions of their hands.

Methods

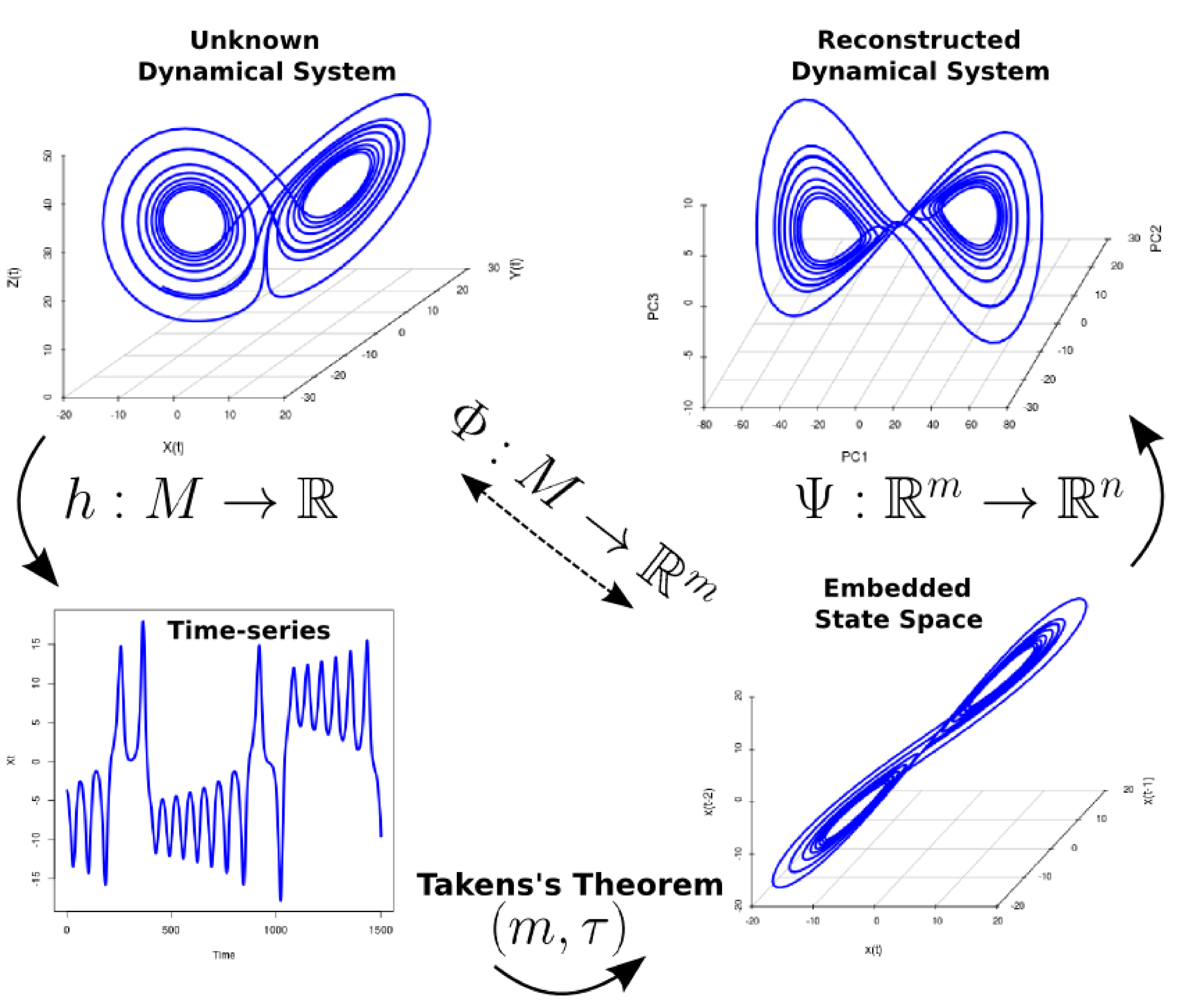
Twelve right-handed healthy participants (two females and ten males) with a mean age of 19.5±0.79 (abbreviated as p01 to p12) were asked to imitate, in a front to front activity, simple horizontal and vertical arm movements performed by NAO.

Data were collected at a sampling rate of 50Hz with two NeMEMSi inertial sensors which provide tri-axial data of accelerometer, gyroscope and magnetometer sensors and quaternions [3].

State Space Reconstruction (SSR)

The state space reconstruction is based on the methods of time-delay embedding and PCA [4]. The method of time-delay embedding is an array of 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.

Our motivation to use the method of time-delay embedding is due to the nonlinear structure of the time-series which is presented as different periods and amplitudes of the time-series between repetitions of movements and across movements of participants



Conclusion and Outlook

It can be noted that participants show different ranges of imitation which can be linked to a scoring system of human-robot imitation. However, the quality of such metric is debatable and needs further investigation. Therefore, there are four areas that we intent to investigate:

- Data collection from a wider range of individuals (differing gender, age and state of health) and from additional inertial sensors attached to the body;
- Exploration of complex movements which can be performed by both persons and NAO;
- Undertake a wider review of nonlinear dynamics techniques that can be used for the assessment of human-robot imitation; and,
- Exploration of deep neural networks for automatic classification of the levels of imitation.

References

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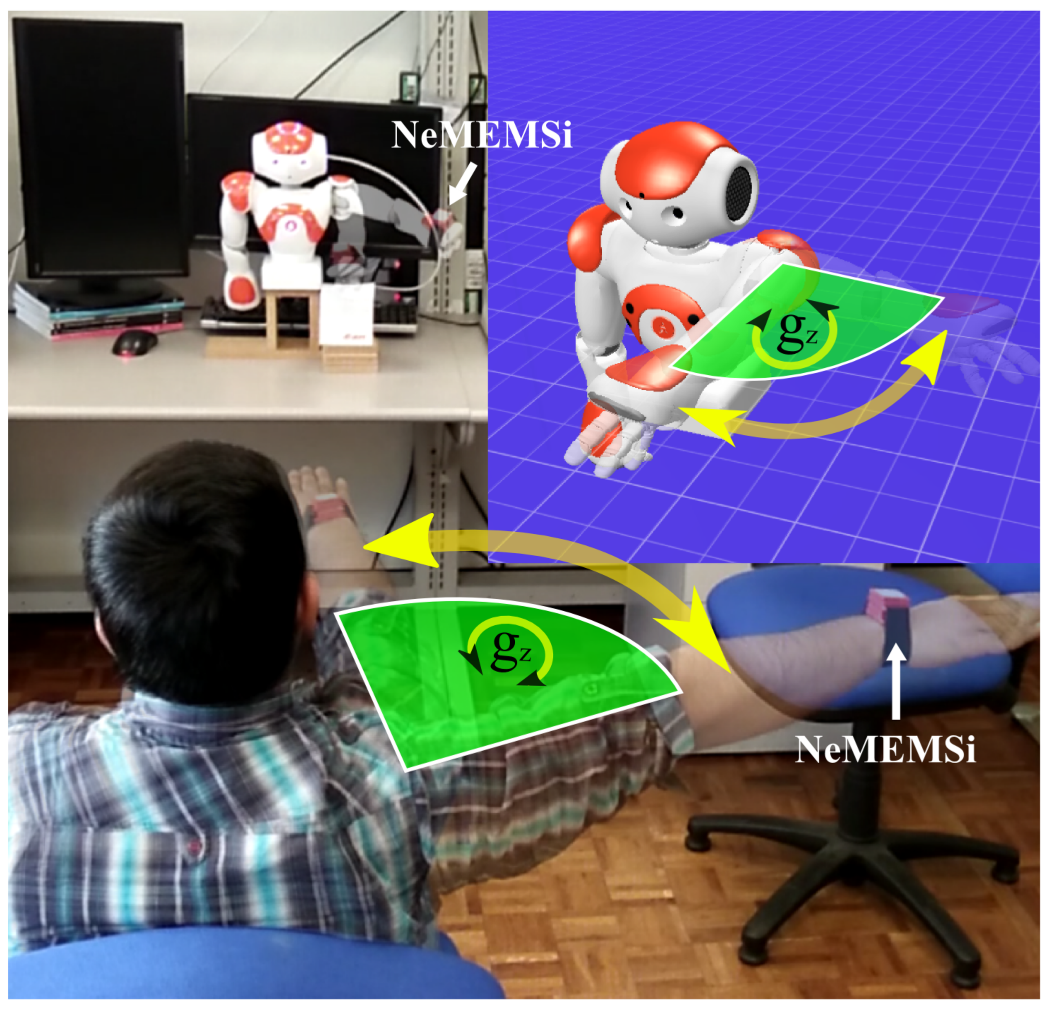
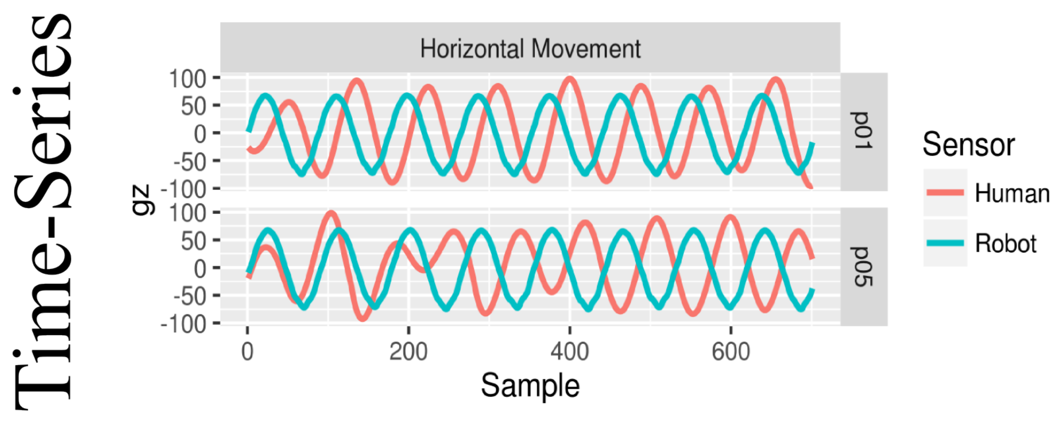
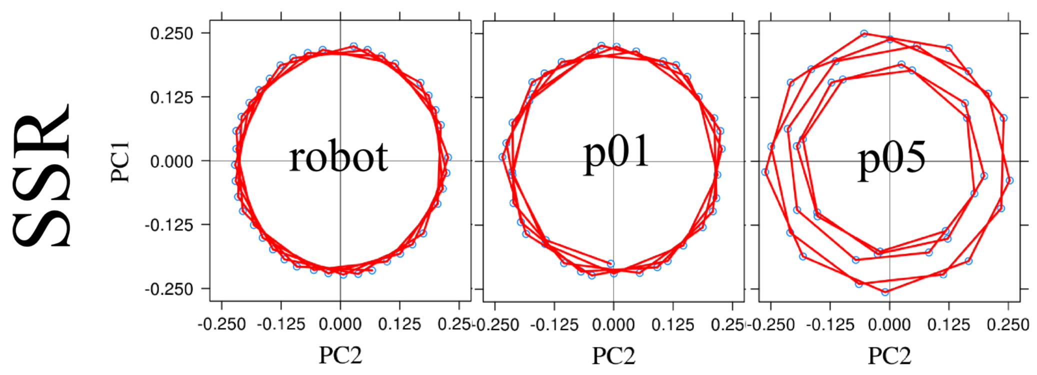
Results

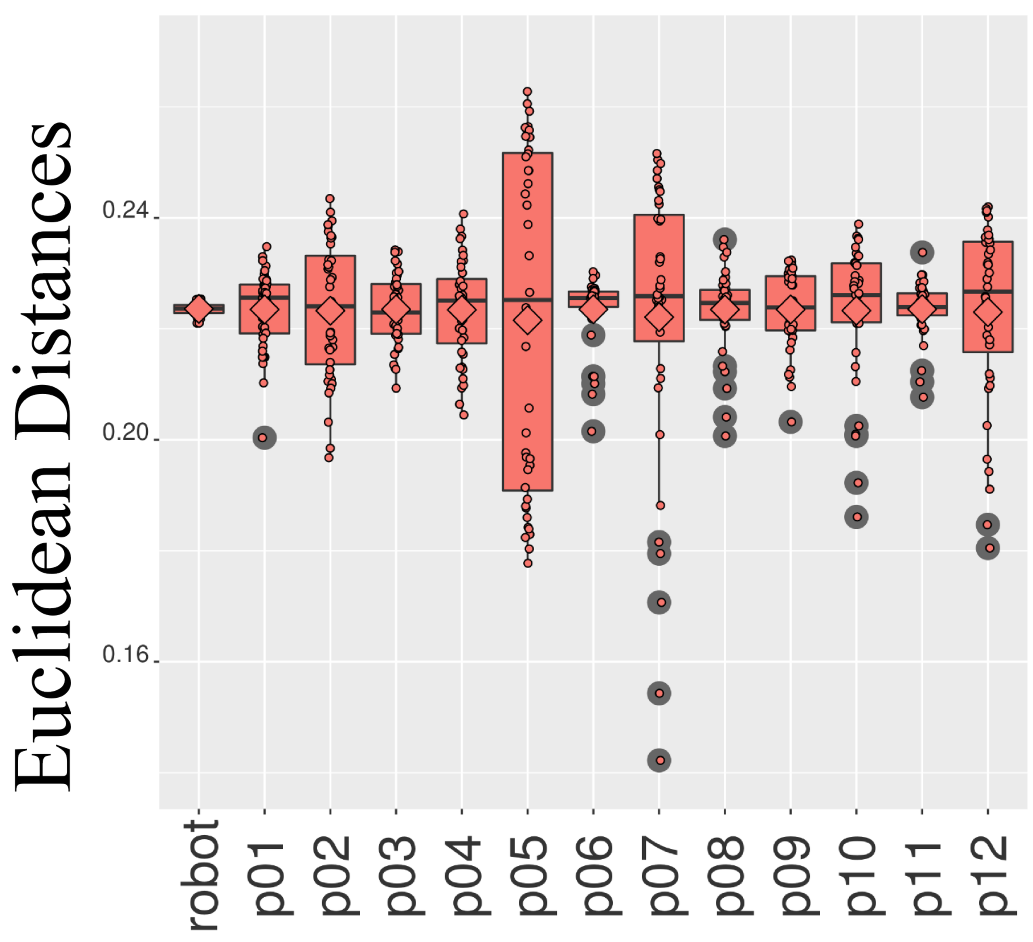
The robot's performance was highly consistent as indicated by the blue lines in time-series and by the tight circular shape in the state space. Compared with the consistency of the robot, p01 was able to imitate the robot's movement well by maintained a good level of consistency as shown both by the time-series and by the circular shape in the SSR. The other participant here, p05, had some problems in following the robot. This is shown by the red line in time-series and the disjointed circular shape of the state space.

One can see that participants p02, p05, p07, and p12 seemed to have more difficulty than others in maintaining a consistent response to the robot's movement.









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