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Towards the Analysis of Movement Variability in Human-Humanoid Imitation Activities

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ABSTRACT

In this paper, we present preliminary results for the analysis of movement variability in order to quantify face-to-face human-humanoid imitation activities. We applied the state space reconstruction's theorem to test our hypothesis where participants, even performing the same arm movement, presented minor difference in the way they moved. With this in mind, we asked eighteen participants to copy NAO's arm movements while we collected data from inertial sensors attached to the participants' wrist and ~~compute~~ estimated the head pose ~~estimation~~ using the OpenFace framework. With the proposed metric, we found that two participants were moving their arms asymmetrically while ~~the~~ others move their arms, ~~within a range of movement variability~~, symmetrically. We also showed that two participants where moving their head even when NAO's head was static. Although the work is in its early stage, the results are promising for applications in rehabilitation, sport science, entertainment or education.

ACM Classification Keywords

I.2.9. Robotics: Sensors; G.3. PROBABILITY AND STATISTICS: Time series analysis

Author Keywords

Human-Robot Interaction; Human-Humanoid Imitation; Wearable Inertial Sensors; State Space Reconstruction; Nonlinear dynamics; Dynamics Invariants

INTRO

INTRODUCTION

Movement variability is an inherent feature within a person and between persons movements [7]. Recently, Herzfeld et al. [5] conducted experiments to state that movement variability is not only noise but a source of movement exploration which at certain point of the exploration such variability is becoming a source of movement exploration. With this in mind, we have found that there is little research in the area of human-robot interaction that is focused on the quantification of movement variability.

methods to explore variability

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The paper is divided into...

METHOD

* Be consistent with the theorem name

State Space Reconstruction's Theorem

The purpose of time-delay embedding, also known as State Space Reconstruction's Theorem, is to reconstruct the topological properties of an unknown $M-$dimensional state space $s(t)$ from a $1-$dimensional measurement $x(t)$ in order to reconstruct an $N-$dimensional embedding space (Figure 1). The

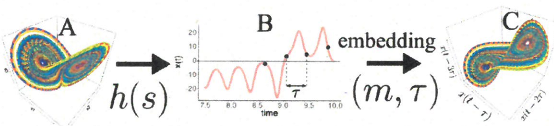

Figure 1. A. $M-$**dimensional state space** $s(t)$**; B.** $1-$**dimensional measurement time series** $x(t)$**; and C.** $N-$**dimensional reconstructed state space** $v(t)$ **where** $M \geq N$ ~~[9]~~ (adapted from [9]).

time-delay embedding assumes that the time series is a sequence $x(t) = h(s(t))$, where $h : S \rightarrow \mathbb{R}^M$ is a measurement function on the unknown dynamical system, being $x(t)$ observable. Thus, the time delay reconstruction in m dimensions with a time delay τ is defined as: $\bar{x}(t) = (x(t), x(t-\tau), ..., x(t-(m-1)\tau))$. Then a further transformation is considered, e.g. PCA, in order to reduce the dimensionality of the $m-$dimensional reconstructed state space to N-dimension [11]. For this work, we assume that the signal, $x(t)$, is produced by some time-varying system in our case the time~~-~~series are produced by the linear acceleration of the inertial sensors. ~~The assumption~~ We assume that the ~~signal~~ time-series exhibits systematic variability within and between persons which leads to the assumption that this signal should, over some time period, exhibit a repeated pattern between and within persons. What we do not know is how reliable the quantification methods for movement variability are and how to establish levels of imitation with a given range of movement variability.

which that invent

Determining the embedding parameters (m and τ)

Although State Space Reconstruction's Theorem has been used extensively in gait recognition and walking, running and cycling activities [4, 10], the computation of the minimal embedding parameters largely depend on the structure of the time~~-~~series (amplitude, frequency, nonlinearity). ~~For this work,~~ To which however we first compute the minimal embedding parameters using the Cao's algorithm [3] and the mutual information and then we manually increase the dimensionality of the reconstructed state space until the attractor is untangled.