Biologically Inspired Cognitive Architectures xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Biologically Inspired Cognitive Architectures

journal homepage: www.elsevier.com/locate/bica

Research article

Demonstration learning of robotic skills using repeated suggestions learning algorithm

Hamed Shahbazi [a,*], Maliheh Alsadat Arshi [b], Kamal Jamshidi [b], Behnam Khodabandeh [a]

[a] Department of Mechanical Engineering, University of Isfahan, Isfahan, Iran
[b] Department of Computer Engineering, University of Isfahan, Isfahan, Iran

ARTICLE INFO

Article history:
Received 26 September 2016
Revised 26 December 2016
Accepted 28 February 2017
Available online xxxx

Keywords:
Imitation learning
Hopf oscillator
Adaptive frequency oscillator
Central pattern generator
Humanoid robots

ABSTRACT

In this paper a new model of nonlinear dynamical system based on adaptive frequency oscillators for learning rhythmic signals is implemented by demonstration. This model uses coupled Hopf oscillators to encode and learn any periodic input signal. Learning process is completely implemented in the dynamics of adaptive oscillators. One of the issues in learning in such systems is constant number of oscillators in the feedback loop. In other words, the number of adaptive frequency oscillators is one of the design factors. In this contribution, it is shown that using enough number of oscillators can help the learning process. In this paper, we address this challenge and try to solve it in order to learn the rhythmic movements with greater accuracy, lower error and avoid missing fundamental frequency. To reach this aim, a method for generating drumming patterns is proposed which is able to generate rhythmic and periodic trajectories for a NAO humanoid robot. To do so, a programmable central pattern generator is used which is inspired from animal's neural systems and these programmable central pattern generators are extended to learn patterns with more accuracy for NAO humanoid robots. Successful experiments of demonstration learning are done using simulation and a NAO Real robot.

Introduction

Nature is usually a very good source of inspiration for science and technology. We can always use these inspirations to build up an artificial instance. "Humanoid Robots" are good examples of this kind of inspiration. Humanoid robots are mechanical structures that are similar to human and generated to mimic the human ability and perform his or her tasks. The main motivation for using these humanoid robots is to achieve human skill and performance (Argall, Chernova, Veloso, & Browning, 2009).

Today, most of these robots are being programmed by experts that have sufficient knowledge of desired tasks. Actually, programming the robot in this way not only is time-consuming, costly and limited to the situations but also is the obstacle for using the robots in daily work by unskilled people. To overcome these problems, one of the most successful approaches that can be used for this purpose is imitation or robot programming by demonstration (PbD). Robots can be overcome these problems by learning new skills. The Robot can learn how the demonstrator acts in many situations. Programming by demonstration greatly reduces the cost of programming. Perhaps, the subject of PbD is one of the situations that converge neuroscience and robotics. This common area of research centers on pattern generators in the spinal cord of vertebrate animals called Central Pattern Generators (CPGs) (Guertin, 2009). Central pattern generators are neural circuits located in the end part of the brain and first part of the spinal cord of a large number of animals. They are responsible for generating rhythmic and periodic patterns in different parts of the body. Although, these pattern generators use very simple sensory inputs imported from the sensory systems. They can produce high dimensional and complex patterns for drumming, swimming, jumping, turning and other types of locomotion. The origin of many movements in animals is the central pattern generators which were discovered by Brone in the early decades of the 20th century (Zielińska, 2009). He discovered that the movement in many animals is an outcome of central neuronal activities in some parts of their neural system, and simple sensory inputs change these activations and make them capable of responding to the extraneous perturbations. The idea that CPGs are neural networks generating complex locomotion patterns with only simple inputs is a provocative one (Righetti & Ijspeert, 2006). In this paper, a model for programmable

* Corresponding author.
E-mail addresses: shahbazi@eng.ui.ac.ir (H. Shahbazi), m.arshi@eng.ui.ac.ir (M.A. Arshi), jamshidi@eng.ui.ac.ir (K. Jamshidi), be.khodabandeh@eng.ui.ac.ir (B. Khodabandeh).

http://dx.doi.org/10.1016/j.bica.2017.02.004
2212-683X/

central pattern generators capable of generating rhythmic patterns with more accuracy is developed.

In Section "Related works" related works in the field of programming by demonstration are reviewed and the advantages and disadvantages of each method are discussed. Section "Learning input signal with Hopf oscillators" introduces the method for making rhythmic patterns in the Nao robot and how to use programmable central pattern generators to generate the desired patterns. In this section, some features of Nao robot are explained briefly. Arm movements which was used in the model are discussed. Section "Repeated suggestion learning algorithm" introduces our method in order to learn the rhythmic movements. Some of the implementations and experimental results in Webots simulator and Matlab Simulink are shown in Section "Experiment al result". In Section "Discussion", the conclusions and future prospective works are stated.

Related works

This contribution deals with the study of programming by demonstration that is a promising approach to automate manual programming of robots (Kober & Peters, 2010). PbD consists of two primary components: task demonstrations from a teacher, and task reproductions from a robot student, as shown in Fig. 1.

Trajectory learning is an important aspect of robot Programming by demonstration. In this case, a teacher must show to the robot how to do a task. Teacher even can be an unskilled person. There are several ways to obtain trajectories that have been shown by a teacher such as motion capture techniques (Ruchanurucks, Nakaoka, Kudoh, & Ikeuchi, 2006), computer vision techniques (Moeslund, Hilton, & Krüger, 2006) and physically techniques (Hersch, Guenter, Calinon, & Billard, 2008) that a robot can be guided through the desired trajectory by moving its joints. In physical guiding, movements are recorded directly on the learning robot and we are away from transferred a system with different kinematics and dynamics that cause errors (Ude, Gams, Asfour, & Morimoto, 2010). A human teacher can train a robot through kinesthetic demonstrations. Kinesthetic guiding records a set of desired movements, which were used to build a library of movement examples. So in this paper we use Kinnect method that has a user-friendly interfaces to get desired input signal and feed this input to system in order to learn it. PbD through Physical Manipulation (LfD-PM) requires the instructor to grasp and guide each part of the robot during a demonstration (Hersch et al., 2008).

Encoded desired trajectories for learning by demonstration have been discussed in numerous papers. Spline-based representations in Miyamoto et al. (1996), Hidden Markov models (HMMs) (Asfour, Azad, Gyarfas, & Dillmann, 2008; Schaal, Peters, Nakanishi, & Ijspeert, 2004) describes some of these methods. A completely different approach would provide in Ijspeert, Nakanishi, and Schaal (2002) based on nonlinear dynamic systems. They represent rhythmic learning and discrete tasks such as tennis strokes and drumming. Nonlinear oscillators are very important modeling tools in biological and physical sciences, and these models have been used strongly to control the rhythmic movements such as locomotion, dancing and drumming. Nonlinear oscillators have interesting properties for rhythmic motor control, including the limit cycle behavior (i.e., the ability to ignore the perturbations and compensate their effects), the smooth online modulation of trajectories through changes in the parameters of a dynamical system and synchronization with other rhythmic systems. The system proposed in Ijspeert et al. (2002) is based on Central oscillators that caused a major drawback. In this approach, frequency of the demonstration signal must be explicitly specified. This means that its approach requires signal preprocessing methods that can extract the frequency of recorded signals (Gams, Ijspeert, Schaal, & Lenarčič, 2009). The implementation of CPGs based on the coupled oscillators are actually designs of stable limit cycles in some interconnected patterns generating oscillators. Righetti and Ijspeert represented a model for construction of a generic model of CPG (Righetti & Ijspeert, 2006). This method was a programmable central pattern generator which used dynamical systems and some differential Equations to build up a training algorithm. The learner model is based on the works of Righetti, Buchli and Ijspeert, which is a Hebian learning method in dynamical Hopfs oscillators. Programmable central pattern generator has been used to generate walking patterns for a Hoap2 robot. By using this type of generic CPG, they trained the generic CPGs with sample trajectories of walking patterns of the Hoap2 robot provided by Fujitsu. Each trajectory is a teacher signal to the corresponding CPG controlling the associated joints (Righetti, Buchli, & Ijspeert, 2006). In this approach, process of frequency extraction and adaptation embedded into adaptive frequency oscillator dynamics totally and does not need preprocessing methods for extracted frequency. They designed a learning mechanism for oscillators, which adapts the oscillator frequency to the frequency of any periodic input signal. Actually, they proposed the dynamical system that composed of a pool of adaptive frequency oscillators with negative mean-field coupling (Section "Learning input signal with Hopf oscillators"). Reproducing and modulating trajectories is also possible using this approach. Gams in Gams et al. (2009) discussed a system for learning and encoding a periodic signal with no knowledge on its frequency and waveform, which was able to modulate an input periodic trajectory in response to some external events. Their system was used to learn periodic tasks under taken by the arms of a humanoid HOAP2 robot for the task of drumming. This model uses two layers of trajectory generation. The first layer,

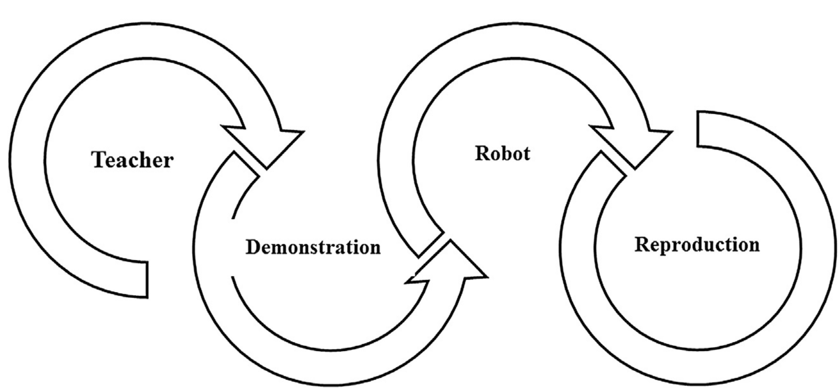

Fig. 1. Learning from demonstration components.

Please cite this article in press as: Shahbazi, H., et al. Demonstration learning of robotic skills using repeated suggestions learning algorithm. *Biologically Inspired Cognitive Architectures* (2017), http://dx.doi.org/10.1016/j.bica.2017.02.004