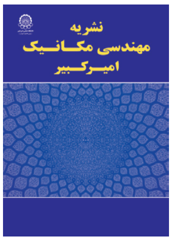

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# Imitation Learning of Complex Behaviors to Humanoid Robots using Evolutionary Optimization of Neural Network of Unit Pattern Generator

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**ABSTRACT:** In this paper, a system based on neural structures known as central pattern generator is presented which enables to acquire the required patterns to move a robot based on a demonstration training. Unit pattern generator can be divided to two subsystems, one is a rhythmic system and the other is a discrete system. The first subsystem is responsible to produce short movements and the second subsystem is responsible to produce rhythmic movements. The special learning algorithm is designed to use these unit pattern generators. Joints and limbs of robot were controlled by Kinect sensor in real time by recognition of the human body skeleton. The work steps were done in this way that the motion sequences of teacher' body were recorded by Kinect sensor, then transmitted to the computer. These motion sequences teach some nonlinear oscillators then they reproduce motions for humanoid robot. As a result, humanoid body joints imitate the teacher movement in a real time. The main contribution of this paper is design of this learning algorithm which is able to simultaneously search for the weights and topology of the network the algorithm synchronize the neural network by coupling the neurons at the last stage.

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## 1- Introduction

Movement production is meant to create a series of control trajectories that are sent to the robot joints during the time. Produced trajectories should be created base on the high-level animus of the robot to do some kind of actions intelligently while considering the retrieved information from sensors and the environmental conditions. Planning and scheduling the control trajectories to satisfy a high -level goal in a robot with a high degree of freedom is very complicated and need machine learning techniques. Since the fast and explicit programming of the learned movement is complex and time consuming, a method is suggested in which an actor trains complex behavior to humanoid robots using the machine learning techniques. In these learning methods, the actor behavior is sent to the robot utilizing the demonstration device, then, the robot learns this movement by imitating the trainer behavior and reproducing the required trajectories. This kind of machine learning is called 'imitation learning'.
Imitation learning, which is a subset of supervised learning, is a new method to teach complex tasks to the humanoid robots [1]. Robot can repeat human movements and produce new tasks by changing various parameters of the algorithms such as velocity, position, and domain. Alike human infants that are able to learn through demonstration, an artificial system can also learn trainer's movements using imitation learning methods [2, 3].
Our focus is on teaching the humanoid robot via playful interaction using natural social gesture.

## 2- Methodology

The first step to control a robot is gathering some movement patterns. These patterns were produced by Microsoft Kinect that recorded teacher movements. Using Kinect enables the player to control the robot without using the hardware controller, and just by moving his body. When data from the Kinect is retrieved, the depth image is analyzed to extract information about users' position. This position data were analyzed in MATLAB and the joints trajectories were obtained. We used Unit Pattern Generators (UPGs) to produce similar trajectories because of smooth and flexible movements. So, some rhythmic patterns were generated by Hopf oscillator based on UPGs [4]. These patterns were optimized by evolutionary algorithms like Imperialist Competitive Algorithm (ICA) to be as similar as Kinect trajectories. Trajectories were simulated in V-rep software to prove the accuracy of this method. In the next step the trajectories were sent to a Bioloid robot to investigate the results.

## 3- Results

We used three evolutionary algorithms to optimize the UPGs trajectories. According to the results and pattern diagrams (Fig. 1) ICA can optimized the UPG trajectories and track the Kinect patterns better than Particle Swarm Optimization (PSO) and Artificial Bee Colony (ABC) algorithms.
The robot in the V-rep track the teacher movements well. We used Nao robot because its degrees of freedom is similar to Bioloid robot [5]. In the next step we connect the robot to MATLAB by Arduino, then send data to the real robot (Fig. 2).

## 4- Discussion

In this paper designing of a puppetry robotic system were described that learn human player behavior through imitation learning. This research proposes new method to retrieve the geometric angle of each joint through demonstration actions

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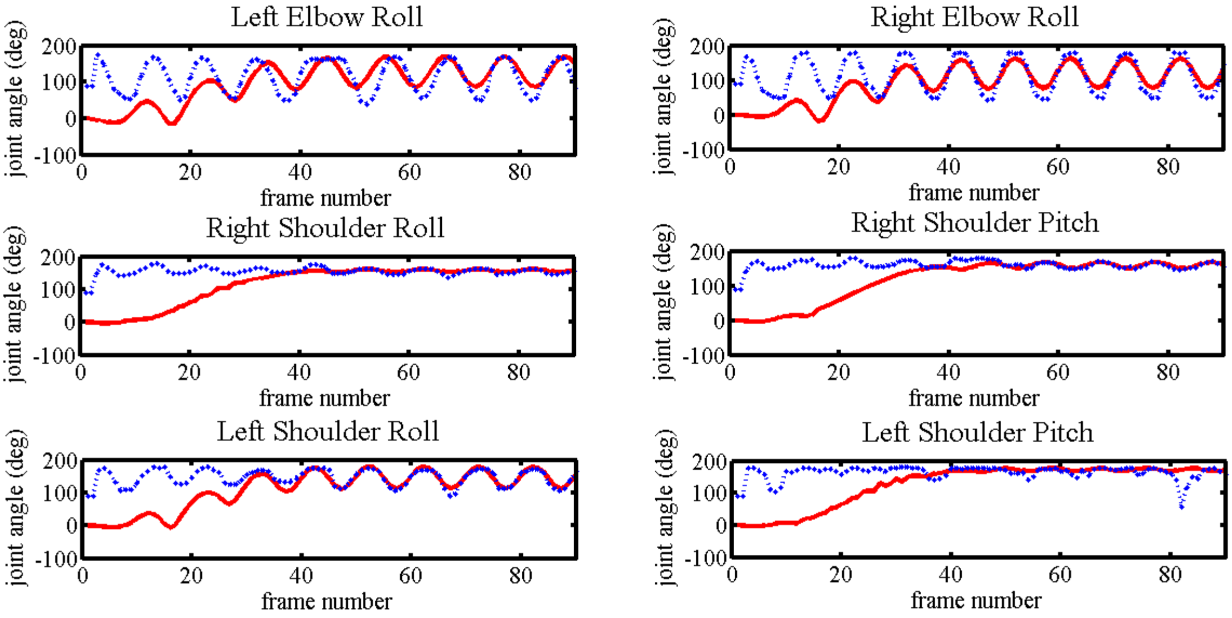

**Fig. 1. Optimized learned patterns by ICA algorithm. Blue trajectories are Kinect output and the red trajectories are optimized patterns.**

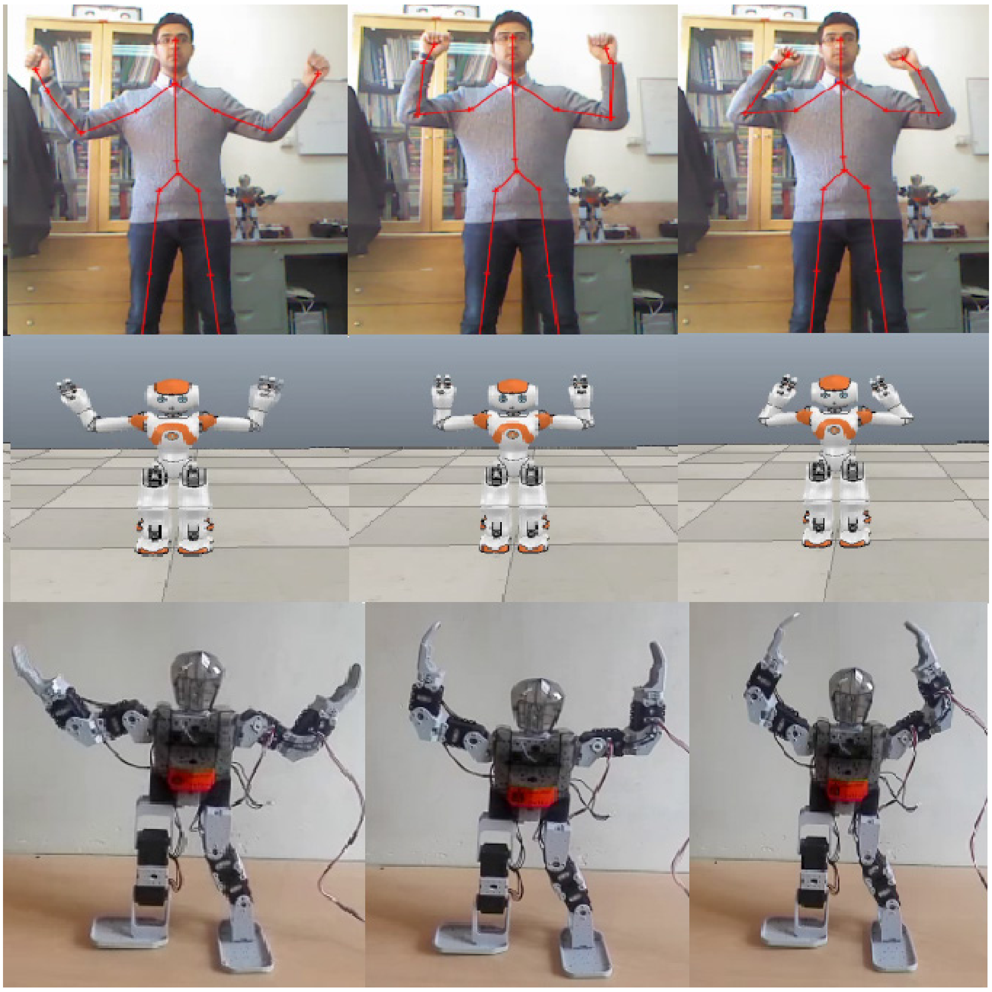

**Fig. 2. System simulation in V-rep, Nao robot imitate human body movement**

using a RGB-D camera and let humanoid robots effectively learn to imitate human movements. It is anticipated that the outcome of this research will contribute to future development of robotic training tools based on Human Robot Interaction (HRI) platform.

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