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LETTER

An automatic system for humanoid dance creation

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Abstract
The paper describes a novel approach to allow a robot to dance following musical rhythm. The proposed system generates a dance for a humanoid robot through the combination of basic movements synchronized with the music. The system made up of three parts: the extraction of features from audio file, estimation of movements through the Hidden Markov Models and, finally, the generation of dance. Starting from a set of given movements, the robot choices sequence of movements a suitable Hidden Markov Model, and synchronize them processing musical input. The proposed approach has the advantage that movement execution probabilities could be changed according evaluation of the dance execution in order to have an artificial creative system. In the same way, a choreographer could give more importance to some movements and/or exclude others, using the system as a co-creation tool. The approach has been tested on Aldebaran NAO humanoid using different genres of music, and experimentations was conduct at presence of real human dancers to have feedback of the goodness of the robot execution. Three professional judges expressed their evaluations about the following points: appropriateness of movements for a given musical genre; the precision to track the rhythm; the aesthetic impact of the whole sequence of movements; and the overall judgment of the robot performance. All the evaluations are very satisfying, and confirm that robot dance is realistic and aesthetically acceptable. The robustness and flexibility of the system allow us to embed the system in artificial creative system in future work. In the discussion we introduce some issues to pursuit this aim, using a previous proposed cognitive architecture based on needs and motivations.

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Introduction

Dance is an important human creative field, and is a great medium of artistic expression able to convey important emotional flows. The body movements of dance and music perception represent a testing domain very difficult to deal with in the context of computational creativity, especially if the dance involves both artificial agents and humans. The artificial agent performing dances must be able not only to perceive music, and react with the appropriate movements sequences, but has to perceive what is happening in the environment, and have to react to the behavior of humans. Dancing robotics should be also an interesting field of researches of human–machine interactions, studying for example the mutual influence during a performance or an improvisation.

A Human body, feeling of rhythmic sounds, reacts in a spontaneous manner with a body movements synchronized with periodicity of music. There is a strong connection between music and body movements, Todd, Lee, and O'Boyle (2002). When we listen to a song, often we beat feet, nod a head, beat hands and fingers on the table or on our legs.

It is difficult for people to dance on choreography without any practice, but all people can dance with rhythmic motions. Conversely is simple for a robot to dance on a choreography, if all the movements are programmed, but it is not easy for robots synchronize motions with different music genres and believing that is intelligent because it seems that it listens and interprets music (see for example Shinozaki, Iwatani, & Nakatsu (2007) for an introduction on concepts and design of a dancing robotic systems).

Pre-programmed choreography is useful for dancing a specific music, but it is difficult to reuse with different musical pieces. In fact, it would be necessary remake movements and synchronize them with music.

We aim to enable a robotic system to follow the rhythm, and its movements strongly influenced by the rhythm input in real time, Nakahara et al. (2009). How can a human synchronize his movements with music? When a human listen a rhythm sound, the beat and structure of rhythm is perceived and these give coordination of movements with the music.

Toiviainen, Luck, and Thompson (2010) investigated music-induced movement, focusing on the relationship between movement patterns and metrical levels of music, revealing that humans embodied the musical stimulus on several metrical levels. Xia, Tay, Dannenberg, and Veloso (2012) have pursued similar research. They used to classify the emotions of dance movements, six primary emotions: Happy, Sad, Angry, Surprised, Fear and Disgust. These primary emotions are used to determine what motion primitives will be executed in relation to the emotion detected in music. Seo, Yang, Kim, and Kwon (2013) have focused on simple rhythmic movements, like head nodding or hand shaking, but flexible for any kind of music, even hand-clapping sound.

The proposed system could be easily inserted into a computational creativity system, given that it is possible to vary the probability of execution of single movements both in the learning phase and execution phase. Internal and external evaluation processes, see Augello, Infantino, Pilato, Rizzo, and Vella (2014b), drive the variation in order to perform ''aesthetically" acceptable execution as in Augello, Infantino, Pilato, Rizzo, and Vella (2013), and in Augello, Infantino, Pilato, Rizzo, and Vella (2014a). Other approaches could be considered more sophisticated, and allow realistic simulation of biologically process, see for example Aucouturier, Ogai, and Ikegami (2008), taking in account the dynamic alternations between synchronization and movement generation observed in human behavior. But such systems have generally high computational costs, and are difficult to integrate in an artificial cognitive architecture for real robot acting in a real environment. We plan to embed the proposed module in the cognitive architecture proposed in past works, Augello et al. (2014), in order to create a dancing robot strongly interacting with human dancers, also at emotional and affective level (see for example Infantino (2012) and Gaglio, Infantino, Pilato, Rizzo, & Vella (2011)).

There are a lot of robot dancing work in the literature from the classic paper of Apostolos, Littman, Lane, Handelman, and Gelfand (1996), to the most recent work of Ros, Baroni, and Demiris (2014), but we aim to build a real implementation of a computational creative agent performing dancing with human mates. To obtain this result, we plane to combine simple elements: creative composition of few elementary movements; emotional perception of music and environment stimuli; and natural interaction with human dancers. The agent will be embodied in a cognitive architecture, and its creative processes are activated according to motivation depending by the urges of a robotic agent. The implementation of the first element requires a robust and efficient association between music and dance. Moreover, we need a data structure suitable for exploring possible dance styles, and capable to introduce evaluation processes.

In the following of the paper, we describe our system that generates a dance for a humanoid robot through the combination of basic movements synchronized with the music. The system made up of three parts: the extraction of features from audio file, estimation of movements through the Hidden Markov Models (Rabiner (1989)) and, finally, the generation of dance.

System description

In this paper we propose an automatic system capable to generate a dance for humanoid robot through the combination of basic movements synchronized with the music.

The overall system is depicted in Fig. 1. The system consists mainly of three parts: the extraction of features from audio file, estimation of movements through the Hidden Markov Models and dance creation.