Modeling rhythmic physical exercises

Zsófia Ruttkay, Herwin van Welbergen

HMI, Dept. of CS, University of Twente,
POBox 217, 7500AE Enschede, The Netherlands
{z.m.ruttkay H.vanWelbergen}@ewi.utwente.nl
http://hmi.ewi.utwente.nl

1. Introduction

In the framework of our ongoing project [2, 3, 4], we aim at developing a Reactive Virtual Trainer (RVT), an intelligent virtual agents (IVA) who can not only perform exercises, but adjust those, and interweave the physical performance with explanations, correcting remarks and social chat. For an IVA in such a role where the demonstrated motion is to be copied by the user, the subtle, physically correct performance of the exercises she is to show is of major importance. The RVT should be flexible in two aspects: what kind of exercises are to be done, put together form a repertoire of simple motions; and how the exercise is to be performed, concerning tempo and intensity. Because of this envisioned flexibility and adaptivity, the RVT cannot rely directly on a mocap repertoire, but should have a model-based framework for both structural 'design' of the exercises and its performance details. In this paper we will show how we model these two aspects, based on analyzing real-life corpora of physical exercises.

2 Ontology, structure and motion characteristics of physical exercises

In figuring out the structure of rhythmic motion sequences used in physical training, we rely on our video corpus recording of physical exercises series guided by a professional trainer, and on literature [1]. A *training session* consists of *repetitive exercise sequences.* Form a structural point of view, a repetitive exercise is either simple or compound, build up as a sequence of several different simple exercise units. A simple exercise consist of one type of motion of certain body parts (e.g. arm pull), while a compound exercise is a sequence of a number of simple exercises, chunked into patterns as: AB, ABAC, AAAB, AAAA BBBB or AAAB AAAC. Often, the simple exercise units are variants considering the body-parts involved, or the direction of the motion performed.

Considering the *joints involved*, we talk about *unimodal exercises* involving joints of the arms, or the legs, or the torso, or the neck, while multimodal exercises involve two or more of these body parts. An exercise is single-sided, namely, right or left, when only right or left limbs are involved. An exercise is *crossed*, if left and right limbs occur but not in a symmetrical way. Usually, the leg and arm on different sides are used (multimodal crossed exercise), but it may be that the left and right arms are used in a different way (unimodal crossed exercise). Single-sided and crossed exercises are asymmetrical, because of the body parts involved. Another aspect is *variation in the motion direction* of exercises, which may be left or right, forward or backward, e.g. making circles with the head left-right, or with right arm forward-backward.

The major structure of exercises is modeled in the form of a generative grammar, reflecting the ontology above. It is to serve as a basis to put together exercises series by an expert. When an exercise is performed, the structural model provides a basis for intelligent structural modifications on the fly.

As of the *dynamical characteristics* of the motion of the body parts, we model exercises by a procedural, kinematics model. We use the phases common for communicative gestures to identify segments of a unit physical exercise. In order to achieve high fidelity of the generated motion (unlike robot-like rotation of joints), we use a motion capture corpus to model the timing of the phases, the amplitude of the motion, the velocity profile and, in some cases, the motion path. We use an automatic method to segment the mocap signal of repetitive exercises to units and phases [5]. Then the characteristics are statistically analyzed to gather default values, and basic correlation between variables like tempo and amplitude.

Finally, in order to automate the extension of an exercise repertoire by just recording some exercise in mocap lab with a great number of markers placed in a standard way, we can also identify automatically the major joints involved in the motion. The rest of the body is also moved slightly, based on a real-time physical balancing model, taking into account the forces emerging from the kinematically controlled motion, usually of the limbs.

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