Chapter 1

Introduction

1.1 The Challenge of Computer Generated Postures

With advances in hardware technology, more powerful computers become available for the majority of users. A few years ago, computer animation was restricted to work on platforms oriented exclusively to 3D graphics. However, nowadays interactive environments or computer animation systems are rather accessible to almost everyone.

Computer animation involves the creation of movement of virtual entities like characters interacting in a virtual environment. It not only embraces resulted motions but also the creation of postures. In the posture case, the user aims at generating a final posture without worrying about the movement in between the initial and final poses. Inverse Kinematics is a technique that allows an easy interaction by the user and, in consequence, an easy generation of postures [Bae01].

As opposed to key-frame animation, where the user has to spend much time producing key poses [Las87], Inverse Kinematics requires the user to specify only the part of the body which he wants to animate and a goal in 3D space. Then the system will do the rest, that is, to drive the effector (hands, feet, etc.) to the goal. However, this technique applied to complex articulated structures uses numerical techniques to converge towards the goal resulting in unnatural postures.

It is an interesting challenge to exploit physiological data like fatigue in the generation of human postures. In particular, in the generation of human postures using Inverse Kinematics.

1.2 Motivation

In the animation of whatever entity, an animal, a formula one car, a human being, it is desirable to obtain a realistic result. Human animations are specially complicated due to the complexity of the human body and the intricate mechanism that produces human movement: articulations, muscles and the Central Nervous System (CNS). In the CNS, there is a sophisticated chain of processes that produce and control the movement of the human body.

In the classification of 3D computer animation techniques we find two main groups, offline animation (movies) and interactive animation. We are interested in the interactive one. Depending on the animation technique used, the realism of the final animations differs qualitatively. Performance animation techniques use devices to obtain performance data. These devices are not available for most of animators and new performances are needed for generating new postures. If the aim is to generate realistic postures, the use of key-framing is arduous. In this case, the realism depends only on adjustments made by the animator. Techniques using dynamic applied to complex figures, as the human body, do not provide the desirable interactive rates. The Inverse Kinematics technique allows an interactive manipulation of articulated structures while incorporating other aspects of the motion affected by physiological aspects as fatigue.

The motivation for fatigue assessment stems from the possibility of simulating such a complex human sensation and using it in the generation of natural looking postures. Postures adopted by a human under fatigued conditions are different than those adopted in non-fatiguing ones. In addition to realistic computer animation, its application is extended to fields as ergonomics, or workplaces design. In workplaces design, a computer system lets to explore situations avoiding doing experiences with "real" subjects. Then, accelerating and making less expensive the design process. Considering the design of an assembly line, a virtual human placing a load in its goal position, several simulations and adjusting can be made during the design before performing final phases of test on subjects. Considering a virtual human acting in a virtual environment, he cannot sustain a load infinitely. His muscular system will be overstrained and he will need to change the posture in order to be able to maintain the load. It should be a postural change that allows the fatigue recovery for the person sustaining a load.

Visualization techniques as skinning and deformation also improve the realism of animations but it is also necessary to pay attention to the postures adopted by the virtual human. It is not very helpful to show a realistic muscle deformation if the posture adopted by the limbs of the virtual body is not natural.

1.3 Thesis Objectives

This thesis concerns the fatigue assessment of human body joints for generating realistic postures. Our objective is to create a model of fatigue at joint level to allow the adjustment of fatigued postures. Of course, our model should be applicable to human–like characters or any articulated structures whose actuators may become fatigued.

We consider a sequence of static poses in the time domain, then introducing a temporal dimension in the posture design process. Thereby, we aim to assess fatigue at joint level under static conditions but considering the pass of time effect. A wider approach is the one followed by studies working at individual muscle level. Our purpose, to propose a model at the "muscle group" level, is motivated by the complexity and computational cost that individual muscle models convey. The approach working at joint level is in an easier way extendable to assess different joints of the human body without the need of an exhaustive description of individual muscle parameters.

We propose to exploit the fatigue model in an Inverse Kinematics framework. As Inverse Kinematics is a computer animation technique extensively utilized nowadays, it is important to search for methods improving obtained postures. Mechanisms using fatigue at joint level would drive the system to adjust achieved postures. Our purpose is to perform experiments in real subjects and compare with results obtained using the simulation framework and the fatigue model.

In addition, this work aims at providing a novel way of posture characterization using the fatigue factor. We store posture data, including joint angles, along with fatigue information and we generate reachability trees of the human arm corresponding to different strategies of reaching. Afterwards, a computerized visualization allows to distinguish a fatigue factor reflected in the reachability volume. Useful information can be extracted from the reachability tree, for example, what area of reachability produces the most fatigued postures and, of course, what postures are adopted when the reaching is done in that area.

1.4 Thesis Contributions

We contribute with a new model of fatigue at joint level and with a new approach of working with human joints. This approach splits a common revolute joint into two half-joints, each of them representing antagonistic muscles. This new concept limits us to the only use of revolute joints, e.g. the shoulder joint is defined as three revolute joints converted to three half-joint pairs.

We provide a simulation environment where fatigue is exploited at two differentiated levels. At a low level, we adjust fatigued postures and at a higher level, we characterize reachable volumes using the fatigue factor.

Due to the lack of strength data, the fatigue model has been validated under an important limitation. Although it is defined in a general way, case studies are restricted to movements in the sagital (lifting) and frontal plane (contraposto case). In order to facilitate its future expansion, it has been designed to be easily extended. It has been developed using the C and C++ programming languages.

1.5 Potential Applications

The Fatigue model can be applied to any scenario where it is useful to assess the potential evaluation of postures adopted by humans under the influence of external or internal forces, i.e. sustaining an external load or the own body mass. We exploit fatigue data obtained from our model in two ways, optimizing and characterizing postures.

In the optimization case, it can be used to predict postural changes under fatigued conditions. For example, a subject sustaining a heavy load has to adjust his posture when his arm joints reach unbearable values of fatigue. Another application can be the study of sitting and viewing postures, for example if we sit with our head in a forward bent position, the ligaments and the muscles in the neck will be under tremendous strain. Then, a change in the posture is needed to avoid neck fatigue.

In the characterization case, we aim at describing a posture using beside joint angles, the fatigue that the posture produces at joint level. A human posture is mainly determined by the set of joint values defined in the skeleton. We add an attribute that also describes a distinctive quality of a posture. This kind of postural characterization can be useful in workplace design in order to evaluate which areas of arm reachability are less fatigued for an industrial worker.

1.6 Overview of the Thesis

Chapter 2 presents the literature related with computer animation and its application to the realistic generation of postures and motions. Chapter 3 describes factors, such as muscular strength, fatigue, general health or state of mind, that influence motions and postures adopted by humans. Chapter 4 describes the fatigue model. This chapter also introduces the half-joint approach and applies it in the design of the fatigue model. Chapter 5 describes how fatigue values are exploited for both postures optimization and characterization. Chapter 6 presents case studies and shows results comparing data obtained in experiments and those achieved by a simulation environment. This chapter also presents results of the cooperation between the fatigue and the reachability module, then generating reachable spaces featured with fatigue data. Chapter 7 gives conclusions and points out directions for future work.