論文の内容の要旨
Abstract of Dissertation

論文題目　A Novel Computer Animation System for Nonprofessional Users
（非専門家ユーザのための新しいコンピュータアニメーションシステム）

氏　名　パントゥウォン　ナタポン
Name of Author　Pantuwong Natapon

Computer animation is the process which uses several techniques of computer graphics to create movements of 2D and 3D objects. For 3D animation, animation authoring comprises of several steps including modeling, rigging, and animation. Typically, these processes need to be completed manually. Skilled animators are required to complete these tasks. Animation authoring might be infeasible for nonprofessional users. The main goal of this dissertation is to bring animation authoring to users with any skill level by developing a computer animation system that can be used by everyone. Such system should enable us to develop several interesting applications, for example, one may wish to develop a storytelling system that automatically generates animation after users tell a story or play with a puppet. Such application requires a novel computer animation system which can be operated with simple interactions by anyone, even nonprofessional users.

Nowadays, several systems have been proposed to reduce the difficulty of computer animation authoring. 3D scanners and several modeling systems have been developed to assist users in the modeling step. In the animation step, motion capture systems have been used in animation production to create the motions for 3D characters for more than a decade. Furthermore, there are several repositories for 3D models and motions, which users can obtain easily. However, it is not easy to combine 3D models and motions to generate animation. The 3D model must first be rigged to make it ready to be animated. The purpose of the rigging process is to identify the skeleton structure that can be used to deform the pose of the 3D model. Normally, this process must be performed manually, and it is too difficult for nonprofessional users. For the motion capture systems, although they can be used to generate realistic motion data for animation, such motion data can only be achieved with high-cost systems and several difficult post-processing tasks. With this reason, it may not be suitable for nonprofessional users to use such systems to obtain motions of a single action with wide variety of styles.

The problems stated above prevent nonprofessional users from performing the animation authoring task. Therefore, we propose a novel computer animation system that is suitable for nonprofessional users. The proposed system enables users to implement computer animation with a small amount of efforts, and allows users to create an animation with their chosen 3D model even if it has not been rigged. Furthermore, it provides the possibility for users to create a new motion with simple interactions. Given these capabilities,

the system has high flexibility which allows users to create computer animations with any 3D model and motion. The proposed animation system consists of three modules: animation module, modeling module, and motion module. The animation module is the module for generating computer animation by re-targeting (transferring) motion data into a 3D model. We use the framework of an existing motion re-targeting based animation system to develop the animation module for our proposed system. In this module, 3D models and motions are retrieved from model and motion databases before performing the re-targeting process. Because the number of motions in the motion database is quite large, searching suitable motion manually is time-consuming, and not convenient for users. We propose to use a puppet interface to generate the query information for retrieving suitable motions from the database. The motion database usually stores several motion sequences, which each of them conveys only a single action, that is, the retrieved motions must be connected to generate a single motion sequence for animation. We propose a new motion concatenation using the cubic Bézier interpolation to create transitions for any consecutive motions. The modeling module is included in the system to automatically generate a rigged 3D model from the input 3D model (if it has not been rigged). We propose a novel template-based automatic rigging algorithm for this modeling module, so users can obtain rigged 3D model without human intervention. The motion module is provided to enable users to create a new motion by editing the example motions in the database. We propose a simple motion editing technique using timeline-based interface which should be suitable for this module.

For the automatic rigging process, we propose an algorithm that automatically embeds the suitable template skeleton into a 3D model. We develop a classification algorithm based on the characteristic of real animals to identify the character class of the input 3D model, and extract the anatomical semantics of each part of the model. The classification rules are applied to the curve skeleton extracted from the input 3D model to obtain the classification results. This classification rules are not restricted to only the standard pose, orientation, or topology, which means 3D models created from any system can be rigged by our proposed method. To reduce computation time, we propose the Skeleton Growing algorithm to extract a curve skeleton from the pseudo-normal vector field constructed inside the 3D model. This algorithm can generate the curve skeleton with short computation time without user intervention. Therefore, the proposed technique can generate a rigged 3D model automatically using a short amount of processing time.

The proposed motion editing techniques have been developed for nonprofessional users in the way that they can edit a previously stored motion to their desired motion with simple interactions. The method firstly extracts the key poses from the motion capture data. It then visualizes the key poses on the timeline. We decide to create the timeline in the 3D environment instead of the 2D environment used in existing works to eliminate the ambiguity problem caused by inappropriate viewing directions. We proposed interaction techniques for motion editing functions that employ several editing algorithms. The proposed editing system provides several editing functions that can be used to edit both the geometry (pose) and temporal information of the motion data. Each editing function is developed with consideration of reducing the difficulty and the completion time of the editing task, so nonprofessional users can use the proposed editing system to create a new motion data by editing example motions.

We propose a motion concatenation algorithm that employs parametric motion synthesis to generate motion data for animation. Two or more motions can be connected to generate a single long motion.

In contrast to existing works which also use the technique of parametric motion synthesis, the proposed method can generate transition for any consecutive motions even though there is no intersection region of their parameter spaces. We use the cubic Bézier interpolation to generate the transition between consecutive motions, so the transition is quite smooth even if the poses between two motions are quite different. We propose an algorithm to pre-compute all possible poses used to control the interpolation. The process to retrieve the suitable poses for interpolation, therefore, can be completed with low computation complexity. Furthermore, we also propose an algorithm to create feature vector for motion clustering. Because we employ the parametric motion synthesis, the example motions must be clustered into motion groups such that each motion group contains motions with similar actions. We propose the feature vector, which is calculated from kinetic energy of each joint of the motion data for this clustering process. The proposed method is faster than the typical methods that calculate the difference between motions frame-by-frame. Moreover, this method is simple because the clustering result can be obtained without any query motion from the users. The process of concatenating motions can be completed without any user intervention, so it is suitable for the proposed animation system for nonprofessional users.

In this dissertation, we also investigate and discuss about the suitable user interface for the computer animation system. We propose to use a puppet interface to generate computer animation. Playing with the puppet is a simple interaction which users should be able to perform with a low learning curve. Such interface can be used to retrieve all required motions from the motion database, which will be concatenated into a single motion before being re-targeted into a rigged 3D model for generating computer animation. Users can use the puppet to retrieve motion data by posing the puppet with the poses of their required motion. The pose information of the puppet is composed of rotation angles of all the joints of the puppet. To obtain such pose information, we attach several visible markers on the puppet. The marker tracking algorithm can identify the orientation of each marker, which can be used to calculate the rotation angle of its associated joint. The marker occlusion problem is also addressed in this dissertation. The proposed algorithm can estimate the rotation angle of each joint by determining the position and orientation of the adjacent markers of the occluded marker.

The contributions of this dissertation are the four algorithms explained above. With the system configuration and all the proposed algorithms, the computer animation system for nonprofessional users can be developed. The proposed system allows users to create animation automatically using the desired 3D models and motions. The experimental results demonstrate the performance of each of the proposed algorithms in both quantitative and qualitative areas. The results confirm that the proposed algorithms provide reliable outcomes for the proposed computer animation system, and all interactions required by each of them are simple enough that nonprofessional users can perform. We believe that with this proposal of the computer animation system, the animation authoring can be brought to all levels of users. Several interesting applications related to computer animation can be developed based on the proposed computer animation system. Such applications should contribute many benefits to both academic and industrial sectors.