SOLVING INVERSE KINEMATICS USING KOHONEN NETWORK FOR 3D HUMAN WALKING

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“Special dedication to my beloved parents Abdul Salam B. A.Rahman & Khairani Bt. Othman and my dearest fiance Mohd Suhaimi Mohd Sapian, thanks for being such wonderful sources of inspiration and encouragement.”

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ABSTRAK

Penggunaan watak animasi di dalam persekitaran maya seperti permainan komputer semakin meluas sejak beberapa tahun lalu. Pelbagai jenis teknik digunakan dalam menghasilkan komputer animasi berbentuk 3 dimensi bagi mencipta sebuah dunia maya di mana karakter dan objek sekeliling boleh berkomunikasi secara interaktif. Salah satu teknik yang meluas bagi animasi model artikulasi ialah kinematik yang bertujuan untuk mengawal postur dan kedudukan model tersebut. Kinematik songsang adalah isu utama dalam projek ini yang mana ia merupakan satu teknik untuk menntukan nilai sudut bagi sesuatu sendi model artikulasi. Terdapat banyak kaedah konvensional dalam menyelesaikan isu kinematik songsang. Walaubagaimanapun, dalam kajian ini, teknik kepintaran pembuatan iaitu rangkaian Kohonen menjadi fokus utama bagi menyelesaikan masalah dalam menentukan set sudut bagi aplikasi model manusia yang berjalan. Dua aspek utama dalam pembelajaran Kohonen di ambil kira iaitu pemetaan dan persaingan antara neuron untuk menghasilkan set sudut yang betul apabila nilai koordinat diketahui. Kebolehan kepintaran buatan ini diuji dengan proses pembelajaran data dan keputusan yang diperolehi boleh membuktikan keberkesanan teknik ini dlaam mencari perkaitan dan kesinambungan antara neuron. Setelah di aplikasikan pada model manusia berjalan, teknik Kohonen ini mempunyai kebolehan menyelesaikan masalah melalui penyusunan struktur topologi apabila diberi beberapa nilai sebagai rujukan dalam proses pembelajaran.

ABSTRACT

Character animation in simulated virtual environments like computer games has progressed rapidly over the past few years. A wide variety of techniques are used in the process of creating 3D computer animation to build virtual worlds in which characters and objects move and interact. A wide-spread method for animating these articulated figures is kinematics. Inverse kinematics technique is the main concern in this project that refers to the problem of specifying the angles values for each joint when the end-point of the character articulation known. There are many different conventional methods to solve this problem, and this attention transformed the concept into a well-known animation alternative. However this study focuses on Kohonen network as an alternative way to solve the inverse kinematics in for walking animation for a simple human model. Kohonen learning algorithm captures two essential aspects of the map formation namely, competition and cooperation between neurons to produce a set of joint angles values when the position is defined. The ability of this artificial neural technique is proven by examining the training process and the result shows the effectiveness of Kohonen in finding the relationship and the continuity of the neurons. As highlighted by walking animation example, the Kohonen draws its good generalization capabilities through the topological order based of only a few reference vectors as a supervisor.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Computer animation is one of the most rapidly expanding areas of creativity in computer graphics. It is used extensively in television and film, animated simulation rides and walkthroughs, computer games and digital environments allowing the creation of virtual actors, props sets and special effects. A wide variety of techniques are used in the process of creating a complex computer animation such as Disney and Pixar's Toy Story as shown in figure 1.1. Virtual conferencing, 3D chat, and other virtual reality applications also require interactive animation. These techniques can be grouped into 2D and 3D. 2D techniques tend to focus on image manipulation while 3D techniques usually build virtual worlds in with interaction of characters and objects.

Figure 1.1: Character animation

3-D animation involves with constructing a virtual world in which characters and objects moving and interacting. Character animation in simulated virtual environments like computer games has progressed rapidly over the past few years. Particularly, character animation using virtual human is able to use many application areas recursively as shown in Fig. 1.2.

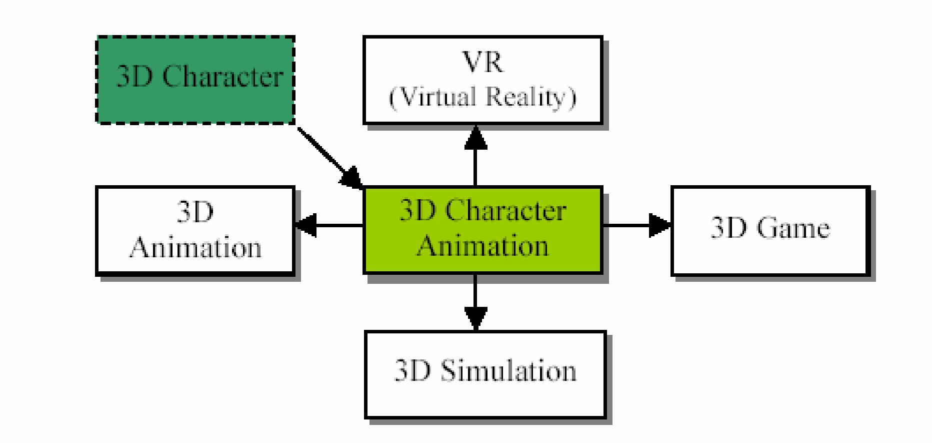

Figure 1.2: Relations of 3D human computer to other areas of computing

The 3D virtual characters usually used in computer animation system, virtual applications and games. This development has also been reflected by the changes of the visual style of computer games, while originally game characters would either be hand-drawn or computer generated 2D images that are projected onto a plane. Modern computer games now use 3D game characters which are real-time animated inside the virtual environment and projected onto the screen.

The character animator must model, animate, and render the 3D scene. Much of research focus on creating characters that are both most realistic visually and in motion, regardless of computational cost in time and processing power. Animated character sequences can be created by artists using traditional computer animation methods in which interactive characters must be rendered at interactive rates. Interactive character animation has been an important part of games for some time now. However, due to the limited capabilities of the game hardware, the animation was fairly simple (J. Lander, 2000). Simple 3D characters enabled a much greater amount of freedom. Characters like Lara Croft in the famous Tomb Raider series were able to respond to their environment. Her simple articulated hierarchical model enabled the animation system to walk, jump run and as well as aim her weapons at targets. Many researchers have explored interesting authoring solutions for animation methods for hierarchical-based body animation of characters including inverse kinematics.

1.2 Background of the Study

Animation of articulated figures has always been an interesting subject of computer graphics due to a wide range of applications. A very similar problem as the robotics engineer is found when animator try to control animation of articulated figures, humans, horses, whales or alien. An articulated figure is constructed as a set of rigid segments that might be thought as body parts (Shih-Kai Chung, 1996). It has rigid limbs and joints and the joints are usually rotational or translational with one single degree of freedom (DOF). To animate articulated figures, the joints must also be rotated to achieve desired position. The joint angles and the objects position are then interpolated to establish the animation using parameter values.

A common method of animation is to move objects by placing its in different positions and interpolating. Many character animations are tedious to produce because of the trial and error process that goes into 3D positioning and orientation of objects. Positioning can be done manually meaning that the user has to specify the angles of each joint of the figure at a time or it can be done using kinematics techniques. Many animator use inverse kinematics algorithm to control the posture of a 3D character. Inverse kinematics technique is adopted from robotics and has the potential to relieve animator from deciding the specification of every motion parameter within a frame. It calculates the angles of each joint of the limbs when end effector points to a specific place.

Most animation systems require the animator to describe the position of the figure. Changing the joint angles brings the articulated figure to a new posture. An animator can define the joint angles for a new posture (forward kinematics). However, it is difficult to estimate the exact joint angles needed to place the articulated figure to a predefined position. This can be a tedious process as animators do not generally think in terms of the values of joint angles. Rather, they draw something at whatever angle looks right (Karen Cynthia Kuder, 1995). Therefore, describing positions by specifying joint angles tends to be an iterative process where an animator uses trial and error to adjust the joint angles until the figure appears at desired position. This positioning problem involves solving the inverse kinematics (IK) of the 3D articulated figure. IK is an approach to reduce the complexity of animating articulated structures. The solution determines the angles of revolution of the joints that position the end-effector of the figure in the desired location in space, given the position of the root and the lengths of the links. Another important use of inverse kinematics occurs in motion capture applications where the positions and orientations of sensors on a live subject are used to drive the animation of a computer model by interpolate the sensor data (Deepak Tolani, 2000).

Finding a configuration that solves the IK problem is remains as open research problem. There is no perfect algorithm for solving this problem and must rely on heuristic techniques. Inverse kinematics offers three ways how to get the solution. Possible methods are algebraic, geometric and iterative (Roman Filkorn, 2000). Past solutions for this problem that use of the various algebraic or algorithmic procedures are become time consuming and need a huge amount of calculation. Some kinematics problems don't have any solution if the target for the end-effector is inaccessible. Iterative methods offer a general solution of inverse kinematics. Their disadvantage is that they converge to only one solution even if there are exists more than one solution or they find a closest solution if it doesn't exist. Matrix pseudoinverse of Jacobian is most widely solution using iterative schemes that are used to compute the desired positional solution from the solution for the velocities. Geometric methods use the knowledge of the manipulator geometry. This method has a disadvantage that solutions for one manipulator cannot be used for a manipulator with different geometry.

Shih Kai (1996) presented an interactive hierarchical motion control system dedicated to the animation of human figure in virtual environment. They used inverse kinematics with optimal approaches to control the complex relationships between the motion of body and the coordination of its legs. Zhao and Badler (1994) proposed a numerical inverse kinematics method for determining the human posture which is applicable to tree structure system.

Neural network solutions have the benefit of having faster processing times since information is processed is parallel. An inverse kinematics solver using an artificial neural network that learns the inverse kinematics system of robot manipulator has been used in many researches. Michael R (1994) examined four neural network algorithms for their ability to adaptively associate stereo camera coordinates with joint positions of a three degree of freedom manipulator arm in a 3D reaching task.

Neural network also can be used to solve this problem by compute the required changes to the joint angles of the figure in order to move the segment to the desired location (Li Zen Wei, 2003). Neural network is used to model the inverse kinematics of robot manipulator including a redundant manipulator (Joseph A Driscoll, 2000). In this paper, variety of network architecture (RBF, multilayer perceptron) was used and their performance was compared. Stuart Kieffer (1991) created a methodology using neural network to learn inverse kinematics relationship for a robot arm. This method is based on Self Organizing mapping algorithm using Widrow-Hoff type error correction rules and the result is indeed successful. Li Xin Wei (2003) proposed a new way to solving inverse kinematics of manipulator based on Adaptive neural Fuzzy Inference System neural network. Simulation result indicates that this method has the advantage of faster learning rate and better real time ability. Suriyanti (2004) presented 3D human walking animation using Backpropagation neural network to create the position and orientation value for forward kinematics equation. Different neural networks were also studied by H. Sadjadian (2005) to solve forward kinematics problem in a three DOF actuator redundant manipulator. Aaron D'Souza (2001) investigates inverse kinematics learning employing optimization criterion to solve the redundancy of kinematics. Four different types of neural network (MLP, RFB, ANFIS, and PNN) have been successfully used to solve forward kinematics and their performances are compared. Table 1.1 below shows the solutions for inverse kinematics problem with simple explanations.

Table 1.1: Possible solution for inverse kinematics

Solution	Description	Paper
Analytical	*1. Closed-form method:* The solution to the joint variables can be directly expressed as a set of closed-form equations. In general, closed-form solutions can only be obtained for 6-degree-of-freedom systems with special kinematics structure. *2. Algebraic elimination:* It expresses the joint variables as solutions to a system of multivariable polynomial equations, or alternatively expresses a single joint variable as the solution to a very-high-degree polynomial. Analytic solutions produce all possible satisfactory solutions. The proximal end is constrained to the origin. Unfortunately, if the system is not perfectly constrained, no unique solution exists.	Abdel-Rahman (1991) developed a generalized practical method for the analytic solution of constrained inverse kinematics problems with redundant manipulators.

Numerical	Numerical approaches iteratively converge to a single solution based on an initial guess that used to compute the desired positional solution. 1. *Newton–Raphson algorithm* The simplest method for solving systems of nonlinear equations. The inverse kinematics problem can be converted into a differential equation 2. *Jacobian* The most widely adopted method to solve inverse kinematics problems uses the pseudoinverse of the Jacobian. The pseudoinverse gives the unique least-squares solution when the system is redundant.	C.Chevallereau (1987) presented the solution for psuedoinverse kinematics problem. I-Ming Chen (1998) addressed the formulation of numerical inverse kinematics solution Samuel R. Buss (2004) introduced to the Jacobian transpose method, the pseudoinverse method, and the damped least squares methods for inverse kinematics (IK).
Optimization	Another approach to solving a redundant system is to use an objective function to be minimized and to apply optimization techniques. Inverse kinematics can also be regarded as a nonlinear optimization problem. 1.*Lagrangian Method::* This method can be used to extend an under constrained redundant system to a perfectly constrained system using Lagrange multipliers. 2. *Cyclic Coordinate Descent Method:* CCD involves in minimizing the system error by adjusting each joint angle one at a time. 3. *Artificial Neural network Approach:* Artificial neural networks provide a flexible learning system. Learning in neural networks occurs through the adjustment of synaptic weights by an error minimization procedure. The advantage of the use of neural networks is the fact that the system does not need to have specific properties for specific problems.	Welman (1993) compared Jacobian and CCD techniques. Zhao & Badler (1994) use an optimization method (nonlinear function) Amar Ramdane (1995) used BP to learn the inverse and forward kinematics equations. P Kalra (2003) use genetic algorithm for multimodal robot inverse kinematics.

In human character animation studies, most of researchers used neural network to solve the kinematics problems, human posture, and locomotion speed, traveling path and motion behavior. In this study, a kohonen network is used to calculate the animation value for human model to walk using inverse kinematics. This project attempts to have more accurate value and reduce times in order to generate walking motion of human model.

1.3 Problem Statement

To control the position and direction of 3D human character based on end effector of inverse kinematics, the controller has to calculate the proper angles of each joint. To calculate the proper angle sets, the inverse kinematics has been researched according to various points of view. The major matter of concern is not the posture of an articulated body but the position and the angles of the end effector in inverse kinematics processes. Based on the problem stated above, the hypothesis of the study can be stated as:

“Could the supervised Kohonen network identify appropriate joint angles of 3D human model which used to create an appropriate sequence of walking animation using inverse kinematics at a minimal time?”

1.4 Project Aim

This study will focus in solving inverse kinematics problem and aimed to animate the walking 3D human model using supervised Kohonen network in finding the set of correct joint angles for animation at appropriate time.

1.5 Objectives

A few objectives have been identified to accomplish the aim of the study:

1. To generate set of joint angles using Kohonen network based on desired end effectors value.

2. To create the walking animation of a 3D model using the coordinates and corresponding joint angles that obtained from Kohonen network.

1.6 Project Scope

The scopes of this project are as follows.

i) Techniques to be used:

1. *3D Hierarchical Model*:
   In this project, a simple 3D human model will be used. This model is a hierarchical character and different body parts of the articulated object

are separate and stored in a hierarchy and joined to each other at pivot points.

2. *Inverse Kinematics Technique:*

   Inverse kinematics technique will be used to determine a joint configuration required to place a particular part of an articulated character at a particular location in global space

3. *Walking animation:*

   The animation of 3D model is limited for walking movement and involve with legs only. The dynamics of structure of 3D human character is not considered. Force, mass and inertia are not applied to animate articulated human body. Walking is a special purpose in animation domain.

4. *Animation value:*

   Values for animation will be generated manually without using specific technique to get initial value for the animation.

ii) Tools to be used:

1. *Programming language C++:*

   Programming language C++ has been chosen and the program is developed using Microsoft Visual C++ version 6.0

2. *Graphics API and library OpenGL and GLUT*

   For rendering purpose, OpenGL API GLUT library will be used. OpenGL is a fast becoming the standard for 3D programming and support all the latest video cards, games and it is provided by all windows platforms.

1.8 Organization of the Report

The plan of this report is presented as follows:

Chapter 2: Literature review. This chapter states some existing methods of inverse kinematics, articulated figure and Kohonen networks. It also contains the review of the previous works for the problems that solve inverse kinematics using neural network.

Chapter 3: Methodology. This chapter describes the system overview and the framework of proposed methodology. It explains the details of architecture of Kohonen network to calculate the animation value for walking character.

Chapter 4: Implementation. In this chapter a method is proposed to implement model, basic algorithm and pseudo code.

Chapter 5: Result and discussion. The present chapter presents the main results of this work and related discussion.

Chapter 6: Conclusion and recommendations. This chapter concludes the contribution of this work and recommends some work for future.

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