

# Vector-Mapping Method for Motion Retargeting of the Virtual Articulated Figures and its Application

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**Abstract**—Motion Retargeting is a movement edition technology that designed for motion capture data of the production of computer animation. The technology of Motion Retargeting now has two problems—large databases and the complexity of the algorithm increased rapidly with the joints increasing. According to this, we propose a new method, Vector-Mapping method of motion retargeting. The initial movement curve is transferred to vectorization and mapped to the target figure. The virtual figure is setting by IK, which moved along the trajectory curve in order to achieve motion retargeting. Finally, we implemented several experiments based on this method and described some ideal results in this paper.

**Index Terms**—Motion Retargeting, vectorization, mapping, virtual arms

## I. INTRODUCTION

Motion Retargeting technology is a motion edition technology of new computer animation proposed firstly in the late 1990s by Autodesk's Gleicher[1]. The basic idea is to capture the movement of data applications to a different joint model, while maintaining the original characteristics of the movement, re-use existing joint movement data. This idea can be applied with the same joint structure but different from the proportion of the virtual characters, and achieved good results. In recently years, many researchers began to study movement retargeting technology based on the "Motion Retargeting" mentality, from the same joint structure extend into the joints with a different topology objects. Through the movement of existing data [2] for Motion Retargeting, has made remarkable achievements. Monzani[3] and others proposed a combination of the use of intermediate skeleton and inverse kinematics model of the movement

retargeting method, which proved a good structure with different joint movement between the virtual role of retargeting. According to the corresponding joint bone technology, Hsieh[4] etc implemented the motion retargeting in virtual characters with different joint structure, such as the motion retargeting between humans and dogs, and between humans and sharks. This makes the reusability of original motion data has been further strengthened.

Technology of motion retargeting is not new, but the existing methods require a large database to store the virtual role models and the collected data of initial motion [5], and the combination of inverse kinematics has been movement on the joint displacement and rotation information redirected to the target object in order to achieve the movement redirect[6]. The calculation process is complex, and with the joint increasing, exacerbated by the complexity of the algorithm redirects to analyze the cost of solving is also growing.

Aiming at the existing problem of motion retargeting that the shackle of a large database, as well as the complexity of redirect algorithm that relate with joint DOF, this paper presents a new way to redirect the movement, Vector-mapping method of Motion Retargeting.

On the basis of virtual role joint model with IK (Inverse Kinematics) settings, curve of the initial motion after vectorization and proportional adjustments, and then redirected to the target, the terminal effector of the target object drive the corresponding joint along the motion curves, so as to realize the motion retargeting. This method only needs to store the initial motion curve, and solve the problem of a large database in a certain extent and the algorithmic complexity doesn't increase when the joints increase.

## II. DESIGN FOR VECTOR - MAPPING METHOD OF MOTION RETARGETING

Currently, retargeting technology mainly applies in two aspects [7]: 1) virtual character with joint connection

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in character animation, 2) facial expression animation. In this paper, the vector-mapping algorithm of motion retargeting only applies to the first case, and the object must be virtual role with joints of IK settings, which is the premise of this method can be realized.

#### A. Modeling of Virtual Role

Virtual character modeling includes two parts, namely, geometric modeling and motion modeling. Geometric modeling bases on the physiological characteristics of natural biological structure of its skeleton modeling; the method in this paper only applies to role model with joint structure. From the kinematic point of view, joint information of moving objects can be simplified, under the premise of ensuring the fidelity of movement. For example, the virtual arm of our experiments in this paper, the joint structure can be simplified as: shoulder, elbow and wrist joints. In order to reflect the vector-mapping method for the movement curve of the operation better in this experiment, joint structure is simplified as shoulder and elbow joint. (Fig.1) (a).

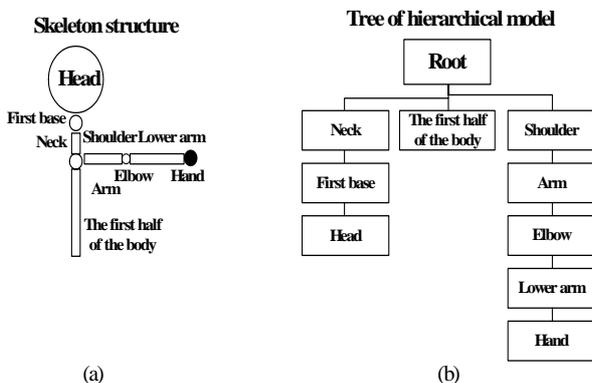


Figure 1. Modeling of virtual role.

#### B. Vector-Mapping Algorithm for Motion Retargeting

The overall idea of Vector-Mapping algorithm for motion retargeting is to set moving object based on IK, read the original motion curve, extract sharp points and vectorize, zoom and adjust the motion curves converted to the motion curves of a re-set target object, finally the motion curves are mapped to the terminal effectors of the target object. According to the trajectory of motion curves, the terminal effector completed a redirect movement. Using vector-mapping to achieve computer animation of the virtual role in the movement retargeting issues, we need the following three steps:

##### 1) The initial motion curves

From the motion capture technology to capture the movement of data generated by computer animation, which is low efficiency, costly and not conducive to the development of computer animation. In this paper, we introduce a virtual scene movement of an object as a reference, tracking, extraction of its trajectory, that is, the initial motion curve. Specific method is to record a animation sequence, generally under 50 frame, which basically guarantee for a full period of motion. The acquisition of the initial motion curve requires the following two-step<sup>[9]</sup>: (1) Moving target detection: to

take "Background subtraction method" to get the moving objects' terminal effector. (2) Moving Target Tracking: to predict the goal of the future with Kalman filter, with the goal of cost function-based matching, tracking and recording the terminal effector's movement, which is the initial motion curve. Simultaneously, record the size of capture object and this movement joints chains. Generally, Capture object is the standard model, in order to adjust different backbone of the ratio of virtual objects in motion curve.

##### 2) Vector-mapping algorithm for motion retargeting

Step 1: read the initial motion curves;

Step 2: according to the vectorization algorithm, calculate the initial motion curves. For random, uncertain motion curves, the vectorization algorithm can be very good to preserve the data information and the characteristic of original motion curves.

Step 3: determine the beginning and the ending of the motion curves;

Step 4: calculate the ratio of backbone between the direct target object and the capture object, the capture object is standard model normally. According to the value of the ratio of backbone, zoom the motion curves corresponding, convert to the motion curves of the direct target object. When the size and the proportion of the target object do not conform to the standard model, its movement may lose the original characteristic, or go against nature, so zoom and adjust the motion curves is very necessary.

Step 5: in the virtual environment, virtual character's position is not affirmatory, in order to ensure that the data information of motion will be mapped to the target object, we must determine the position of terminal effector of the target object, and unified the coordinate system of the starting point of motion curves and the terminal effector of the target object.

Step 6: determine the surface of movement of direct target object. In 2D situation, the surface is plane still, in 3D situation, determine the movement surface in line with the movement characteristics.

Step 7: according to the principle of line-face mapping, we can mapped the data information of target object to the terminal effector.

##### 3) Complete motion retargeting

Direct target object is the joint model with IK settings, given the target location of terminal effector, computer will calculate the data information of joint automatically. Motion curves is a series of target points of terminal effector, along the trajectory of motion curves, the direct target object completed the whole movement.

### III. VECTOR - MAPPING ALGORITHM FOR MOTION RETARGETING

#### A. Cusps Extraction of the Initial Motion Curves

The initial motion curve with high randomness and uncertainty, in order to avoid losing their original characteristics and efficient to save the key feature points, we must first extract the tip points, namely curvature extreme point. In this paper, we use the method of chord

length ratio[10] to calculate the curvature of the curve and look for the local maxima and mark the point for cusps(Fig.2). Specific steps as follows:

Step 1: extract the point  $P_i(x_i, y_i)$ ,  $P_{i-k}(x_{i-k}, y_{i-k})$ ,  $P_{i+k}(x_{i+k}, y_{i+k})$  in motion curves;

Step 2: according to two point's form of linear equations, we can obtain the straight line equation which connects  $P_{i-k}$  and  $P_{i+k}$

$$Ax + By + C = 0 \tag{1}$$

And  $A = y_{i-k} - y_{i+k}$ ;  $B = x_{i+k} - x_{i-k}$ ;  $C = x_{i-k}y_{i+k} - x_{i+k}y_{i-k}$

Step 3: chord length  $L_{ik}$  between the point  $P_{i-k}(x_{i-k}, y_{i-k})$  and  $P_{i+k}(x_{i+k}, y_{i+k})$

$$L_{ik} = \sqrt{(y_{i-k} - y_{i+k})^2 + (x_{i-k} - x_{i+k})^2} = \sqrt{A^2 + B^2} \tag{2}$$

Step 4: the distance of the point  $P_i(x_i, y_i)$  to the chord  $L_{ik}$  mark as

$$d_{ik} = \frac{|Ax_i + By_i + C|}{L_{ik}} \tag{3}$$

Step 5: base on the method of chord length ratio we can obtain the curvature of the curve in the point  $P_i$ :

$$c_{ik} = \frac{d_{ik}}{L_{ik}} \tag{4}$$

Step 6: if  $c_{ik}$  is greater than or equal to threshold, mark  $P_i(x_i, y_i)$  as cusp;

Step 7: turn to step 1 until another endpoint of the curve

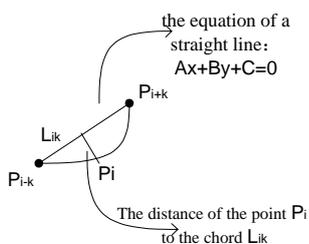


Figure 2. Schematic of chord length ratio.

**B. The Fitting- Vectorization Calculation of Tangential Line and Straight Line**

With high randomness and uncertainty, the initial motion curves must save its data information to meet the request of vector calculation. For this feature we choose the vectorization algorithm of curve-line fitting based on tangential line [11]. The main purpose is to use the fact that the tangent of the curve can reflect the changes of its curvature, and the distance of the point to the tangent which can be calculated in standard vectorization. The curve segment at a certain distance within the threshold can be fit with this straight line, and curve segment greater than the threshold can be fit with another tangential line. The idea of using this method of the

fitting- vectorization calculation of straight line as follows:

Set the minimum point of the initial motion curves in the direction of  $x$  as starting point  $e_{start}$  and  $e_{end}$  as the other side of the end for the movement.

Draw the tangential line  $L_{e_1}$  of curve from  $e_{start}$ , and then calculate the distance  $d$  of the point in the curve to the tangential line  $L_{e_1}$ , if  $d = D$  ( $D$  as the threshold), mark this point as  $p_1$ ; And then draw the tangential line  $L_1$  through  $p_1$ , if  $d = D$  mark this point as  $p_2$ ; By analogy, draw the tangential line  $L_n$  through  $p_n$ , when  $d = D$ , mark this point as  $p_{n+1}$ , until the distance  $d \leq D$  that finishing point  $e_{end}$  to the last tangent  $L_m$ ; Use straight line connect the points  $e_{start} p_1, p_1 p_2, \dots, p_n e_{end}$ , namely complete the fitting- vectorization of curve(Fig.3).

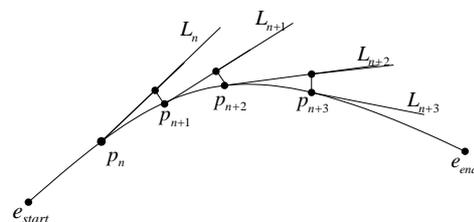


Figure 3. Tangential line and straight line fitting schematic.

**C. Mapping Algorithm Based on Scaling Transformation**

After the initial motion curves optimization-calculation, we get a series of athletic data point information, and connect the data points that are motion curve after optimization. The movement information will be mapped to the target object to finish motion retargeting process. However, before mapping the data information, we need to calculate the proportion of backbone between the reset target object and the standard model. According to the proportion of the backbone, we must zoom the motion curve after optimization corresponding, convert it to the motion curve of target object and then to be mapped. So we can avoid distortion of motion retargeting between models with different proportions of backbone.

In 2D circumstance, the movements of the reset target object are in 2D plane. With the increasing degree of freedom in the 3D case, freedom of movement of virtual roles objects is also increase, we need determine the curved surface of movement of the target object and then the motion curve mapping to the curved surface of movement, so as to finish motion retargeting. According to different situations between 2D and 3D, we adopt a mapping mode which based on scaling transformation [12]: The motion curve after vectorization and the target plane of motion do the same mapped meshing, adopt mapping mode which based on scaling transformation. The change of proportion is divided into three cases in Fig.5. Algorithm flow chart shown in Fig.4. The plane of motion curve after vectorization and curve and the target

plane of motion do the same mapped meshing. So, all of them have the same quantity of grids.

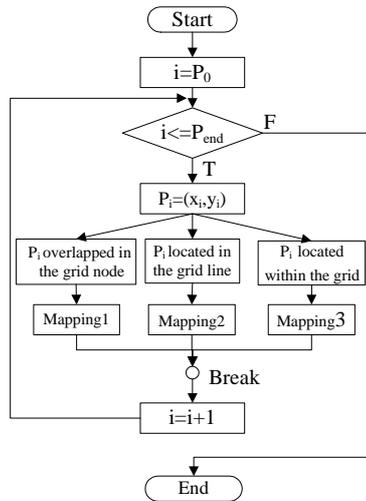


Figure 4. Flow chart of algorithm based on scaling and mapping.

Mapping 1:  $P_i(x_i, y_i)$  overlapped in the grid node (Fig.5 (a))

Determine the row and column of grid line where original point located in;

According to the same row and column, we can get the mapping point in the target plane of motion;

Mapping 2:  $P_i(x_i, y_i)$  located in the grid line (Fig.5 (b))

Determine the row and column of grid line where the original point located in;

Find the grid line corresponding to the target plane of motion, and calculate a, b and the arc length b1;

According to the relationship of scale  $a/b = a1/b1$ , determine the mapping point in the target plane of motion corresponding.

Mapping 3:  $P_i(x_i, y_i)$  located within the grid (Fig.5 (c))

Set up parameter curve according to the original point in the surface (as shown);

Determine the grid where the original point and its mapping point located in;

Calculate AB, AC; DE, DF; BO, BE; A1C1 and D1F1;

According to the proportion  $AB/AC = A1B1 / A1C1$  and  $DE/DF = D1E1/D1F1$  determine the points B1 and E1 in flattening map;

Extract the points B1 and E1 in flattening map, and generally, these points have different v-direction parameter values, calculate their average value v0, and through v0 draw a new u-direction curve, which has the same points B1' and E1' with the grid line;

Calculate the length of the arc B1'E1', with the u-direction curve crossing B1' and E1', we can determine the corresponding point O1 of O according to the scaling relation  $BO/BE = B1'O1/B1'E1'$ ;

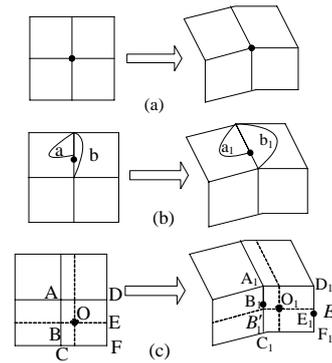


Figure 5. Three cases of scaling transformation.

#### IV. VECTOR - MAPPING ALGORITHM FOR MOTION RETARGETING EXPERIMENTAL RESULTS

##### A. MatLab Experimental Simulation

Following the idea of vector - mapping algorithm of motion retargeting, computer can calculate the information of its intermediate joint automatically So in MatLab simulation, we can just check whether the motion curve or the feasibility of our method in computer animation can be verified.

Because we need to extract the information of motion curve, and design it again, for random trajectory of motion curve we adopt the method of extracting pixels and its movement information.

As shown in Fig.6. Then do the fitting- vectorization calculation for initial motion curve by using least-square method. Besides computing easily, using this method can maintain the characteristic of original curve.

In a new window displays the motion curve of vectorization, and a fixed point of reset target object, as shown in Fig.7, in the 2D circumstances, the situation that fitting vectorization and mapping of the initial motion curve. In Fig.8, in 3D circumstances, the situation that fitting vectorization and mapping of the initial motion curve.

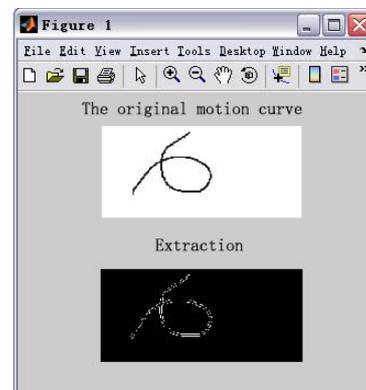


Figure 6. Read and extract the initial motion curve.

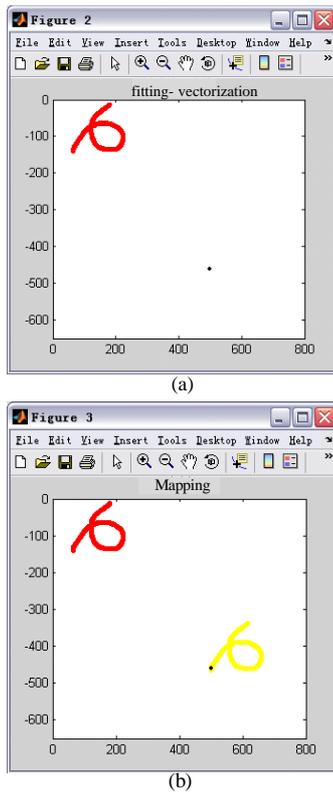


Figure 7. 2D fitting vectorization and mapping.

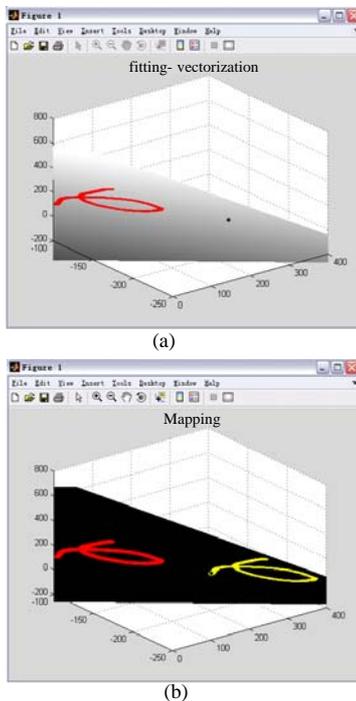


Figure 8. 3D vectorization and mapping.

After MatLab experiment, for any motion curve, the method of vector-mapping is good and the result is precise. Because the method of vector - mapping is for virtual object with IK settings, and the object's terminal effector can drive corresponding joint moving together. If

the motion curve can vector-mapping correctly, then the motion retargeting can finish. After the simulation above, the method of vector-mapping proposed in this paper is feasible. Next, we study the concrete object- virtual arm to verify our method in virtual environment.

*B. Using the Virtual Arm to Verify Vector-Mapping Algorithm of Motion Retargeting*

This experimental simulation adopts Visual c++ 6.0 &OpenGL. Use the method of vector-mapping, by taking two virtual arms with identical skeleton structure but different lengths as research objects.

We use the random motion curve to verify motion retargeting between the two virtual objects and get a good result. The experimental simulation adopts MFC frame structure. In the framework generated by MFC, the movement and motion retargeting of virtual objects in work area can be achieved.

The virtual object in experiment is virtual arm, which uses the HI settings. Define a structure T\_Bone , set the hierarchical relationship of father-son between bones, and define the proportion of backbones, the length of the bone, and rotate, translate variable, and then use the algorithm of IK Solver to set up the virtual arm.

Motion retargeting between the two virtual arms has some characters as : In virtual scene, the position of mouse directly relate to the position of Model-1 arm terminal. If the target points in the reachable area, terminal effector will move to the target point based on inverse kinematic, Track the position of mouse to complete a movement and record the movement of the curve. Then this movement can be mapped to Model-2 virtual arm, and the virtual arm moves along the motion curve. Motion retargeting between the two virtual arms is completed. As shown in Fig.9:

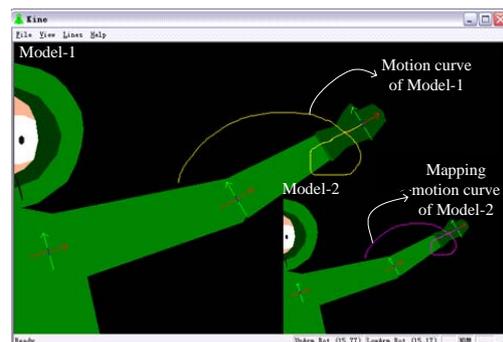


Figure 9. Motion retargeting between the two virtual arms.

Another mapping method is motion curves mapping, namely reading motion curves, and we use the vector - mapping algorithm of motion retargeting to extract the cusps and data information of the initial motion curve, and then mapping to Model-1 and Model-2. Model-1 is standard model direct mapping, and Model-2 as a small scale model must map after scaling. The movement of virtual arm has the problem of reach ability, we must limit the area of mapping motion curve, and only in the area within the scope the point can be effective. Model-1 and Model-2 move along their own motion curve. As shown in Fig.10.

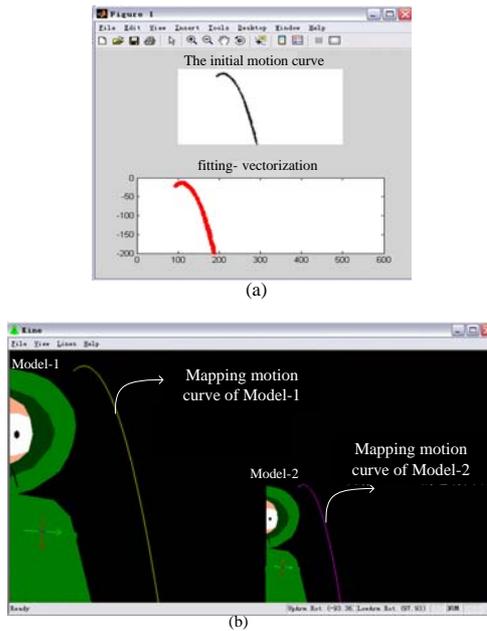


Figure 10. From the motion curve to Motion retargeting between the two virtual arms.

## V. CONCLUSIONS

The IK Solver for 3D Max set the joints connecting to the model, and the vector-mapping method of motion retargeting is proposed in this paper, take the two virtual arms with identical skeleton structure but different backbone proportion as research objects, our method can be verified and we can receive a good result.

The idea of motion retargeting is reuse the existing data and information as much as possible. Also, we can use our method in a much wider range of areas. Based on the joint model with IK settings, we can use our method to achieve motion retargeting in objects with different skeleton structure and different backbone proportion. Our method is applicable between a role object with a skeleton structure and an object without having a skeleton structure. If all kinds of objects have the relationship of hierarchy, all objects can be considered as bone. Using our method can further strengthen the reusability of existing data, save the time and the cost of computer animation production.

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