

Animation synthesis for virtual fish from video

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Abstract

CG(Computer Graphics) is widely used in many kinds of fields, because of the recent progress of the CG techniques, especially, in modeling and rendering techniques. In the field of VR(Virtual Reality), CG techniques are very important in order to make two dimensional or three dimensional virtual world. It is, however, very difficult to represent virtual creature with locomotion and behavior.

In this paper, estimation method of fish position and posture from video using object matching technique is proposed. Then, some basic behaviors are segmented from the obtained three dimensional positions and postures based on changes of the angle and speed. Finally, a novel locomotion is generated using the segmented basic behavior.

Keywords: Animation synthesis, Object matching, Motion estimation, Motion control

1 Introduction

It has become possible to generate CG images with reality by the improvement of CG(Computer Graphics) techniques, especially modeling and rendering techniques. In commercials or weather reports, many CG images have been utilized frequently. Not only in movies but also in VR(Virtual Reality) researches, CG techniques have become important ones to make two or three dimensional world.

As regards the technique to represent a stable creature at present, it is possible to generate a highly realistic image. If motions are tried to be represented, however, it is difficult to generate visually natural motions. Many trials for generating natural movements of creatures by using CG(Computer Graphics) techniques have been studied. Some of these researches[1][2] represent natural fish locomotions. Sanmiya et. al.[3], [4] proposed a method which define mathematical models by analyzing the motion of creatures in observations. Tu et. al.[1] proposed a method to make an artificial creature move by defining principal motion patterns of fishes and giving parameters of mental status which are factors to cause

the motion. Each of which, however, remains some problems in easily to use and generality.

In this paper, by using object matching for a fish, a method to estimate 3D position and posture of the fish from video is proposed. Moreover, the time sequence of the obtained position and postures in 3dimensional world is segmented to basic movements based on the changes of angle and speed. As a conclusion, a method to generate a novel locomotion and behavior of a virtual fish is shown by synthesizing stored segments.

In the following section, a literature of generating an animation of artificial creatures is reviewed. In the section3, a method to estimate motion parameters of a fish from video using object matching is explained. In 4th , 5th sections, motion parameters obtained in the section3 are divided into motion segments that denote a fundamental unit of motions and a method to generate automatic motion and a method to control trajectory by assigning control points are explained, respectively. Finally, a conclusion and future work are discussed in the last section.

2 Literature

In 3DCG, in order to generate animations, many researches using kinematics, inverse-kinematics, dynamics have been proposed. In these days, a method to represent a motion by using a physical model[5] or researches using artificial life[6], citeAL:Sims94a are proposed to generate a motion of artificial creatures. Especially in researches regarding a motion generation of an artificial creature, the following researches try to represent a motion of fish.

A framework for animation with minimal input from the animator is proposed by Tu et. al.[1]. They define a physics-based, virtual marine world, in which artificial fishes inhabit. These motion patterns are decided by using a few mental state variables. In addition, a method to learn a fish's motion automatically is proposed[7]. Because these methods use complicated algorithm, however, it is difficult to generate motions in real time. Moreover, Manabe et. al.[8] try to represent a motion of fish by applying a fan movement of caudal fin based on vibration wing theory. It makes a virtual colored carp swim by vibrating the fin

with a constant frequency. It, however, has a problem that the algorithm has to set the angle of bend in the body against the fin by comparing with the swimming of a real carp heuristically.

On the one hand, some researches aim to realize a real time generation of fish motion[9]. Though this method enables a school of fish to locomote in real time, a motion to vibrate the body is given heuristically. Moreover, researches in regard to motion generation of an artificial creature which aim at interaction with users[10],[11] are proposed. Yamaguchi et. al.[?] propose a method to interact with a fish in a virtual water tank. It extracts a motion of a fish which swims in the water tank on a real world and makes a virtual fish swim in a virtual water tank using extracted motion parameters. It can generate a motion of virtual fish without analyzing the motion of a real fish itself by using a real image. The virtual fish itself, however, is not deformed, and only motion vector is obtained by a real image. It, therefore, remains some problems about generating realistic motions. Kurihara[11] proposes a system in which user interacts with a dolphin and generates a motion of dolphins in real time. It employs task-oriented approach and path planning to obtain motion primitives such as “swim” or “turn”. Then an autonomous motion is generated using these motion primitives. Schödl et. al.[12] proposes a method to generate a non-periodic video sequence which is called “video texture” by using several parts of consecutive video images. In this paper, an image of several fish’s swimming in the water tank is generated for one of applications. Since a two dimensional video image is used, however, it is difficult to represent three dimensional motion with depth.

Aiming at assistance of fishery, some researches to represent a school of fish have also been discussed. Sugiyama et. al. record temporal and spatial movement of a school of fish for a long period of time and define a mathematical model which represents it. A method to search optimal parameters from the obtained parameters is proposed[3]. In order to model a motion of a school of real fish, however, various motions in a water tank under a uniform condition have to be collected. It is, moreover, necessary to define appropriate functions which presents various motions.

The authors, therefore, propose a method that three dimensional motion of a fish is extracted from video in which a fish is swimming by using object matching. Then, an animation of a virtual fish is reproduced using the extracted motion parameters. It is not necessary to analyze the motion of fish itself. It needs just only a simple object as a model. Moreover, motion segments are generated from the obtained consecutive motion parameters. By synthesizing the motion segments, a novel locomotion is generated.

3 Motion parameters extraction from video

This section describes a method to obtain three dimensional motion parameters from video using object matching.

3.1 System overview

There are two kinds of swimming styles of fishes which inhabit in the sea or river. One is a horse mackerel type which vibrates the rear half of the body and the other is an eel type which vibrates the whole body from the head to caudal fin. The fashion of movement in the creatures under water is wavy motion which begins from the head like progressive wave and, increases the amplitude of the vibration and makes the wavelength short in the tail of the body. It is said that fish changes its figure as a consecutive curve fits along the length of fish.

In considering this characteristic of swimming fashion of fish, the system used in this paper is configured as illustrated in Fig.1. Motion parameters of a virtual fish for generating animation are obtained by the images captured by two cameras, one of which is the upper side of a carp that is swimming in a water tank, and the other of which is the side of it. The optical axis of these cameras are set to be perpendicular each other and the synchronized images of two digital video cameras are used as input images in order to obtain vibrating motion of the fish easier. Object matching is employed by using a region of the fish which is obtained by the difference of a fish image and a background image, and by using the edge image obtained by canny edge detector. Three dimensional model which makes smooth deformation is used in object matching. A center of gravity of the fish, an inclination of the head and curvature of the backbone are obtained as motion parameters[13]. The obtained motion parameters are divided into motion segments that denote a fundamental unit of motions. Then, automatic locomotion is generated using these motion segments. Moreover, other locomotion is also generated by assigning control points. The process overview is shown in Fig.2.

3.2 A 3D virtual fish model

A three dimensional virtual fish model utilized in object matching process and animation generation is described in this section. The model is configured based on a structure of a real fish.

3.2.1 Characteristics of a fish

In this paper, motion parameters of a fish are obtained from a real motion of a fish. A carp is employed as target fish for the reason of the body size and its habit. The swimming fashion of a carp belongs to the horse

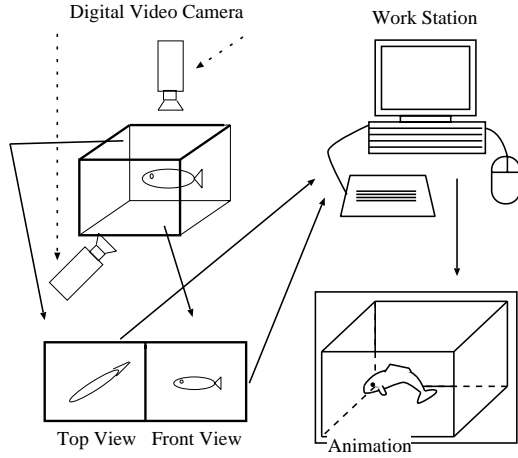


Figure 1: System configuration

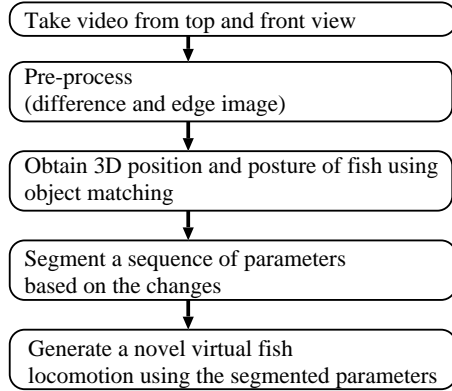


Figure 2: Process overview

mackerel type mentioned above. In this swimming fashion, a caudal fin moves as a fan and then it gains driving force by repellent force of momentum against the water. It is, therefore, necessary for fish to vibrate its body and gain the driving force in order to advance,

From a skeletal structure point of view, head is composed of bone and head length of a fish is almost one-third of its total length. Furthermore, it has a backbone composed of a great many of spines. The head, therefore, cannot deform, but the rear part of the body deforms smoothly. As a result of preliminary observation, the head hardly deforms, and only inclination and direction in the water tank coordinate system change. On the other hand, the body deforms smoothly along the backbone. The observed fish forms are shown in Fig.3.

3.2.2 A virtual fish model

As described in the previous section, the characteristics of the deformation of a fish are different from each part. Three dimensional model of a virtual fish employed for object matching is configured in which



Figure 3: Forms of a fish in preliminary observation

a body structure of a fish is divided into the following three parts. In this paper, the positions of fins are not extracted in the parameters extraction process, but models of fins are created in order that the same model should be used in generating animation based on the obtained motion parameters.

Head: Because the head hardly deforms and it can be regarded as rigid body, it is synthesized by the simple polygons.

Body: Body has a backbone composed of a great many of spines, and it deforms smoothly. In order to realize a smooth deformation, NURBS(Non-Uniform Rational B-Spline) is employed. As illustrated in Fig.4, a model is configured by some groups of control points.

Fin: Since pectoral fin or caudal fin does not have muscles itself and it is just attached with the body, it is configured by connecting a polygon as a plate with the body.

The body part of three dimensional model of a virtual fish is drawn in Fig.5. A center of gravity of the fish is set to the base of the fish's head which locates at about one-third from the head, and it is set to the origin of modeling coordinate system. The number of parameters obtained in posture estimation process is 9. These are a center of gravity $\{G_x, G_y, G_z\}$, the inclination of a fish's head $\{R_y, R_z\}$ and the angles $\{A_0, A_1, A_2, A_3\}$ between skeletons which determines the posture of the body. These parameters are illustrated in Fig.5, respectively. In this paper, an assumption that there is no twist motion around the x axis in the local coordinate systems of the fish is employed.

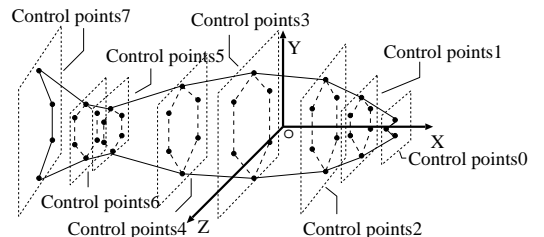


Figure 4: Control points

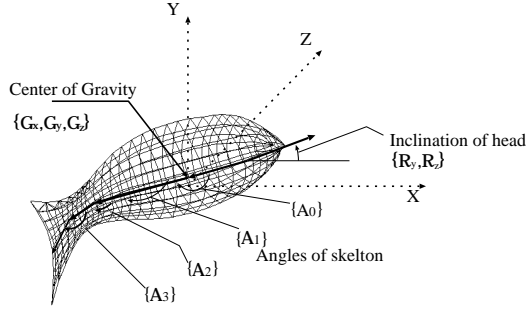


Figure 5: 3D model for object matching

3.2.3 Calibration of a 3D model

In order to create an appropriate three dimensional model which is used for object matching, a fish is captured under restricted conditions in which the posture of fish is ideal straight. Then, difference images against a background image and edge images of the upper side and the front side are generated. Next, a small size model is used as an initial model, and matching is performed varying the width and height of the 3D model for each image. The most appropriate model which has the highest evaluation value is employed as a 3D model for object matching.

3.3 Acquisition of motion parameters using object matching

In order to obtain the motion parameters of a fish, object matching is employed for each frame of consecutive input images and the posture of fish is estimated. As initial values of posture in estimation process of each frame, the posture of a previous frame is used. Moreover, a reduction of matching process is realized by hierarchical matching.

3.3.1 Acquisition of motion parameters of the first frame

In the first frame, a procedure to extract motion parameters is different from it on and after the second frame. The motion parameters are obtained from the first and the second frame. First, a difference image between the first frame and a background image in which a fish doesn't exist is generated and then the image is binarized. Next, the region in which a fish exists is extracted by performing dilation and erosion. A skeleton is extracted for the image captured from the upper side of the water tank, in order to estimate the inclination of the head. In the same way, a skeleton is extracted in the second frame. Center points of two obtained skeletons are obtained, and then a translation vector of a fish is calculated. The progress direction of the fish is estimated from the translation vector, and it assumes that the fish's head is in the same direction of the progress direction. Then, the

skeleton is divided into seven equal parts. Line segments formed by the second, third, fourth, fifth of points and the end points make a skeleton of a virtual fish. Finally, motion parameters $\{A_0, A_1, A_2, A_3\}$ are obtained from the skeleton of the virtual fish.

3.3.2 Evaluation function

The motion parameters of the first frame obtained in the previous section are utilized as the initial values of the next frame, the motion parameters of each frame are obtained in turn. In extraction of the motion parameters, object matching is employed by using a difference image obtained from the upper side and the front images and using the edge image detected in canny edge detector[14].

Define that the parameters which determine the posture of three dimensional model is denoted as $X = \{x_i \mid 0 < i \leq n\}$. Where, n denotes the total number of parameters of three dimensional model. As shown in Fig.6, S denotes the area of a fish in the difference image and $P(X)$ denotes the area by projecting three dimensional mode onto the image plane.

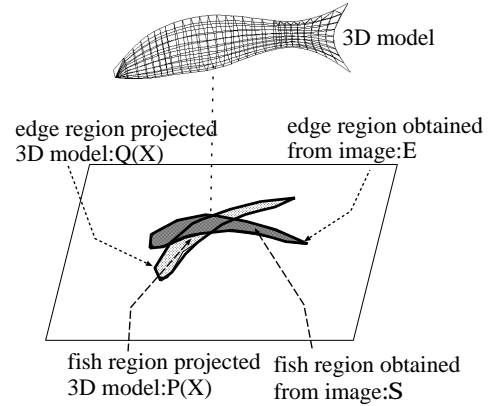


Figure 6: Evaluation of the posture of 3D model

$f(A)$ is defined as a mapping function which calculates the area of region A on the image plane. An evaluation function with regard to area is defined as follows;

$$J[X] = \frac{f(P(X) \cap S) - f(P(X) \oplus S)}{f(P(X))} \quad (1)$$

where, \oplus is XOR operator of both regions and \cap is AND operator of them. In the same way, suppose that E denotes the edge region obtained from canny edge detector and $Q(X)$ denotes the edge region in which the model is projected onto image plane, and an evaluation function with regard to edge is defined as the following formula.

$$K[X] = \frac{f(Q(X) \cap E) - f(Q(X) \oplus E)}{f(Q(X))} \quad (2)$$

The weighted sum of the formula(1) and (2) is employed as the evaluation function of the object matching. The function $V[X]$ is shown in equation(3).

$$V[X] = J[X] + W \times K[X] \quad (3)$$

where W is weight.

3.3.3 Posture estimation from upper image

First, matching of the head region is performed by using the image captured from the upper side of the water tank and x, z coordinate values of a center of gravity of a fish $\{G_x, G_z\}$ and inclination around y axis $\{R_y\}$ are estimated.

In the estimation of the head region, the region is searched within 100×100 pixels centered on the center of gravity of previous frame. Fish usually swims toward the head direction at a certain speed, because of its body structure and the swimming fashion. Therefore, suppose that the head region on the current frame exists around the prolongation of the inclination of the head on the previous frame and the head region is searched within a restricted area. Because a fish goes forward without changing its direction in most cases, the matching can perform effectively. In the case it does not satisfy this assumption such that a fish twists its body to accelerate or twists the body to change direction, that is to say, in the case the value $V[X]$ is smaller than a certain threshold, region restriction is not employed, but matching is performed around the head region of previous frame. The matching procedure is explained as follows;

1. The position and angle are predicted roughly, as the value of $\{G_x, G_z\}$ are changed 3 pixels and that of $\{R_y\}$ is changed 3 degree, respectively. The search range is limited in the restricted region. In this prediction, the matching ratio with regard to edge which is denoted in formula(2) is used for an evaluation function.
2. If the matching ratio mentioned above is larger than a certain value, $\{G_x, G_z\}$ and $\{R_y\}$ are changed 1 pixel and 1 degree within ± 3 , respectively. The most optimal parameters which make it the largest that the value of evaluation function shown in equation(3) is searched.
3. In the case matching ratio of step1 is always smaller than a certain value, it is judged that the region prediction is failed. Then, process 1 is performed without any region restriction.

The upper input image and the result of estimated head region are shown in Fig.7(a) and (b), respectively. In the posture estimation process of the body, the optimal parameters are searched by changing the value $\{A_0, A_1, A_2, A_3\}$ in turn. The result of the estimated body is drawn in Fig.7(c).

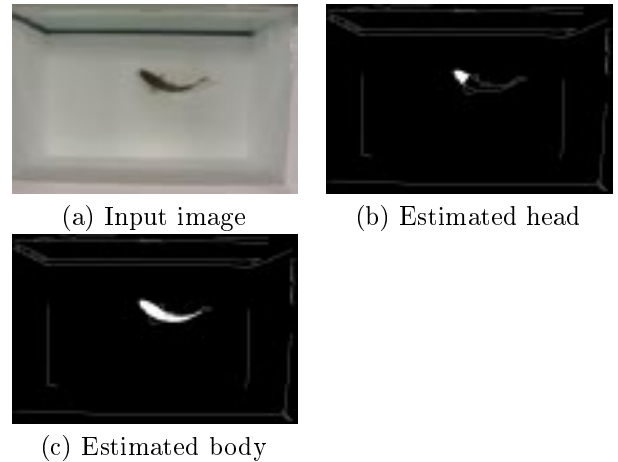


Figure 7: Posture estimation from upper image

3.3.4 Posture estimation from front image

Based on the parameters $\{G_x, G_z, R_y, A_0, A_1, A_2, A_3\}$ obtained from the upper image, the y coordinate value of the center of gravity $\{G_y\}$ and $\{R_z\}$ which is the inclination around z axis are searched. Though the fish usually vibrates the body in order to gain the driving force, the body cannot be changed its direction upper and lower direction rapidly. In the matching process, G_y and R_z are, therefore, changed by 1 pixel and 1 time, respectively, so that the optimal parameters which make evaluation value the largest are searched. Fig.8(a) and (b) illustrate the input image and the result of posture estimation from the front image.

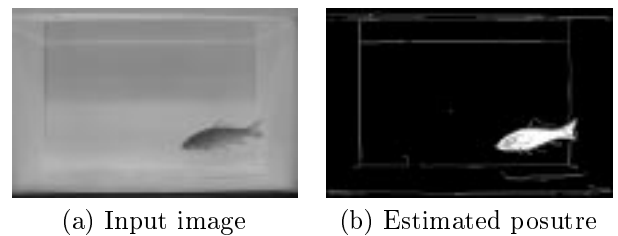


Figure 8: Posture estimation from front image

4 Motion generation of a virtual fish

4.1 Classification of the movements based on motion parameter

A fish gains driving force by repellent force of momentum against the water. In changing its course, it makes the direction of the head turn around by twisting the whole body. In the movement of a fish, a behavior of the body itself and a locomotion in underwater have tightly relations in each other. Therefore, it is necessary that the behavior like a twisting and

transition in the locomotion should be regarded as one movement. In this paper, a basic unit of the movement represented by the combination of such behavior and locomotion is called “segment”.

4.1.1 Classification of fish posture

Postures of a fish at each frame are classified into basic posture P and non-basic posture \bar{P} . Basic posture denotes that a fish stretches its body almost straight, and that each value of parameters $\{A_0, A_1, A_2, A_3\}$ obtained at the previous section is within ± 4 degree. The rest of postures, in which the fish leans its body, denotes non-basic posture.

4.1.2 Division into segments

The motions which have vibrating motion and deceleration motion are extracted from the motion sequence. The vibrating motion denotes a motion from P to \bar{P} and the returning to P again. The deceleration motion denotes the movement which keeps up the posture of P successively. The concept of the classification of the movement is shown in Fig.9. The movement as $F_1 \rightarrow F_2 \rightarrow F_3$ in Fig.9 is the one in which a fish makes the body vibrate only for a certain amplitude and returns to the basic posture. These changes of postures are regarded that the fish accelerates for moving forward or leans the body for turning. On the other hand, in the movement $F_0 \rightarrow F_1$ in Fig.9, a fish moves toward a certain direction without vibrating the body. In this movement, it is regarded that the fish advances just by inertial force and that the speed decelerates.

However, in the case that the direction of the fish hardly changes as $F_1 \rightarrow F_3$ and $F_3 \rightarrow F_5$ illustrated in Fig.9, that is, such a movement of vibrating the body to accelerate, it is also divided into segments. Therefore, the merge of vibration behavior is performed by the following procedure described in the next paragraph.

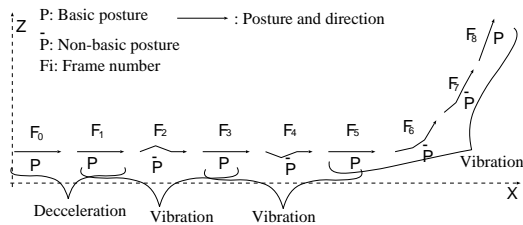


Figure 9: Segmentation into basic behaviors

4.1.3 Merge of segments

In the case that the amount changes of the head's inclination is smaller than a threshold in consecutive vibrating motions, plural vibrating motions which

were described in the former are merged into one segment. If the angle $\{R_y\}$ around y axis at the first basic posture and the angle at the last basic posture should be smaller than a certain threshold T_h in the two consecutive vibrating motions, they are merged. On the other hand, if the angle is larger than the threshold, segments are kept divided as different movements. Three motions, which are deceleration motion as $F_0 \rightarrow F_1$, acceleration motion as $F_1 \rightarrow F_5$, and right turn or left turn motion as $F_5 \rightarrow F_8$ are obtained as shown in figure10.

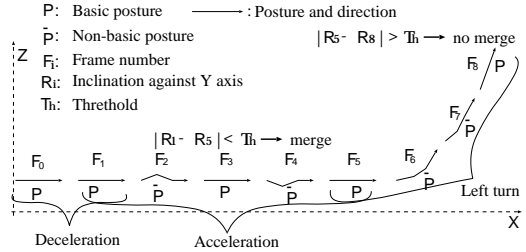


Figure 10: Segmentation into basic locomotion

4.1.4 Results of motion segments

A movement of virtual fish generated by obtained motion parameters is illustrated in figure11(a) and the results of the divided segments are shown in figure11(b)~(d). The results of the segments are shown on the local coordinate system of the first basic posture. Fig.11(a) shows every 3 frames of the trajectory of the center of gravity of the fish in 150 frame motion parameters obtained in the previous section as black points. It also shows the posture of a fish at the beginning and ending of the segment. Fig.11(b)~(d) are segment which is obtained by the movement of Fig.11(a), and each shows right turn, acceleration and deceleration motion. These figures show trajectory of the center of gravity of the fish in every 3 frames, and illustrate the posture of a fish in every 5 frames.

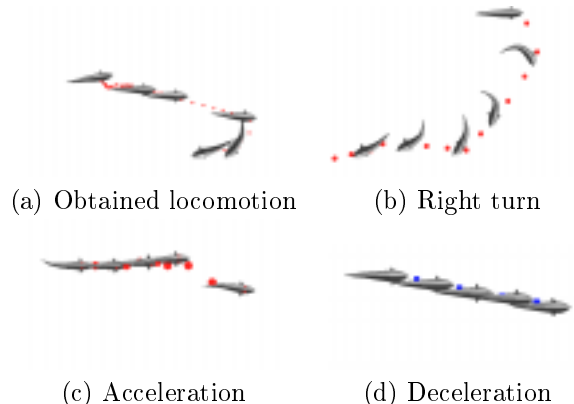


Figure 11: Segmented locomotion

4.2 Motion Synthesis of a Virtual Fish

A method to generate a novel motion of a virtual fish by connecting several segments is discussed in this section.

4.2.1 Rule for connecting segments

As shown in Fig.12, a motion synthesis of virtual fish is realized by connecting the end points of each segment. In connecting segments, coordinate system is transformed in order that the new segment should be aligned with the final basic posture of the previous segment. As described in the previous section, the motion of a fish is connected smoothly because all postures of the fish in the ends of segments are basic postures. Also in a novel movement generated by connecting segments, unnatural motions by changing the body postures don't appear.

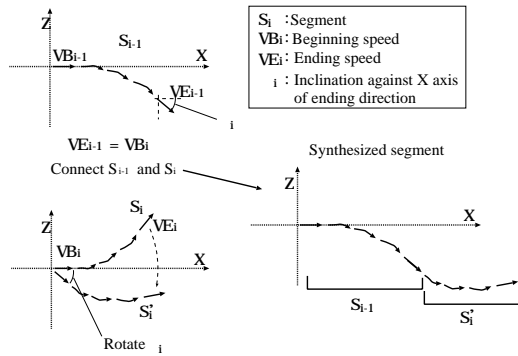


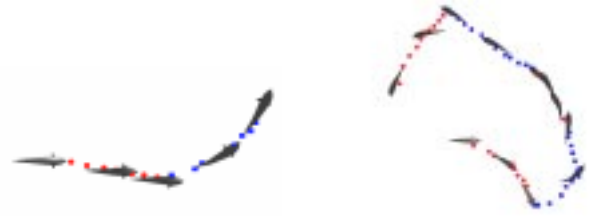
Figure 12: Connection rule of segments

On the other hand, unnatural movements are generated in the case that the arbitrary two segments are connected because the speed of virtual fish is different from each segment. Therefore, the following restricted conditions are given in connecting two segments S_{i-1} and S_i . It is connected only in the case that the ending speed Ve_{i-1} of segment S_{i-1} and the beginning speed Vb_i of segment S_i are almost the same. As a result of preliminary experiments, the beginning speed Vb_i and the ending speed Ve_i of each segment were within the range of $0 \sim 6$ pixel/frame. Therefore, in this paper, the speed is divided into 3 ranges and the connection should be permitted if the speed is within the same range.

4.2.2 Results of motion synthesis

The generated animation using the connecting rule described in 4.2.1 are shown in figure13. The points in the figure denote trajectory of the fish's center of gravity, and virtual fishes in the end of segment are illustrated. In generating animation, segment which satisfies the possibility of connection is selected at random and then connected. In the case it doesn't satisfy the possibility, segment data is selected from a

set of data at random until the one which satisfies is selected.



(a)Deceleration + left turn (b) complex locomotion

Figure 13: Examples of jointed segments

5 Motion synthesis of virtual fish by assigning control points

In this section, a trajectory control method in which virtual fish passes through control points, is described.

5.1 Trajectory control using control points

To control the trajectory of a virtual fish's movement, the connection conditions are more restricted than the one in previous section. As shown in figure14, to generate a motion aiming to go towards control point C_i , a segment which makes the position to be closest to C_i is selected. Moreover, by virtual fish's center of gravity passing through the region of a certain distance from the control point C_i , the target control point is changed to the next control point C_{i+1} .

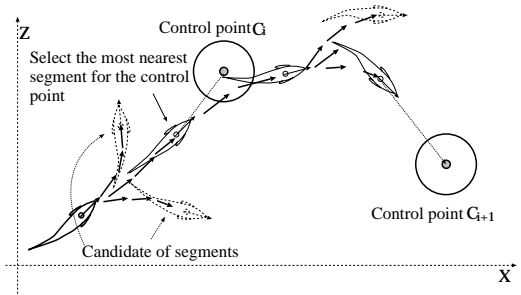


Figure 14: Selection of segment based on control points

5.2 Experimental results

The result of virtual fish movement by assigning several control points is illustrated in figure15. Figure15 shows the movement every 60 frames. Each control point is drawn by a small cube, and it shows a virtual fish is moving in specific order.

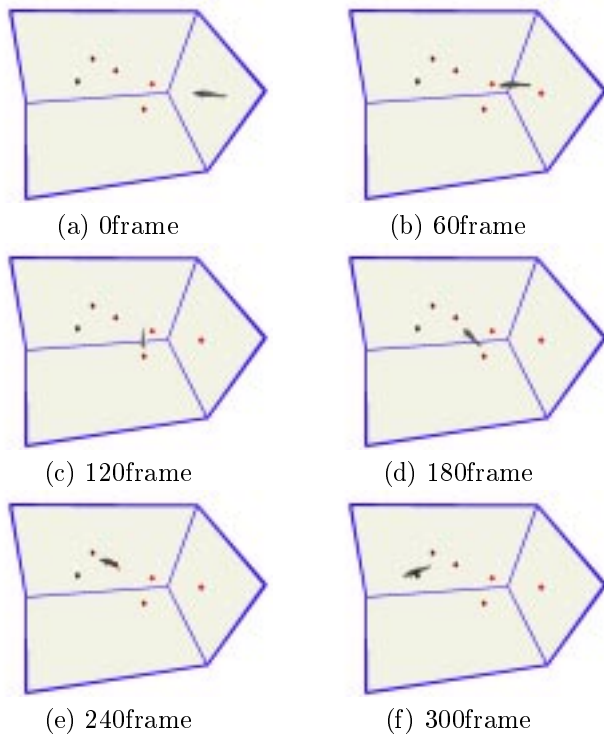


Figure 15: Control of virtual fish locomotion using control points

6 Conclusions

In this paper, a method to obtain motion parameters of a fish is proposed by employing posture estimation of the fish. In posture estimation, object matching technique is performed to each frames of the video taken from a real fish in a water tank. Motion parameters denote a center of gravity, the inclination of a fish's head and the angles between skeletons which determines the posture of the body. These represent a transition of the movement of fish with the change of times. The method to divide the motion parameters into several segments by using the characteristics of the motion of fish is proposed. The method presents the virtual fish's movement which is quite natural by synthesizing according to the segment connection rule.

We are planning to propose a more accurate and more high performance extraction method of motion parameters. It is also a charming theme to make a motion data base and its retrieval. Furthermore, we are trying to generate retargetting motion from the obtained motion parameters and compare with physical-based model technique quantitatively.

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