Motion Curved Surface Analysis and Composite for Skill Succession using RGBD Camera

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Abstract: The skill succession method is almost oral. It is not quantitative but qualitative. Quantitative succession is difficult. In this research, after tracking of a subject's motion using RGBD camera, a subject's motion is visualized as the motion curved surface. Expert and beginner perform the sports and entertainment motion, and the character of the surface is analyzed. The character is the maximum curvature and surface area. In addition, we suggest the composite surface, because one RGBD camera is not all tracking motion by occluding the obstacle or subject' body parts. Finally, we confirm the validity of skill succession by watching skeleton motion movie and curved surface.

1 INTRODUCTION

Beginner trains to watch and imitate the expert behavior, in the entertainment of the Noh play and Kabuki play, and sports play, engineering of operating a machine (Hashimoto et al., 2011). However, their skill succession/teaching are qualitative, not quantitative. They are expressions in abstract languages, such as onomatopoeia, or metaphor of an object image, and the quantitative evaluation is difficult to express and perform (Hasegawa and Fukumura, 1996). Therefore, the skill succession/teaching cannot be confirmed, the same behavior is not always repeated.

Then, an expert's motion is captured by video camera photography, and the motions are analyzed in research or software (Takeo and Natsu, 2011), (Cheung et al., 2003; Sigal and Black, 2006). The method is the motion capture by one or more camera sets, with the background subtraction technique, extracts a human's outline/marker joints and displays only a human's motion. The motion can be preserved, and the reproducibility is high. However the extraction of human position is difficult, and quantitative evaluation is limited or no meaning. Furthermore, human joints are needed to capture equipped markers, by forcing marker wearing on a subject. Therefore, we can hardly expect to track the usual motion.

We focus Microsoft Kinect, which is a reasonable and easy operation, and capture the motion using it. Kinect can recognize pictures and depth positions, which is a useful tool function and expected the application to three-dimensional measurement. Kinect can extract a human's outline, and the position of the human skeletons and joints. In the conventional research, angles of the skeleton and joint positions are measured (Murao et al., 2011; Hashimoto et al., 2014). In addition, we visualize a human joint trajectory of motion into a curved surface (it is called a motion curved surface), and we extract the difference between beginners and experts from the form or curvature of the motion curved surface in previous research (Mitsuhashi et al., 2014; Suneya et al., 2014). Therefore, we can evaluate technical skill quantitatively, and except the skill succession/teaching for expert's skill easily. However, some joints are not tracked by occluding an obstacle or body parts (joints, body, arm, leg, head...), (Deutscher et al., 2000) because tracking view is one direction (one Kinect). Therefore, the motion curved surface is lacked by the occlusion. On the other hand, we have never confirmed the validity of skill succession using a motion curved surface.

In this research, we compose the motion curved surfaces made from the multiple Kinect view, so as to track the whole joint motion in more detail. Moreover

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we investigate the effectiveness of the composite motion curved surface. In addition, we confirm the validity of skill succession by watching skeleton motion movie and curved surface.

2 EXPERIMENT METHOD

2.1 Motion Tracking Method

In this paper, we track the motion of human's joints in drawing gesture expression using Kinect. A user expresses object shape by moving the right hand, left hand, or both hands with depth sensing and image recognition. Figure 1 shows the tracking situation. Kinect is placed the height position of 1.75m and the distance between Kinect and a user is 2.0m. Figure 2 shows an image recognition of the user. Figure 2(a) shows an image recognition of the user. Figure 2(b) shows a depth image recognition with human joints and skeleton model. Position of joints and skeletons is estimated by Kinect driver. In this paper, we measure the position of a right hand, right elbow, right shoulder, left hand, left elbow, left shoulder, and neck. Line segments by gesture are displayed with measuring the position of the hand (right or left hand) using the OpenCV library. Line segments by gesture are displayed with measuring the position of the hand (right or left hand) using OpenCV library. Kinect programing language is C/C++ and using openNI2,

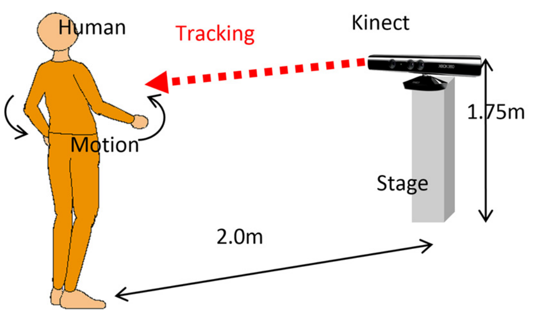
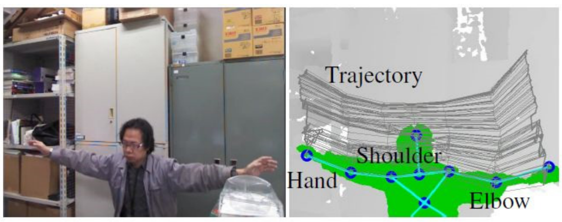


Figure 1: Motion tracking situation.



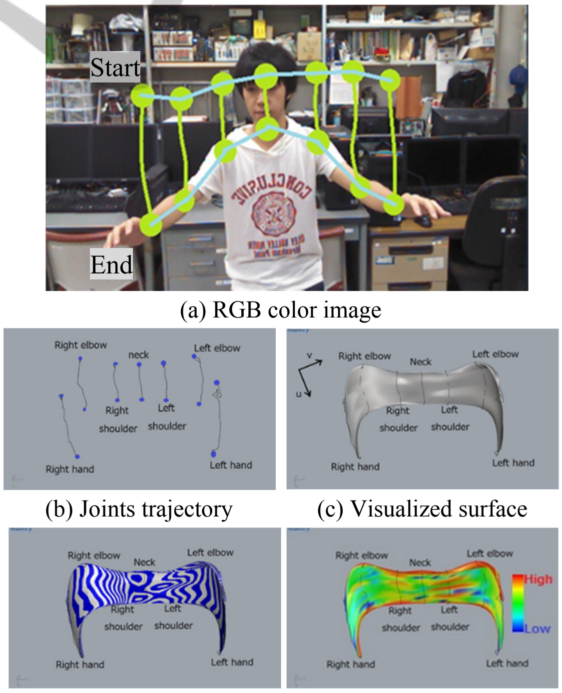
(a) RGB color image (b) Depth image

Figure 2: Kinect view.

NiTE2 library. A user's motion is tracked in every 0.02 second, and the measured position is placed with the time series.

2.2 Curved Surface Visualization

The subject's motion is visualized to a curved surface in the preceding section. In order to visualize a curved surface, the data of a subject's joint position of point cloud based on a time series is preserved, and B-spline curved surface is fitted to the point cloud by the approximation. The curved surface makes a subject's trajectory the direction of u, and makes joint positions the direction of v. Figure 3 shows motion, trajectory and curved surface when the subject opens the arms and squats down. The generated curved surface calculates the size of a curved surface, normal vectors, tangent vectors, and curvatures using 3D-CAD software Rhinoceros in Figure 3. Figure 3(b) shows the trajectory of upper joints. Figure 3(c) shows the visualized curved surface. Figure 3(d) shows the gradation display of curvature and Figure 3(e) the zebra mapping display. Zebra mapping is an analytical technique to visualize continuities of the curvature.



(a) RGB color image

(b) Joints trajectory (c) Visualized surface

(d) Zebra mapping (e) Gradient curvature

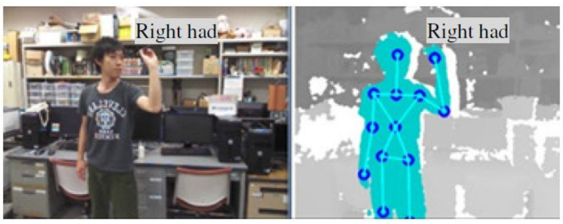
Figure 3: Visualized motion curved surface.

However, if all the motions are transferred the curved surface display, a curved surface will be twisted or overlapped. Then, tangent and normal vectors are calculated, and the first standard normal and tangent vectors are decided. And a curved surface is divided if the angle between the standard vector and the other is larger than 180 degrees. Furthermore, a curved surface is divided also if the self-intersection on a curved surface or edge is occurring. Then, we are able to prevent a twist and overlap of a curved surface.

3 ANALYSIS OF SKILL MOTION

3.1 Throw Motion in Darts

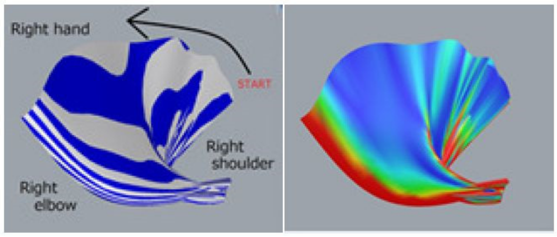
We investigate the difference of throwing motion in Darts between 5-year-experience expert and beginner. Subjects perform the darts motion in the front of Kinect, their upper half of the body (hand, elbow, and shoulder) is tracked. The situation of throwing motion in darts is shown in Figure 4. Figure 4 (a) shows expert's motion of RGB color image and depth image with joints and skeletons, and Figure 4 (b) shows beginner's motion. The visualized curved surface of the expert's motion is shown in Figure 5. Figure 5 (a) shows the curved surface with the gradient curvature distribution when a right arm is throwing and Figure 5 (b) shows the curved surface with zebra mapping. The visualized curved surface of the beginner's motion is shown in Figure 6. The curved surface is divided hand-elbow and elbow-shoulder, because there is the self-intersection in Figure 6. Figure 6 (a) shows the curved surface with gradient curvature distribution when a right arm is throwing and Figure 6 (b) shows the curved surface with zebra mapping. In this result, the expert's motion



(a) Expert (mirror image)

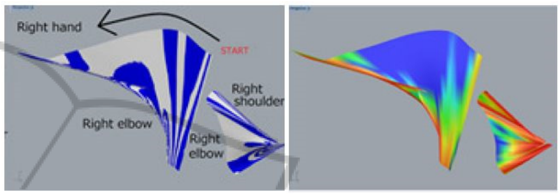
(b) Beginner (mirror image)

Figure 4: Throwing motion in darts.



(a) Zebra mapping (b) Gradient curvature

Figure 5: Motion curved surface of expert in darts.



(a) Zebra mapping (b) Gradient curvature

Figure 6: Motion curved surface of beginner in darts.

Table 1: Maximum curvature, area, and shape in darts.

	Maximum curvature [rad/mm]	Area [m^2]	Shape
Expert	0.91	0.18	Fan shape
Beginner	0.24	0.12	Triangle

surface is fan shaped, the elbow is fixed. Namely, the expert's hand trajectory is curved. Expert turns his hand toward the target in the finish. According to an expert's opinion, fixing the elbow is most important. On the other hand, the beginner's surface is triangle shape. Namely, the beginner's hand trajectory is straight. From Figure 5 and Figure 6, curved surface of expert's motion had more flat parts than the beginner's motion on the whole. This result is the same in zebra mapping. The striped zebra pattern of the beginner's motion is heterogeneous. As mentioned above, the measuring result of the maximum curvature and the curved surface area is shown in Table 1. From Table 1, the expert's surface of change of curvature is focally larger than the beginner's surface. Beginner's surface at start is largest curvature. On the other hand, the expert's surface area is similar to the beginner's area.

3.2 Leg Raising Motion in Stretch

We investigate the difference in leg raising motion (side plank) of Stretch 3-year-experience expert and beginner. Subjects perform the darts motion in the front of Kinect, their lower half of the body (foot, knee, and hip) is tracked. Side plank is a motion that the whole body is supported using the arm and leg, and opposite leg is raising up and down. The situation of throwing motion in side plank is shown in Figure 7. Figure 7 (a) shows expert's motion of RGB color image and depth image with joints and skeletons, and Figure 7 (b) shows beginner's motion. Figure 8 shows the multiple curved surfaces of whole body in leg raising motion. In Figure 8, we need to focus the lower half of the body. Figure 9 (a) shows the curved surface with the gradient curvature distribution when a right leg of expert is raising and Figure 9 (b) shows the curved surface with zebra mapping. Figure 10 (a) shows the curved surface with the gradient curvature distribution when a right leg of beginner is raising and Figure 10 (b) shows the curved surface with zebra mapping. From figures, the stripped zebra pattern of expert is along the curved lines, but beginner's pattern is not. As mentioned above, the measuring result of the maximum curvature and the curved surface area is shown in Table 2. From Table 2, the expert's surface of change of curvature is focally larger than the beginner's surface. On the other hand, the expert's surface area is larger than beginner's area.

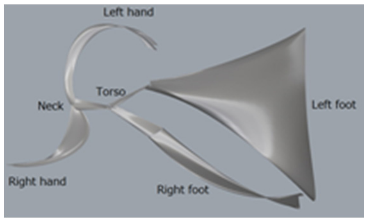
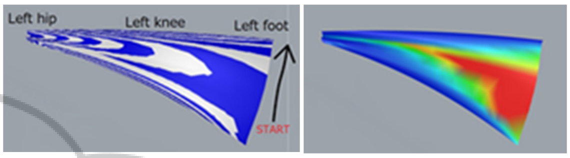
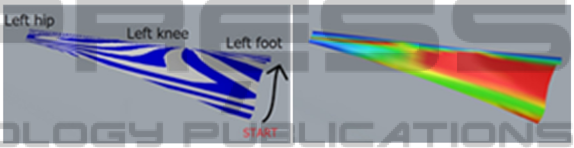


Figure 8: Motion curved surfaces of body in side plank.



(a) Zebra mapping (b) Gradient curvature

Figure 9: Motion curved surface of expert in side plank.



(a) Zebra mapping (b) Gradient curvature

Figure 10: Motion curved surface of beginner in side plank.

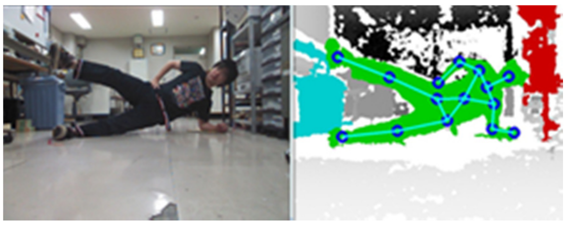
Table 2: Maximum curvature, area, and shape in side plank.

	Maximum curvature [rad/mm]	Area [m^2]	Shape
Expert	0.87	0.29	Triangle
Beginner	0.21	0.13	Rectangle

3.3 Evaluation of Curved Surface

Table 3 shows the maximum curvature, area, and shape of motion curved surface in swimming the crawl, karate thrusts (Mitsuhashi, Ohyama, and Hashimoto, 2014), darts throw, side plank, and calligraphy. From Table 3, we find the expert's maximum curvature and area is larger than beginner's. Additionally the expert's shape is complicated, the beginner's shape is flat. Therefore, we need to focus the maximum curvature, area, and shape, and their outputs or results are also important.

(a) Expert



(b) Beginner

Figure 7: Leg raising motion in side plank.

Table 3: Maximum curvature, area, and shape of the motion curved surfaces.

		Maximum curvature [rad/mm]	Area [m^2]	Shape
Swimming crawl	Expert	5.60	0.19	Concave
	Beginner	0.82	0.43	Convex
Karate thrust	Expert	10.63	0.21	Thin
	Beginner	1.74	0.66	Thick
Darts throw	Expert	0.91	0.18	Fan shape
	Beginner	0.24	0.12	Triangle
Side plank leg raise	Expert	0.87	0.29	Triangle
	Beginner	0.21	0.13	Rectangle
Caligraphy	Expert	0.46	0.15	Projection
	Beginner	0.24	0.10	Flat

4 COMPOSITE CURVED SURFACE

4.1 Limitations of One Kinect View

Body joints are tracked by one Kinect until preceding chapter, for that reason, some joints are not tracked by occluding an obstacle or body parts oneself. In addition, the motion curved surfaces are different shape from the front view and back view. Because the motion surface exist both the correct tracking parts and incorrect tracking parts. Therefore the tracking all motion in large or rotating motion is difficult for one Kinect. Then, we suggest to track the motion from the multiple direction using the multiple Kinect, the multiple curved surfaces are composited. Figure 11 shows the surface composition method. One correct surface and the other correct surface are composited, and the incorrect surfaces are ignored from Figure 11. Figure 12 shows the tracking situation of multiple Kinect. The composite curved surface is made with 2 Kinect in this paper.

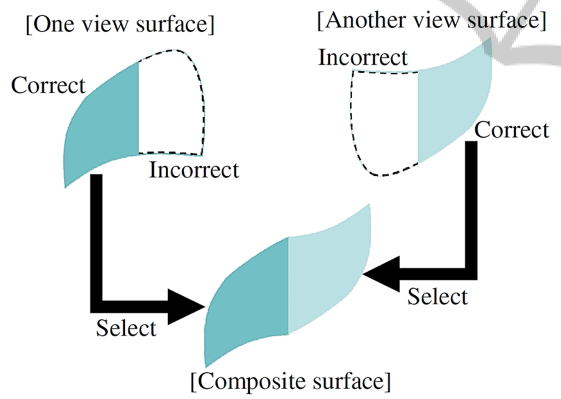


Figure 11: Schematic of composite surface.

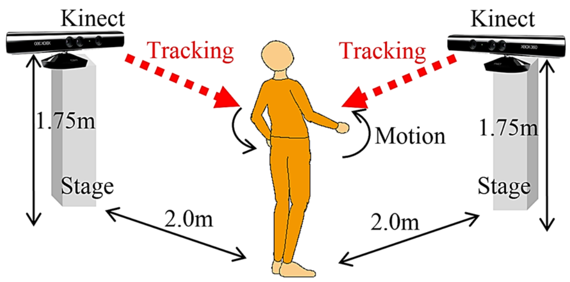


Figure 12: Tracking situation of multiple Kinect.

4.2 Validity of Composite Curved Surface

Throw in darts in preceding chapter is tracked using 2 Kinect, one Kinect is tracking from front view position to 1.50m distance, and the other is from a side view position to 1.50m distance. Because we confirm the validity of the composite curved surface. Figure 13 (a) shows the motion curved surface from side view, Figure 13 (b) shows from front view. The curved surface of Figure 13 (a) exists the incorrect parts at the start and end and the correct parts in hand trajectory, because the depth sensor is less exact than image processing. On the other hand, the motion curved surface of Figure 13 (b) exists the correct parts in all motion. Then, the Edge 2 and Edge 3 are changed to the Edge 5 and Edge 6, watching the RGB image view. In this result, the composite surface is similar to the motion surface from front view. Figure 13 (c) shows the composite curved surface. Therefore, we prove the composite surface from multiple view valid.

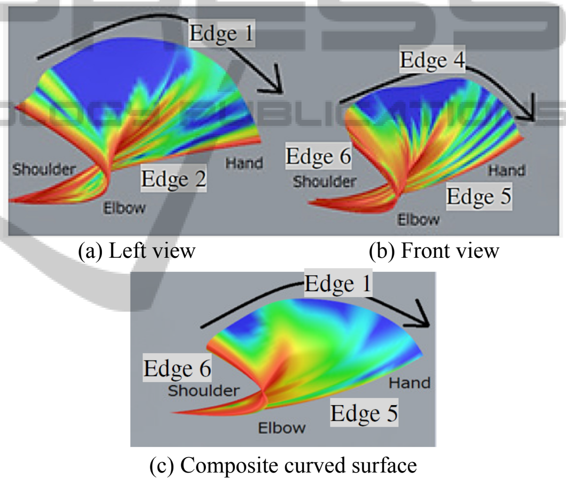


Figure 13: Composite motion curved surface of expert in darts throwing motion.

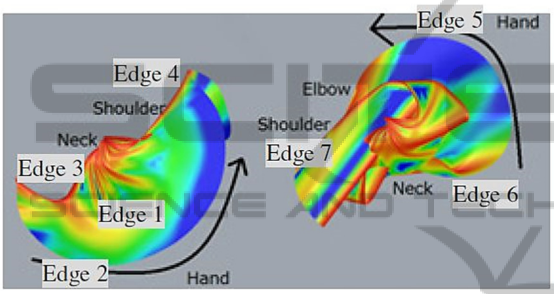
4.3 Swing Motion in Tennis

Large and rotating motion is tracked using the composite curved surface method. It is a swing motion in tennis. Some joints are occluded by the arms of oneself at start and end. Figure 14 shows the situation of multiple Kinect for rotating motion in tennis. One Kinect is placed in the front, the other is placed in the back. Figure 15 shows the motion curved surface from top view using multiple Kinect. Figure 15 (a) shows from back view, Figure 15 (b) shows from front view. The curved surface of Figure 15 (a) exists the correct parts in Edge 1 and Edge 2 (at the start) and the incorrect parts at the end by occluding the arm. On the other hand, the motion curved surface of Figure 15 (b) exists the correct parts in Edge 3 (at the end) and the incorrect parts at the

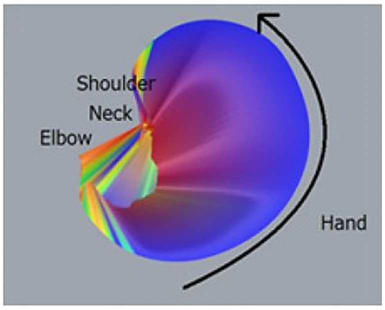
(a) Perspective view


(b) Back view (c) Front view

Figure 14: Situation of swing motion in tennis.



(a) Back view (b) Front view



(c) Composite curved surface

Figure 15: Composite motion curved surface of expert in darts throwing motion.

start. Then, the composite surface is made from selected the Edge 1, Edge 2, and Edge 5 watching the RGB image view. Figure 15 (c) shows the composite curved surface. From Figure 15(c), expert's motion surface from top view is more smooth and concave than the beginner's surface. Then, the measuring result of the maximum curvature and the curved surface area is shown in Table 4. From Table 4, the expert's surface of change of curvature is focally larger than the beginner's surface. On the other hand, the expert's surface area is larger than the beginner's area. Therefore, we can make the motion curved surface and the difference of the expert and beginner from large and rotating motion also.

Table 4: Maximum curvature, area, and shape of composite surface in tennis.

	Maximum curvature [rad/mm]	Area [m^2]	Shape
Expert	2.40	1.84	Concave
Beginner	1.30	1.16	Flat

5 SKILL SUCCESSION USING MOTION CUVED SURFACE

We have never succeeded using a motion curved surface, only confirmed the difference of the expert and beginner in a motion curved surface character. The skill succession method is watching a skeleton motion (animation) and curved surface. The animation is 3D viewer. It can rotate and translate the view position and focal position. The animation program is written by C++ and openGL library, and it read the joint data. Figure 16 shows the skeleton movie and motion curved surface of right upper half of the body in swimming the crawl. Then, we confirm the validity of skill succession using a motion curved surface. First, two beginner subjects are tracked the throw motion in darts. Next, one subject watch only the motion movie, and the movie are expert's motion. The other watch the skeletons motion (animation) and curved surface, the skeleton motion (animation) is the expert's or subject oneself. And both subjects train to watch or move in 10 minutes. Figure 17 (a) shows the watching only movie and moving situation, Figure 17 (b) shows the skeleton motion and curved surface of right upper half of body (hand, elbow, and shoulder). After training, two beginner subjects are tracked the throw motion in darts again

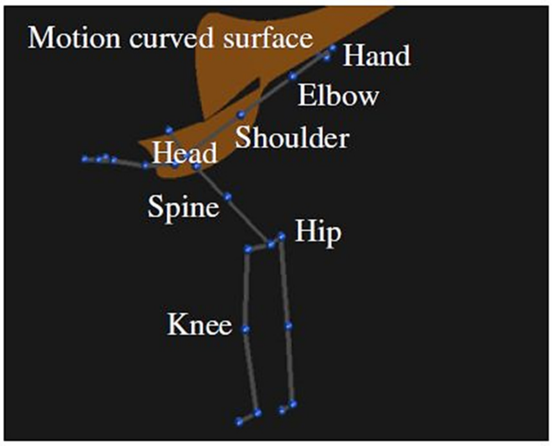
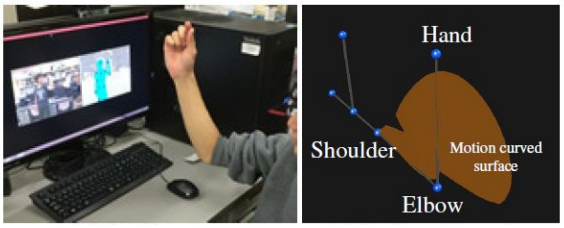


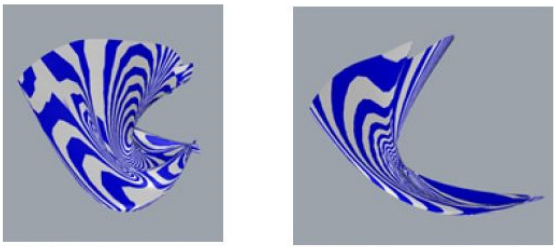
Figure 16: Skeleton animation and motion curved surface in swimming the crawl.



(a) Watching video (b) Motion with surface

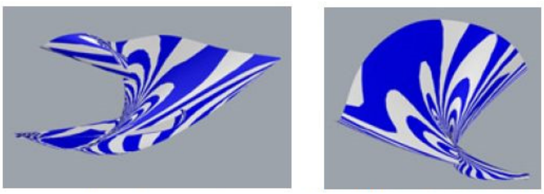
Figure 17: Training the throwing motion in darts.

Figure 18 shows the before training curved surface for two beginner. They are triangle shape or exist straight trajectory of hand, and two subjects don't fix the elbow. Figure 19 shows the after training curved surface. Figure 19 (a) shows the only watch motion movie, Figure 19 (b) shows the skeleton motion and curved surface. From figures, the surface of Figure 19 (a) remain the same shape. On the other hand, the surface of Figure 19 (b) is similar to expert's fan-shaped surface, and his trajectory is a curved line (segment). Table 5 shows the maximum of curvature and area for expert, only movie training, and skeleton and curved surface training. The skeleton and curved surface trainer's motion are similar to expert's motion from Table 5. In this result, we prove the skill succession using the motion curved surface valid.



(a) Watching video (b) Motion with surface

Figure 18: Motion curved surface of before training.



(a) Watching video (b) Motion with surface

Figure 19: Motion curved surface of after training.

6 CONCLUSIONS

In this research, expert and beginner perform the sports and entertainment motion for skill succession,

Table 5: Maximum curvature, area, and shape throwing motion training in darts.

			Maximum curvature [rad/mm]	Area [m^2]	Shape
Expert			0.91	0.18	Fan shape
Beginner	Only movie	Before	0.26	0.15	Triangle
		After	0.47	0.16	Triangle
	Skeleton and Surface	Before	0.53	0.13	Triangle
		After	0.82	0.17	Fan shape

and the character of the surface is analyzed. Additionally we combine the motion curved surfaces made from the multiple Kinect view, so as to track the whole joint motion in more detail. We investigate the effectiveness of the composite motion curved surface. In addition, we confirm the validity of skill succession by watching skeleton motion movie and curved surface. In this result, we find the expert's maximum curvature and area is larger than beginner's. Moreover the expert's shape is complicated, the beginner's shape is flat. In addition, we can make the composite motion curved surface from multiple Kinect, and the difference of the expert and beginner from large and rotating motion also. Finally, we prove the skill succession using the skeleton animation and motion curved surface valid. In future work, the database is constructed the other motion curved surface, and the motion velocity or acceleration curved surface is suggested. In addition, the new method of skill succession using motion curved surface.

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