# The Curved Surface Visualization of the Expert Behavior for Skill Transfer Using Microsoft Kinect

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Abstract: Method of teaching and inheriting for skill is almost oral. It is not quantitative but qualitative. Quantitative inheriting of skill is difficult. In this paper, after tracking of a subject's skill motion using Microsoft Kinect, a subject's motion is visualized as the curved surface. A curved surface is fitted in the positions of a subject's joint, or the direction of trajectories. Expert and beginner perform swimming and karate motion. After the motions are tracked, the trajectories of joints are transformed to a curved surface. The difference of an action between an expert and a beginner is extracted by investigating curvatures and form on the visualized curved surface. Therefore, we expected that technical skill is transferred easily.

## 1 INTRODUCTION

The actions at the time of dances, sports, and engineering are different greatly to an expert and a beginner. However, methods of teaching and inheriting for skill is almost oral. It is not quantitative but qualitative. Quantitative inheriting of skill is difficult. In the case of sports, the experts express in abstract languages, such as onomatopoeia, or metaphor of an object image. However, they can’t teach or inherit exactly and quantitatively. In the case of engineering (Takeo and Natsu, 2011), the experts can’t express a motion of fingertips and arms orally in technical parts, such as machine tool operation. Then, after seeing an expert's operation, the beginner trains by performing imitated the operation. In addition, the inheritance is impossible when experts leave suddenly. Moreover, since quantitative evaluation cannot be performed, the same motion is not always repeated. Then, an expert's motion is captured by video camera photography, and the motions are analysed in research or software (Cheung, Baker and Kanade, 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 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, in order that motion capture may require large scale equipment, the possible capture place is restricted in many cases. By forcing marker wearing on a subject, we can hardly expect to track the usual motion.

Then, 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. Therefore, a human motion can be extracted easily on a small scale. In the conventional research, angles of the skeleton and joint positions are measured (Murao, Hirao and Hashimoto, 2011). However, there is no research that the whole body motion is evaluated. Moreover, the quantitative evaluation of joint angle and extracting position may be no meaning. Namely, joint angle evaluation is not transferred easily, and exact joint angles is not necessary in many cases. In this paper, our purpose is that a human joint position of motion is visualized to a curved surface, and we extract the difference between beginners and experts from the form or curvature of the curved surface. We focus the human upper half body, investigate the trajectories to the both hands, elbows, shoulders, and the neck.


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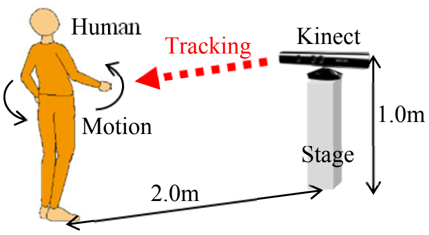
Afterwards, B-spline curved surface are fitted to the joint trajectories in post processing. The form and curvature of a visualized curved surface are displayed visually and quantitatively, and the difference of motion between an expert and a beginner is extracted. Therefore, we expected that technical skill is transferred easily.

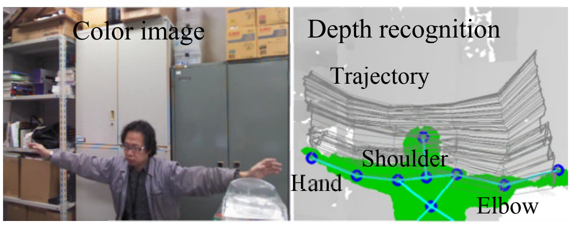
# 2 EXPERIMENT METHOD

## 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 (a) shows the tracking situation. Kinect is placed the height position of 1.0m and the distance between Kinect and a user is 2.0m. Figure 1 (b) shows an image recognition of the user. 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 OpenCV open source. A user's motion is tracked in every 0.03 second, and the measured position is placed with the time series.




(a) Situation

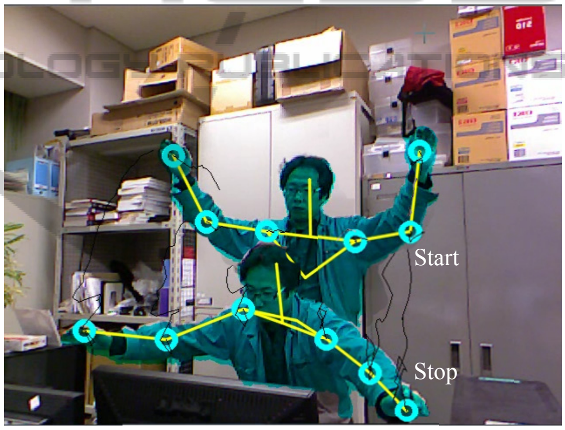



(b) Kinect view

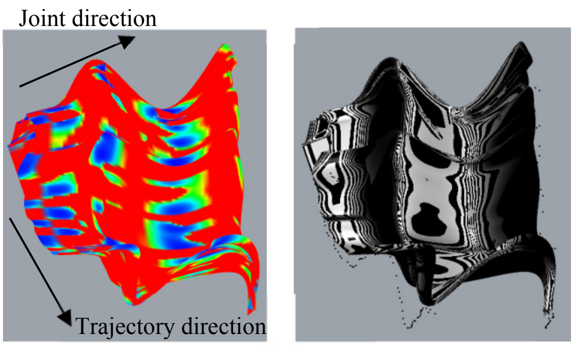
Figure 1: Motion tracking system.

## 2.2 Curved Surface Visualization

The subject's motion captured using Kinect 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. The curved surface makes a subject's trajectory the direction of *u*, and makes joint positions the direction of *v*. Figure 2 shows motion 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 2. Furthermore, the gradation display of curvature and the zebra mapping display are also performed. Zebra mapping is an analytical technique to visualize continuities of the curvature.




(a) Motion




(b) Gradient curvature (c) Zebra mapping

Figure 2: Visualized curved surface.

Fitting method to a curved surface is an approximation. The lines are only continuous segments because the trace of the drawing is a discrete point cloud; that is, the drawing lines are not enough to create curved lines. Then, the point cloud is converted to fitting curve lines. Approximation is the method for smoothly passing a curved line or surface through only the neighbourhood of the point cloud, not through all the points. It enables the operator to control the occurrence of the gap and swing of the drawing position fuzzily. Therefore, we adopt the approximation method. In this study, the curved line or surface is a uniform cubic B-spline. It allows for drawing a singular point and maintaining the curvature continuity. The expressions of the uniform cubic B-spline curved line $\mathbf{L}(t)$ are as follows.

$$\mathbf{L}(t) = \mathbf{N}(t)\mathbf{Q} \tag{1}$$

Here, $\mathbf{N}(t)$ is the matrix of the B-spline function, $t$ is a parameter, $\mathbf{Q}$ is the matrix of control points $\mathbf{Q}_i$ ($i$=0, …, $nq$-1). We must perform fitting, although currently, the control points and the parameter are unknown. Then the control points and the parameter $t$ can be obtained using the matrix $\mathbf{P}$ of the drawing point $\mathbf{P}_i$ ($i$=0, …, $np$-1)

$$\mathbf{Q}_i = \mathbf{N}^{-1}(t)\mathbf{P} \tag{2}$$

$$t_i = \begin{cases} 0 & (i=0) \\ t_{i-1} + \dfrac{\left|\mathbf{P}_i - \mathbf{P}_{i-1}\right|}{\sum_{i=1}^{np-1}\left|\mathbf{P}_i - \mathbf{P}_{i-1}\right|} & (i = 1, \cdots np-2) \\ 1 & (i = np-1) \end{cases} \tag{3}$$

The expressions of the surface $\mathbf{S}(u, v)$ are as follows, similar to that of the line.

$$\mathbf{S}(u,v) = \mathbf{N}(u)\mathbf{N}(v)\mathbf{Q}_{i,j} \tag{4}$$

$$\mathbf{Q}_{i,j} = \mathbf{N}^{-1}(v)\mathbf{N}^{-1}(u)\mathbf{P} \tag{5}$$

Here, the expressions of the parameters $u$, and $v$ are omitted because they are equivalent to $t$.

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 like Figure 3. 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.

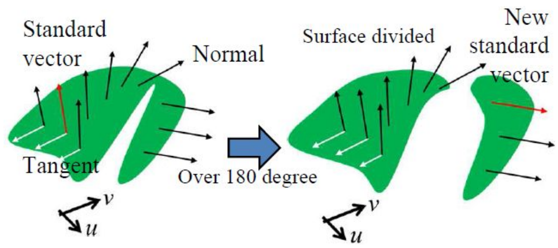


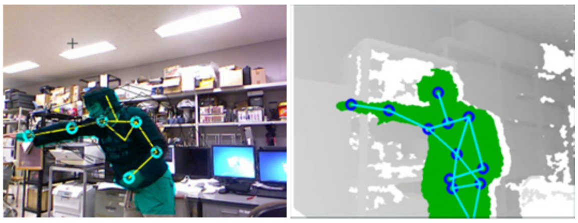

Figure 3: Condition of divided curved surface.

## 3 CURVED SURFACE EVALUATION OF EXPERT AND BEGINNER

### 3.1 Swimming Crawl Motion

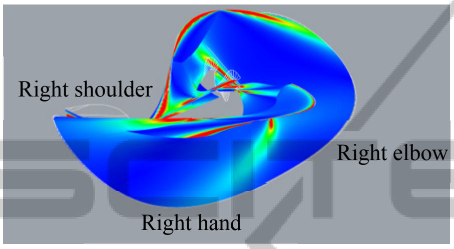
We investigate the difference of crawl motion in swimming between 10-year-experience expert and beginner. Subjects repeat the crawl motion in the front of Kinect. There are 15 pieces of curved surface. Subjects rotate in the yaw direction (z axis) of 45 degrees from Kinect front so that Kinect can track the crawl motion easily. The situation of crawl motion in swimming is shown in Figure 4. Figure 4 (a) shows expert's motion, 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 flung up, 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. Figure 6 (a) shows the curved surface with gradient curvature distribution when a right arm is flung up, and Figure 6 (b) shows the curved surface with zebra mapping. 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. On the other hand, the expert's surface of change of curvature is focally larger than the beginner's surface. According to an expert's opinion, the motion of scratching water should be reduced as less as possible. In addition, the size of an expert's curved surface is smaller than the beginner's surface.

As mentioned above, the measuring result of the maximum curvature and the curved surface area is shown in Table 1 (a). From Table 1 (a), the expert's maximum curvature are larger than beginner's curvature, and the expert's area is smaller than the beginner's area. Therefore, the curved surface change of curvature and area of the crawl should be focused in order to crawl with expert's motion.

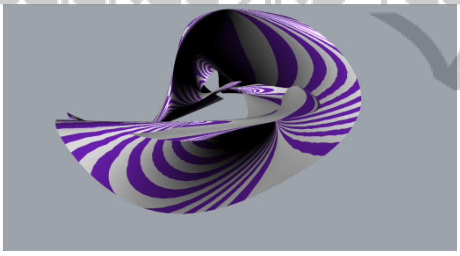


(a) Expert (b) Beginner

Figure 4: Crawl motion in swimming.

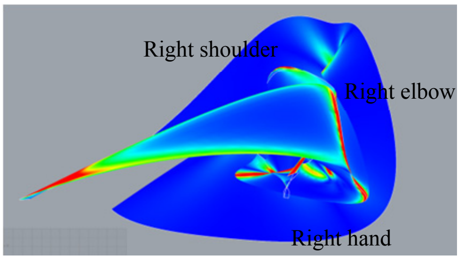



(a) Gradient curvature distribution



(b) Zebra mapping

Figure 5: Curved surface of expert motion.



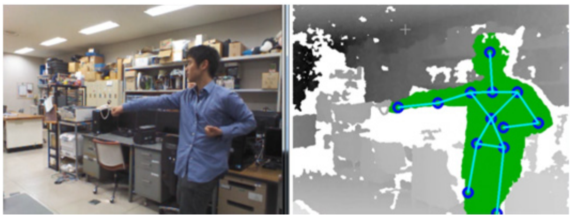

(a) Gradient curvature distribution

(b) Zebra mapping

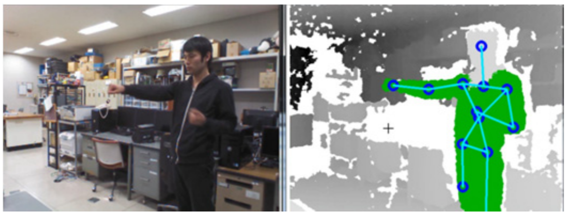
Figure 6: Curved surface of expert motion.

### 3.2 Karate Thrust Motion

Like swimming, we investigate the difference of thrust motion in karate between 5-year-experience expert and beginner. Subjects repeat the thrust motion in the front of Kinect. There are 10 pieces of curved surface. Subjects rotate in the yaw direction (z axis) of 45 degrees from Kinect front so that Kinect can track the thrust motion easily. The situation of thrust motion in karate is shown in Figure 7. Figure 7 (a) shows expert's motion, and Figure 7 (b) shows beginner's motion. The visualized curved surface of the expert's motion is shown in Figure 8. Figure 8 (a) shows the curved surface with the gradient curvature distribution when a subject hit with a right arm and fist, and Figure 8 (b) shows the curved surface with zebra mapping. The visualized curved surface of the beginner's motion is shown in Figure 9. Figure 9 (a) shows the curved surface with the gradient curvature distribution when a subject hit with a right arm and fist, and Figure 9 (b) shows the curved surface with zebra mapping. From Figure 8 and Figure 9, curved surface of expert's motion had more flat parts than the beginner's motion on the whole. The striped pattern of the zebra is heterogeneous like swimming. On the other hand, the expert's surface of change of curvature is focally larger than the beginner's surface. According to an expert's opinion, the thrust trajectory should be straight. In addition, the size of an expert's curved surface is smaller than the beginner's surface.



(a) Expert

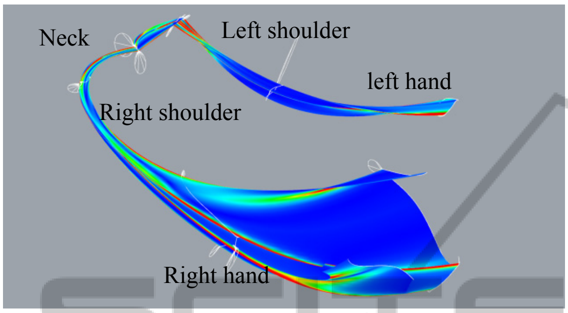


(b) Beginner

Figure 7: Thrust motion in karate.

### 3.3 Curvature Evaluation

As mentioned above, the measuring result of the maximum curvature and the curved surface area is shown in Table 1 (b). From Table 1 (b), the expert's maximum curvature are larger than beginner's curvature, and the expert's area is smaller than the beginner's area. Therefore, the curved surface change of curvature and the area should be focused in order to thrust with expert's motion in the same of crawl motion.



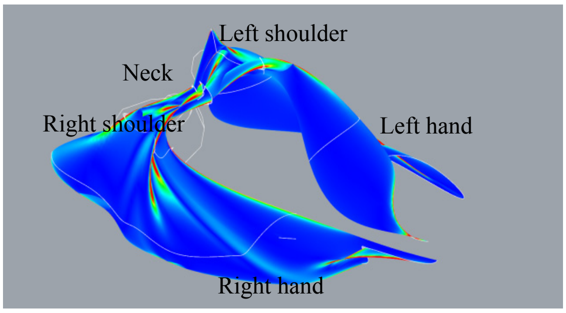

(a) Gradient curvature distribution

(b) Zebra mapping

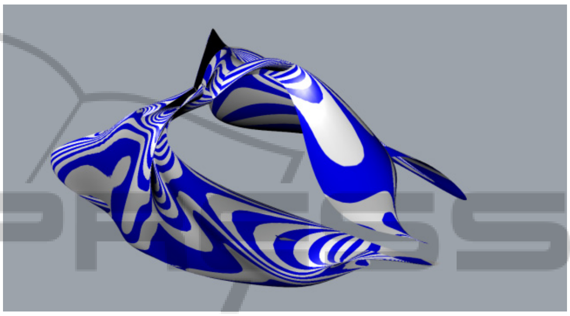
Figure 8: Curved surface of expert motion.

# 4 CONCLUSIONS

In this paper, a human joint position of motion is visualized to a B-spline curved surface, and we investigate the difference between beginners and experts from the form or curvature of the curved surface. The form and curvature of a visualized curved surface are displayed visually and quantitatively, and the difference of motion between an expert and a beginner is extracted. In result, the expert's maximum curvature are larger than beginner's curvature, and the expert's area is smaller than the beginner ' s area. The curved surface change of curvature and the area should be focused in order to act with expert's motion. In future, the effectiveness of this technique is established by acquiring a large amount of the expert's motion database, and we track various expert's motion to transfer skill.




(a) Gradient curvature distribution



(b) Zebra mapping

Figure 9: Curved surface of expert motion.

Table 1: Curvature and area.

(a) Crawl in swimming

| | Maximum curvature [rad/mm] | Area [$m^2$] |
|---|---|---|
| beginner | 0.8 | 0.43 |
| expert | 5.6 | 0.19 |

(b) Thrust in karate

| | Maximum curvature [rad/mm] | Area [$m^2$] |
|---|---|---|
| beginner | 1.7 | 0.66 |
| expert | 10.6 | 0.21 |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