Suggestion of Motion Velocity/Acceleration Curved Surface

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Abstract: The skill teaching/succession method is not quantitative but qualitative, which is abstract oral or gesture expression. Quantitative teaching is difficult for teacher/instructor. In previous research, Expert and beginner perform the sports and entertainment motion, and the character of the motion curved surface is analysed using Microsoft Kinect (RGBD camera). The character is the maximum curvature and surface area. However, the usage of characters is uncertain. In this research, we investigate the correlation of maximum curvature and surface area from motion curved surface in before and after training. Therefore, we visualize the different correlation of experts and beginners from the characters and the transition of the skill training.

1 INTRODUCTION

Motion training of sports, art, and engineering is difficult quantitatively, because it is almost trial-and-error. Adjustment of force (pressure) or velocity for motion skill is necessary, but the method of teaching for skill is almost oral (onomatopoeia or metaphor) or watching the movie, they are qualitative (Fujino, Inoue, Kikkawa, etc., 2005). For example, the qualitative teaching of force (pressure) adjustment and muscle tone for motion seems to be effective, because the nuance of complicated motion is able to be expressed easily and is impressed strongly. However, the qualitative expression method (teaching) is vague, and the instructor can't make the learner (beginner) to copy the expert motion perfectly (Taki, Hasegawa, Fukumura, 1996). Then, the quantitative teaching is also necessary. The adjusting velocity/force or muscle tone is measured or analyzed using acceleration sensor or myogenic potential sensor, but the measurement using the sensor can only analyze the local motion. The showing local motion analysis is difficult to understand the expert motion intuitively or visually. On the other hand, only using image processing seems to be difficult to measure or analyze.

In previous research, we suggest the "Motion Curve Surface", it is expressed by human joint positions and times using Microsoft Kinect. We evaluate the user motion by its curvature. Firstly, we visualize a physical motion (human joint trajectory) using the motion curved surface, and extract the difference between beginners and experts (Mitsuhashi, Ohyama, and Hashimoto, 2014), (Suneya, Kutsuna, and Mitsuhashi, etc., 2014). Therefore, we can evaluate technical skill quantitatively, and suggest the skill teaching method for expert instructors. Secondly, we compose the motion curved surfaces made from the multiple Kinect view, so as to track the whole joint motion in more detail, and confirm the validity of skill succession by watching skeleton motion movie and curved surface (Mitsuhashi, Ohyama, and Hashimoto, 2015). Thirdly, we investigate the correlation of character from the many motion curved surfaces. The character of motion curved surface is maximum curvature and surface area. By means of expressing the diagram of the motion curved surface character, the different and tendency of experts and beginners is extracted. After then, we investigate the transition of training effectiveness for beginners from correlation diagram (Mitsuhashi, Ohyama, and Hashimoto, 2016). However, we can only clarify the human motion trajectory, but are not clarifying the timing, rhythm, and force (pressure). They are necessary to achieve of expert motion. In addition, expert instructors can teach the skill motion easily, because they can teach skill important

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point effectively.

In this paper, we suggest the motion velocity curved surface and the motion acceleration curved surface, and the validity is investigated. Firstly, we explain the calculation (definition) of motion velocity/acceleration curved surface. The calculation method is used the differential geometry, and the express is the RGB color gradation using OpenGL library. After that, the surfaces are investigated using some motion samples for the validity. The differences of expert and beginner motion are visualized using expert opinions, velocity, acceleration, and timing from the surfaces.

2 CALCULATION OF MOTION VELOCITY/ACCELERATION CURVED SURFACE

The previous motion curved surface is expressed by the joint trajectories using approximation fitting. The trajectories are arranged by *u*-direction of joints and *v*-direction of time, and they are captured and calculated using Microsoft Kinect and Kinect SDK. We analyze the shape, area, and curvature of motion curved surface. However, the force adjustment, timing, and rhythm can't be expressed using only the area, shape, and curvature of motion curved surface. Then, the motion velocity/acceleration curved surface is suggested using the differential geometry. Kinect can store the joint positions, but also times. Consequently, the velocity and acceleration can be expressed using time derivative (the joint positions are differentiated by time). When the joint position $\mathbf{P}_{u,v}$ and time $t_{u,v}$ is given, the velocity $S_{u,v}$ is expressed by equation (1).

$$S_{u,v} = \frac{\left|\mathbf{P}_{u,v} - \mathbf{P}_{u,v-1}\right|}{t_{u,v} - t_{u,v}} \tag{1}$$

Here, $S_{u,v}$ is the absolute value because the direction of $S_{u,v}$ is already known. The *u*-direction of the joints is not differentiated because it is not changed by time. The acceleration $A_{u,v}$ is expressed by equation (2) like the velocity calculation.

$$A_{u,v} = \frac{S_{u,v} - S_{u,v-1}}{t_{u,v} - t_{u,v}} \tag{2}$$

Here, $A_{u,v}$ is a positive or negative value. In addition, the each acceleration is changed by integrating joint mass. After that, the velocity/acceleration is visualized (expressed) on the motion curved surface using the RGB color gradation. The RGB color (r, g, b) of velocity $S_{u,v}$ is expressed by equation (3).

$$(r,g,b)\begin{cases} (255,0,0) & (S = S_{\max}) \\ (255,temp,0) & (S - S_{\min} \geq 0.75(S_{\max} - S_{\min})) \\ (temp,255,0) & (S - S_{\min} \geq 0.50(S_{\max} - S_{\min})) \\ (0,255,temp) & (S - S_{\min} \geq 0.25(S_{\max} - S_{\min})) \\ (0,temp,255) & (S \geq S_{\min})) \\ (0,0,255) & (S = S_{\min}) \end{cases} \tag{3}$$

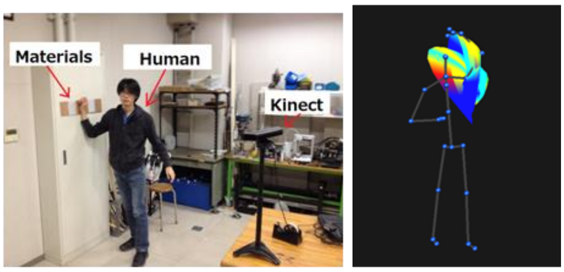
$$temp = 0.5 \times \left(1 - \cos(4\pi\left(\frac{S_{u,v} - S_{\min}}{S_{\max} - S_{\min}}\right)\right) \times 255$$

Here, $S_{\max}$ is the maximum velocity, $S_{\min}$ is the minimum velocity. The parameter r, g, b ($0<=r$, g, $b<=255$) is color strength (red, green, blue). $S_{\max}$ is expressed by only red. $S_{\min}$ is expressed by only blue. The acceleration is expressed by the same method. Therefore, the skill level of the adjustment force, rhythm, and timing can be visualized. The previous motion curved surface is expressed by the velocity or acceleration in the next chapter (Mitsuhashi, Ohyama, and Hashimoto, 2014) , (Mitsuhashi, Ohyama, and Hashimoto, 2015).

Our IDE (Integrated Development Environment) is Visual Studio Express 2015 for Windows Desktop. Written program is C++, program library is OpenGL and Kinect SDK. Subject motion expressed by skeleton animation from Figure 1, and the motion curved surface (curvature, velocity, acceleration) is expressed at the same time. The joints are blue ball, skeleton (bone) is gray bar. The method of converting joint points into the curved surface is approximation fitting.

3 EVALUATION OF MOTION VELOCITY/ACCELERATION CURVED SURFACE

The sports motion is expressed by the motion velocity/acceleration curved surface using the calculation method of the previous chapter, because the validity of the surface is investigated. The motion is throwing in darts, crawl in swimming, and defense in karate.



(a) Tracking state (b) Skeleton animation

Figure 1: Motion tracking state.

3.1 Throw Darts Motion

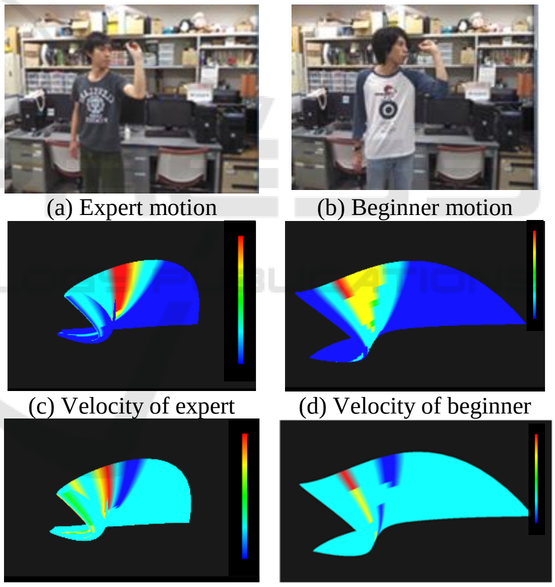
Figure 2 shows the motion velocity/acceleration curved surface of expert and beginner in darts throw motion. They are formed by the joint trajectories of right hand, right elbow, and right shoulder. In addition, the gradation color bar is the range of velocity of acceleration, and added in Figure 2 sides. Table 1 shows the maximum velocity, the minimum velocity, the maximum acceleration, the minimum acceleration, and timing of maximum velocity (or acceleration) in darts throw motion. The expert has the fastest in darts release from Figure 2. On the other hand, the beginner has the fastest in start throwing; his velocity is constant in darts release. Expert’s velocity is faster than the beginner’s velocity from Table 1. Acceleration results are also. In the expert’s opinion, he needs to let a snap for wrist in darts release; he needs to concentrate in wrist or hand. To verify these results, we analyze the numerical results. Figure 3 shows the velocity and acceleration of right hand, elbow, and shoulder. Expert’s maximum velocity/acceleration is in release darts and beginner’s is in throwing start from Figure.4. Therefore, we can evaluate also from velocity, acceleration, and timing.

3.2 Crawl Motion in Swimming

Figure 4 shows the motion velocity/acceleration curved surface of expert and beginner in crawl motion. They are formed by the joint trajectories of right hand, right elbow, and right shoulder. Table 2 shows the maximum velocity, the minimum velocity, the maximum acceleration, the minimum acceleration, and timing of maximum velocity or acceleration in crawl motion. From Figure 4, the expert has the fastest in the downswing of right arm (enter into a water), beginner has the fastest in upswing of right arm (go out from a water). Expert’s velocity is faster than the beginner’s velocity from Table 2. Acceleration results are also. In the expert’s opinion, he needs to push the water; he needs to concentrate in enter to water.

3.3 Defend Motion in Karate

Figure 5 shows the motion velocity/acceleration curved surface of expert and beginner in karate defense motion. They are formed by the joint trajectories of right hand, right elbow, and right shoulder. Table 3 shows the maximum velocity, the minimum velocity, the maximum acceleration, the minimum acceleration, and timing of maximum velocity or acceleration in defense motion. From Figure 5, the expert has the fastest in the upswing of both arms (defense start), beginner has the fastest in the downswing of both arms (defense release). Expert’s velocity is slower than the beginner’s velocity from Table 3. In the expert’s opinion, the arm trajectory is short, and he needs to concentrate on stop arm (defend start); to accelerate the arm in the upswing.



(a) Expert motion (b) Beginner motion

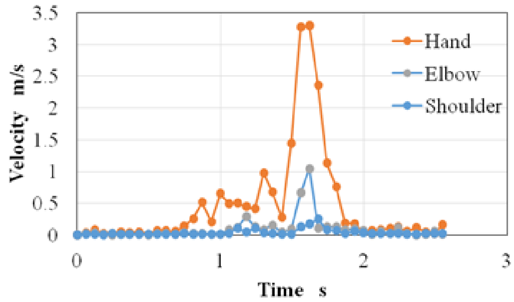
(c) Velocity of expert (d) Velocity of beginner

(e) Acceleration of expert (f) Acceleration of beginner

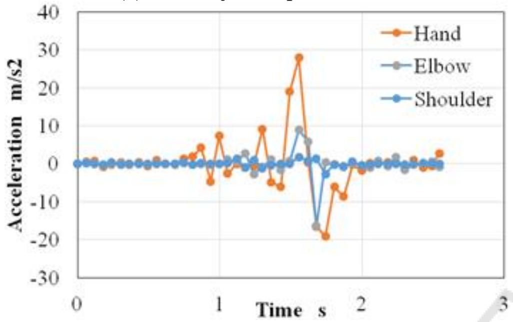
Figure 2: Motion velocity/acceleration curved surface in darts throw.

Table 1: Maximum/minimum velocity/acceleration, timing in darts throw.

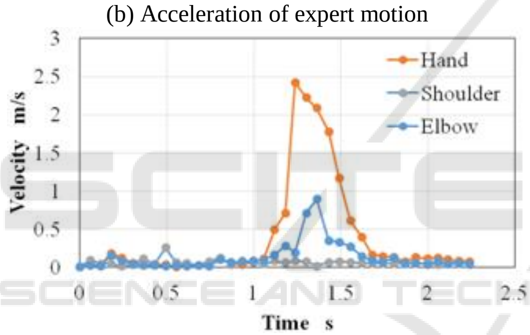
	Expert	Beginner
S_{max}	3.30	2.43
S_{min}	0.00	0.00
A_{max}	27.98	29.60
A_{min}	-19.13	-9.84
Position	Release	Start



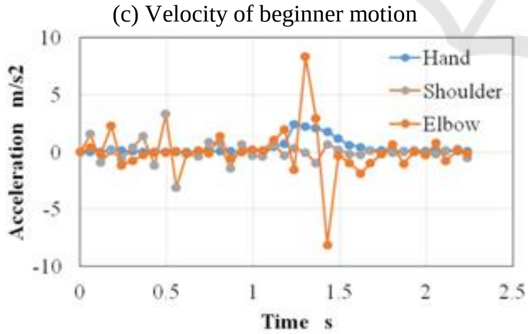
(a) Velocity of expert motion



(b) Acceleration of expert motion



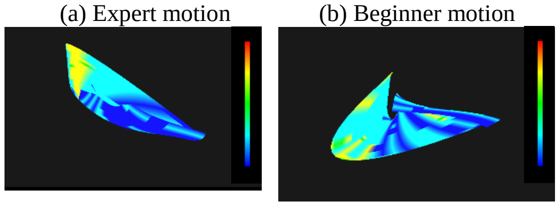
(c) Velocity of beginner motion



(d) Acceleration of expert motion

Figure 3: Numerical analysis of velocity/acceleration.


(a) Expert motion (b) Beginner motion


(c) Velocity of expert (d) Velocity of beginner

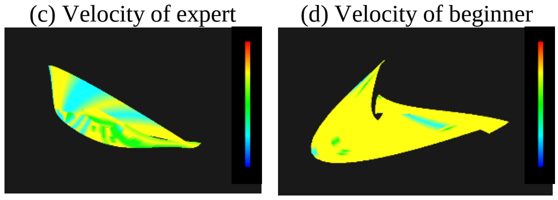

(e) Acceleration of expert (f) Acceleration of beginner

Figure 4: Motion velocity/acceleration curved surface in swimming crawl.

Table 2: Maximum/minimum velocity/acceleration, timing in swimming crawl.

	Expert	Beginner
S_{max}	6.02	5.73
S_{min}	0.00	0.00
A_{max}	64.96	47.85
A_{min}	-68.40	-85.52
Position	Downswing	Upswing

4 CONCLUSION

We suggest the motion velocity curved surface and the motion acceleration curved surface, and the surfaces are investigated using 3 sports motion samples for the validity. The motion velocity/ acceleration surface is expressed by time derivative, the express method is the RGB color gradation. After that, the differences of expert and beginner motion are visualized using velocity/ acceleration from the surfaces. In this result, the difference is the maximum velocity timing, and maximum velocity/acceleration value. So, we can evaluate the difference from velocity, acceleration, and timing. In future work, we adopt the other motion samples using the surface, and suggest the motion force curved surface.

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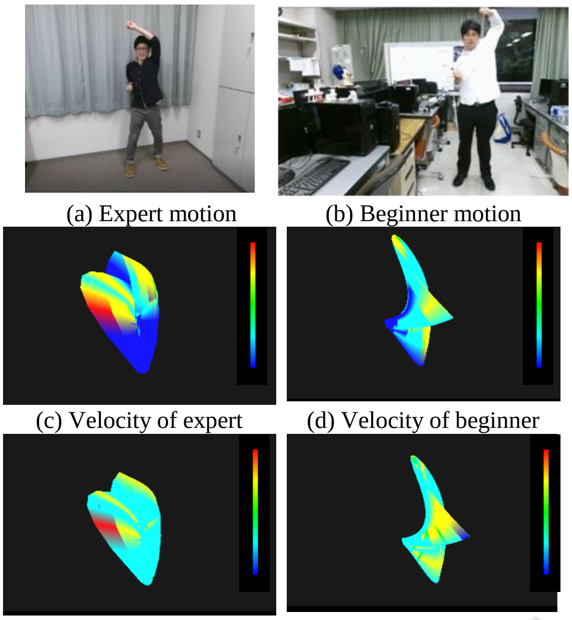

(a) Expert motion (b) Beginner motion

(c) Velocity of expert (d) Velocity of beginner

(e) Acceleration of expert (f) Acceleration of beginner

Figure 5: Motion velocity/acceleration curved surface in karate defence.

Table 3: Maximum/minimum velocity/acceleration, timing in karate defence.

	Expert	Beginner
S_{max}	1.42	4.02
S_{min}	0.00	0.00
A_{max}	4.12	22.06
A_{min}	-3.30	-24.45
Position	Upswing	Downswing

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