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Development of Motion Visualization System with The Center of Gravity for Novice Learners

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Abstract: To control the center of gravity of the body is one of the most important issues in motor skill learning, however, it is difficult for us to imagine the center of gravity, because he/she cannot see it. Furthermore, when he/she learns motor skill by coach or reference book, the center of gravity is often described with ambiguous expression, therefore, he/she find it difficult to know the center of gravity. In this background, we developed a motion visualization system with the center of gravity for novice learners The learner's motion data is got by wearable motion capture system with gyroscope. By using this system, a learner would be able to visually understand the relationship between his/her body movement and the center of gravity.

Keywords: motor learning, body's center of gravity, motion capture, skill, badminton

1. Introduction

To move a body is to move the center of gravity. Therefore, it is clear that the center of gravity is important in motor skill learning. Thus reference book or coach often gives advice about the center of gravity. However, learners cannot understand the center of gravity very well, because the advice about it is implicit or described with ambiguous expression. Furthermore, it is difficult for us to imagine it, because we cannot see it. Accordingly, invisibility of the center of gravity prevents learners from the mastering motor skill.
In this background, Kubo et al estimated the center of gravity visually [1]. The fitness software :Wii Fit or Wii Fit Plus shows the shift of the center of gravity by the projection on the ground. These researches show the center of gravity from one viewpoint.
For in related research on motor skill learning, Soga, A. et al developed application system[2][3]. This research shows the learning support by using 3D models.
The goal of this study is to design and develop a skill learning support environment for novice learners to improve his/ her arbitrary motion in motor skill learning. We developed a motion visualization system with the center of gravity. This system displays the physical center of gravity and movement with learner's 3DCG born model. The 3DCG models are made by OpenGL. We made the animation from the motion data which we acquired by a motion capture system. By using this system a learner can see his/her movement and the center of gravity from the any view point. Moreover, the learner can easily understand the relationship between body movement and the movement of the center of gravity. Therefore, we think that learning performance would increase.
In addition, we performed an evaluation experiment which decided whether a learner was able to improve his/her motor skill by the visualization of the center of gravity. Moreover, we performed a questionnaire survey after the experiment.

2. The Calculation Method of The Center of Gravity

The position of the center of gravity of human body is calculated as follows.
(1)Divide human body into 15 parts.
(2)Calculate the position of the center of the gravity of each part.
(3)Calculate the integrated center of gravity.
We need to know the length and mass of each part of the body for calculating the partial center of gravity. We can get the length of part of the body by a motion capture system. Ae et al intended for youth athlete for the wide area for build and divided a body into 15 parts: the head, upper trunk, lower trunk, left upper arm, right upper arm, left forearm, right forearm, left hand, right hand, left thigh, right thigh, left leg, right leg, left foot, and right foot. They estimated those mass and a centroid position and the centroid ratio by use of a mathematical model[4]. We used this mathematical model in this study.
For example, when we demand a x value of the head, the partial center of gravity can be calculated by math formula (1). Figure 1 shows endpoints of physical parts. Endpoint a and endpoint b represented each endpoint of each physical part. The position of the endpoint is calculated by the data which we acquired by the motion capture system.

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix} + r \begin{bmatrix} b_x - a_x \\ b_y - a_y \\ b_z - a_z \end{bmatrix} \quad \cdots (1)$$

X': x value of the partial center of gravity
Y': y value of the partial center of gravity
Z': z value of the partial center of gravity
a_x: x value of the endpoint a
a_y: y value of the endpoint a
a_z: z value of the endpoint a
r: the centroid ratio
b_x: x value of the endpoint b
b_y: y value of the endpoint b
b_z: z value of the endpoint b

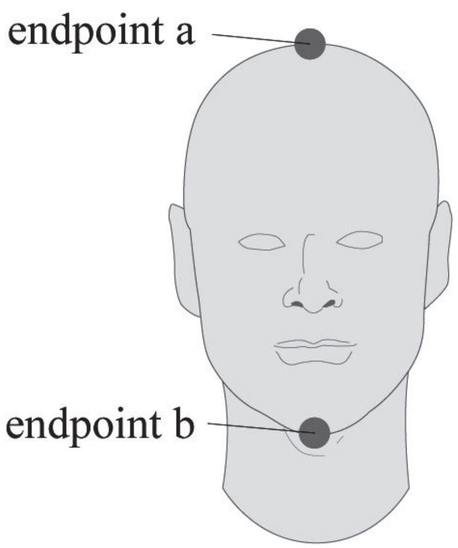

Figure 1 The example of the physical part (The head)

When I demand a x value of the center of gravity, it can be calculated by math formula (2)

$$\begin{cases} X = \sum_{i=1}^{15}(m_i x_i) \,/\, \sum_{i=1}^{15} m_i \\ Y = \sum_{i=1}^{15}(m_i y_i) \,/\, \sum_{i=1}^{15} m_i \\ Z = \sum_{i=1}^{15}(m_i z_i) \,/\, \sum_{i=1}^{15} m_i \end{cases} \quad \cdots (2)$$

X: x value of the center of gravity
Y: x value of the center of gravity
Z: x value of the center of gravity
m: the mass of each part of the body
x: x value of the partial center of gravity
y: y value of the partial center of gravity
z: z value of the partial center of gravity

3. Motion Visualization System with Center of Gravity

3.1 System Summary

It is easy for the learner to understand the relationship between movement of his/her body and movement of the center of gravity by making it visible. Therefore, we developed the motion visualization system with the center of gravity for novice learners. We think that it might be helpful for the motor skill learning. This system displays learner's 3D bone animation and the learner's center of gravity. An Expert's motion data is captured by wearable motion capture system(IGS-190) in advance. IGS-190 has directional sensor. In addition, it sends and receives data by wireless thus the learner is able to move wide area.

3.2 The Procedure for Use of The System

Procedure to use the system is as follows.
1. An expert's motion data is measured by the wearable motion capture system in advance, and store the data is stored in the system.
2. The learner measures his/her motion by the wearable motion capture system, and store the data in the system.
3. The system opens two windows. One window shows the expert's motion by bone animation with the center of gravity. The other window shows learner's motion by bone animation with the center of gravity.
4. The learner can find the difference between expert's motion and learner's motion.
5. The learner trains himself/herself to minimize the difference.
6. The learner repeats 2 - 5.

This system displays the bone animation in the three-dimensional space, therefore, the learner can check his/her movement from any viewpoint. The learner can zoom in, zoom out, replay the motion, and change the viewpoint by using a mouse and the keyboard. In addition, the learner can see movement of the center of gravity by displaying trajectory of the center of gravity. Moreover, the learner can know the passage of time intuitively, because the trajectory varies from blue to red as time passages. Figure 2 shows an example of bone animation of learner's movement and trajectory of the center of gravity.

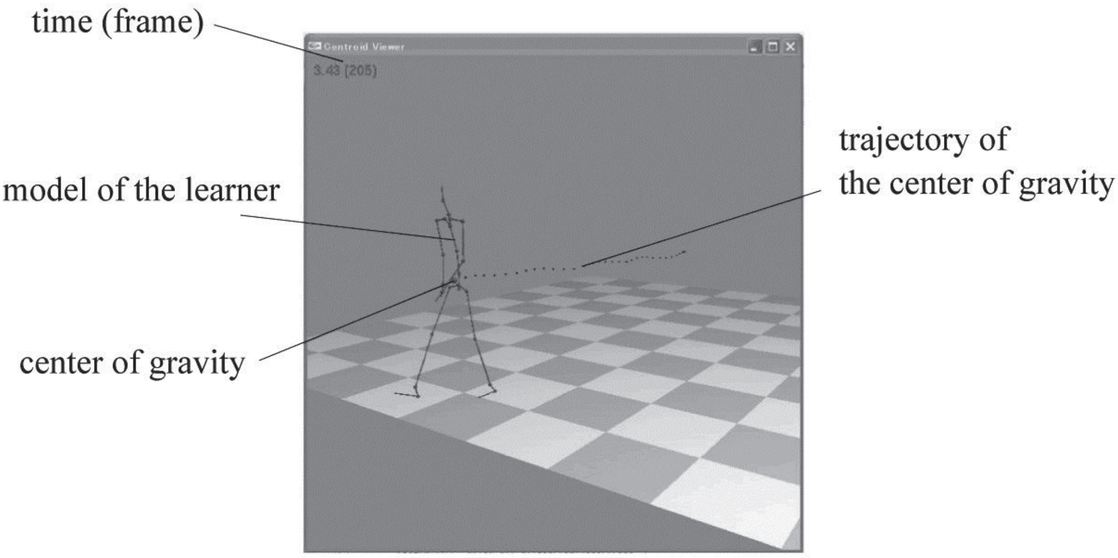

Figure 2 Bone animation of learner's movement and trajectory of the center of gravity

4. Evaluation

4.1 Experimental Methodology

We performed an evaluation experiment to verify effects and the utility of the system. We chose two kinds of forms which are basic shots of badminton: long high serve and high clear as a test domain in this experiment. The reason why I choose these shots are because a learner moves feet a little but moves body much, therefore I think the center of gravity is important in motion of long high serve. In addition, I make sure of the effectiveness of the system by the movement in a wide area in the motion of high clear. This is because there is a reason that movement with a whole body without moving a foot can utilize the characteristic of the system. Subjects are six male students in their 20's. We divided them into two groups. One group is experimental group in which subjects use the system with seeing the center of gravity. The other group is control group in which use the system without seeing the center of gravity. Long-high serve is the shot in badminton by which a player shots a shuttle as highly and far back in the court as possible from the service line to the opponent's court with underhand stroke. High clear is the shot in badminton by which a player shots a shuttle as highly and far back as possible from back in his/her own court to the opponent's court with overhand stroke. In addition, we performed a questionnaire survey after an experiment to evaluate a usability and effectiveness of the system.

4.2 The Flow of Experimentation

The flow of the experiment is as follows.
(1)We told the target point in the opponent's court, and then, we explained how to swing in basic long serve, the trajectory of the shuttle.
(2)Subjects in both group hit five shuttles without any practice by wearing a motion capture system. We measured subjects' motion and flying distances of the shuttles. These data represents subjects' ability before learning. We measured flying distance by measuring the perpendicular lines from the fall spot of the shuttle to a service line. If the shuttle did not go

over the net or a subject hit a wood shot, we didn't count them in the trial. A wood shot is a legal shot in which the frame hits the shuttle of the racket.
(3)After subjects finish hitting five shuttles, they compare their own motion data with expert's motion data by using the system. Subjects in experimental group use the system with seeing the center of gravity. On the other hand, subjects in control group use the system without seeing the center of gravity.
(4) Subjects in both group hit five shuttles by wearing a motion capture system. We measured subjects' motion and flying distances of the shuttles. These data represents subjects' ability after learning.

After finishing the experiment for long high serve, we performed the experiment for high clear by the same procedure as the long high serve. A flying distance by the high clear is length of a perpendicular when hitter dismantled the vector that bound the spot of the hind leg heel when he hits the shuttle and the fall spot of the shuttle together to a horizontal ingredient and a perpendicular ingredient in a net.

4.3 Result of Experimentation

Table 1 and table 2 show pre-learning and post-learning results of flying distance of the shuttle by long high serve. We rounded off flying distances to 10-digit.

Table 1 Pre-learning result by long high serve (cm)

		1	2	3	4	5	average
experimental group	A	760	700	800	800	700	752
	B	780	730	870	770	810	792
	C	580	580	650	680	510	600
control group	D	760	710	740	680	760	730
	E	330	500	590	460	490	474
	F	750	530	600	580	500	592

Table 2 Post-learning result by long high serve (cm)

		1	2	3	4	5	average
experimental group	A	830	800	780	770	820	800
	B	850	950	910	830	780	864
	C	680	820	520	530	730	656
control group	D	730	730	700	720	750	726
	E	590	490	660	380	600	544
	F	690	660	640	650	750	678

We found that the average of flying distance of all the subjects in the experimental group increased by comparing the averages in table1 and table2. We also found that the average of flying distance of all the subjects in the control group also increased except subject D by comparing the averages in table1 and table2. Therefore, it is difficult to show a learning effect by visualization of the center of gravity by the results.
We define maximum difference as the difference between maximum flying distance of pre-learning result and that of post-learning result. Similarly, we define minimum difference as the difference between minimum flying distance of pre-learning result and that of post-learning result. The maximum difference becomes larger in experimental group than control group. In other words, as for the experimental group, the maximum flying distance comparatively increased. On the other hand, we could not find difference for minimum

difference between experimental group and control group. From this result, we understood that the maximum flying distance tended to be easy to come to increase by learning with visualization of the center of gravity indication.

Table 3 and table 4 show pre-learning and post-learning results of flying distance of the shuttle of high clear. We rounded off flying distances to 10-digit

Table 3 Pre-learning result of high clear (cm)

		1	2	3	4	5	average
experimental group	A	910	1020	990	1050	1100	1014
	B	640	560	710	640	680	646
	C	960	970	830	1040	920	944
control group	D	960	1100	960	1170	1140	1066
	E	1010	920	1070	1100	930	1006
	F	860	900	800	850	670	816

Table 4 Post-learning result of high clear (cm)

		1	2	3	4	5	average
experimental group	A	1050	1070	1160	1130	990	1080
	B	670	830	800	850	640	758
	C	920	920	860	1000	1030	946
control group	D	1100	1160	890	1100	1040	1058
	E	920	670	1000	1030	940	912
	F	960	880	830	1000	840	902

By table 3 and table4, subject A and B of experimental group largely increased. Subject C in experimental group and subject D in control group did not show learning effect. Subject E in control group largely decreased. Therefore, there seems to be a tendency to increase flying distance a little in experimental group, however, we didn't find clear conclusion.

4.4 Result of Questionnaire Survey

We performed questionnaire survey about a feeling of use or the effectiveness of the system with six subjects. Subjects answered each question by five point scale. Score 5.0 means most positive score and score 1.0 is most negative score. In addition, subjects described their opinion by free description. Table5 shows questionary sentence

Table 5 shows questionary and the answer result of the questionnaire. The number in the right column indicates each is average each of rating. Questionnaire number 2 and 3 are questions only to experimental group, and questionnaire number 4 is a question only to control group.

Table 5 Questionnaire results

	question	average
1	Was the operation of the system comfortable?	3.0
2	Do you think it is effective to learn skill by seeing movement of the center of gravity?	3.7
3	Did you know a center of gravity position?	4.0
4	Did you understand how to move your bodies correctly?	3.8
5	Do you want to use a system in the future? (experimental group)	4.0
5	Do you want to use a system in the future? (control group)	3.7

We show some opinions by free description as follows.
Positive opinions:

- I was able to discover defects of my movement.
- I understood well the difference of the center of the gravity between expert's movement and my movement.
- I am glad that I can watch my movement from any view point.

Negative opinions:

- It is difficult for novice learners to improve their form even if they noticed differences.
- An unnecessary trajectory of the center of gravity was displayed and was obstructive.
- It is difficult for me to relate the center of gravity to physical movement

We verified effect of visualization of the center of gravity by positive opinions, because subjects told that they understood deeply their movements and movements of the center of gravity. On the other hand, we also found some disadvantages by negative opinions, because subjects told that they understood the difference between their own movements and expert's movement, however, they also told that they didn't understand how to improve their movements.

5. Conclusions

We developed the system which visualizes body motion with center of gravity in this study. We expected that a learner understood his/her body motion and a relationship between his/her body movement and the movement of center of gravity. To evaluate the system, we chose two kinds of forms in badminton as a test domain. We found that the flying distance of the shuttles tended to increase a little; however, we didn't get a clear conclusion by the experiment results. Since there is an opinion that there may be more important factors than the factor of the center of gravity in badminton, we would like to verify the learning effect of this system by the other sports.
This system was effective for learner to understand his/her movement and movement of the center of the gravity. The learner was able to notice the difference between expert's movement and his/her movement and also difference between expert's trajectory and learner's trajectory of center of gravity. However, the problem is that the learners cannot find the method how to improve his/her movement. To solve this problem, we have to develop a new function which advises the difference between learner's movement and expert's movement and also advises how to improve learner's movement.

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