A LEARNING SUPPORT SYSTEM REGARDING MOTION TRIGGER FOR REPETITIVE MOTION HAVING AN OPERATING INSTRUMENT

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ABSTRACT

In the learning support for repetitive motions having an operating instrument, it is necessary for learners to control not only their own body motions but also an instrument corresponding to the body. This study focuses on the repetitive motion learning using single operation instrument without the movement in space; i.e. jump-rope and hula-hoop. The proposed system makes it possible for learners to strengthen their ability of perceiving the motion timing depending on the instrument state in time.

KEYWORDS

Repetitive motion, Learning support, Skill development, Motor control

1. INTRODUCTION

In the science of physical sports, it is often used the term skill. (Magill 1998) stated that skills have meant the task with the specific goal to be achieved. For example, the batting skill in baseball has a goal to hit back a ball to a certain direction aiming at accurate timing. Therefore, players require spontaneous body motions. This study deals with motor skills in such a context. In addition to movements such as batting, piano and dance, they need a kind of motor control. On the other hand, movements that respond quickly to opponents and kicking accurate shot to avoid the keeper's saving in soccer games need perceptual skill. Further deeper sensing of foreseeing a step ahead and instructing next play are developed on cognitive skill. In these skills, it is mentioned that accuracy of time, position, and force are factors of the success. This study regards target fields focused on human nervous system, the musculoskeletal system, the body, and the behavior to enable these skills as motor control. Additionally, this study touches upon fields focused on learning process and promotion of acquisition as motor learning.

Tracing a body movement as digital data has become easier with the rapid progress of wearable devices and sensor technologies. A lot of studies on learning support are proposed using information processing techniques. According to (Soga et al. 2004), learning support systems for physical skill development require major three functionalities. The first one is to observe skills of a human, whereas the second one is a function to evaluate a motion using an observed data. The third one is a function to provide the feedback to the learner based on an evaluation result. In repetitive motion, the accuracy of the motion timing is significantly effective. It should be adjusted dynamically through these processes. Therefore, we need to take into account of what good timing of a motion is in order to evaluate and to provide the feedback.

This study supports human development of the repetitive motion with an instrument such in playing hula-hoop and jump-rope. Motor control depends on the ability of parallel processing for both controlling the body motion and the instrument thereof. Namely, learners need appropriate motion in accordance with the movement of an instrument. Therefore, this paper tries to design the learning support system that estimates an instrument trajectory and a presented body motion for controlling it.

2. FEEDBACK FOR MOTOR SKILL DEVELOPMENT

2.1 Repetitive Motions

A kind of continuous skill includes the repetitive motion. As the feature of continuous motion, there is no end assuming ideal condition to repeat periodically same/similar motion divided by segmentation criteria. For example, a swimmer repeats normally same motion paddling water by the arms and legs as long as possible. In swimming neither devices nor instruments are used for experts. Running or swimming without any instruments are controlled by only own body motions. In other words, these movements do not operate anything but their body. Just imagine consider rope skipping and performing hula-hoop. Figure 1 illustrates relationship between human's motion and an instrument's motion. From Figure 1, the success or failure with an instrument in continuing are influenced by not only player's own body motion but also the instrument motion.

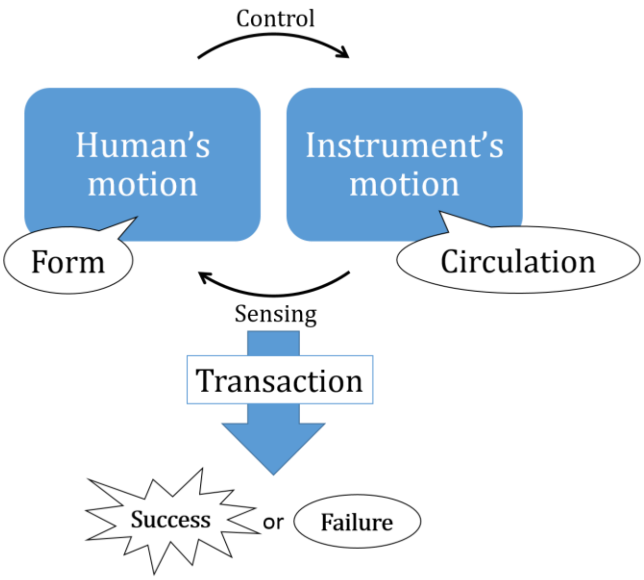

Figure 1. Relationship Human's Motion and Instrument's Motion

2.2 Feedback Timing

A system provides generally a feedback to learners in learning support of motor skills. The feedback information for learners is presented aiming at improving performance. It is significantly necessary to apply the feedback information to learners at effective timing. The feedback timing is available in three cases which are clearly distinguished by relative order. The first one is a case of where the system supplies it before exercise, as a preparatory phase. The second one is a case of where the system supplies after exercise, as a recalling phase. These two types work on asynchronous timing. In contrast, the last one is a case of where the system supplies during exercise. This type works on synchronous timing.

2.3 Purpose

Repetitive motions tend to take a long time. Therefore, when the repetitive motion is supplied with the feedback to learners at asynchronous timing, an influence to them is small, because a consciousness about the body motion during exercise fades as time goes by. In contrast, when the repetitive motion is supplied with the feedback to learners at synchronous timing, they can immediately remind the feedback information and reflect to the motion because they can aware the movement form of their body motion during exercise.

Synchronous timing is more appropriate in applying the feedback information. Therefore, this study tries to design and develop the learning support system to provide the appropriate feedback at synchronous timing. In this study, the proposed system supports repetitive motions with an instrument, where its concrete target is hula-hoop. Furthermore, this study focuses on a timing to control body motions.

3. METHODOLOGY

3.1 Timing of Hula-Hoop

Hula-hoop exercise has a circle instrument called a hoop. To keep a rotation of the hoop as long as possible by a waist motion back and forth becomes a hula-hoop skill. In addition, a hula-hoop player must control both player's body motion and the hoop. Therefore, s/he needs to give appropriate vibrations to keep a rotation of the hoop. Although this exercise is a continuous skill, there is actual end of exercise by failing. In order not to fail, the hula-hoop player should acquire the timing to give appropriate vibrations. In other words, the player needs to learn the motion timing of the waist for restoring the hoop, which is falling down, to a stable position during this exercise. This study focuses on the timing as one of a factor for stabilizing an instrument motion and proposes a supporting method of the motion timing for controlling the hoop.

3.2 Concrete Motion Image

Figure 2 illustrates the bird's eye view of simple forward and backward movement of the waist and the hoop in time series. Z-axis is front and back direction of the player and X-axis is right and left direction of the player. From the Figure 2, when the player performs a hula-hoop, the position of the hoop is always changing. Therefore, the player needs to apply vibration in line with the position of the hoop. This study focuses on positional relationship between player's waist and the hoop in front and back direction of the player. When the hoop is positioned in front of the player, the player's waist should be controlled backward. When the hoop is positioned behind the player, the player's waist should be operated forward. The player adjusts the hoop height along with the movement of the waist. However, the timing of the implication dominantly depends on each learner's movement from the frequency view point.

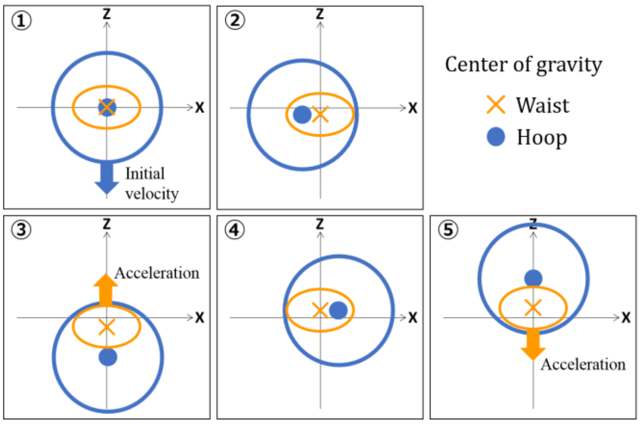

Figure 2. Concrete Image of Waist and Hoop Movements

3.3 Monitoring System

In this study, the system monitors hula-hoop using a motion capture system. Especially, we use the optical type being applicable for a quick movement. The optical type uses plural infrared cameras and markers. At first, a total of ten infrared cameras are placed in a room to eliminate blind spot. We set player's left and right directions as each plus and minus of X-axis, upper and lower direction as each plus and minus of Y-axis, and front and back direction as plus and minus of Z-axis in the three-dimensional coordinate.

Markers are reflected infrared light to acquire motion data, and attached several positions of the object where we want to acquire the motion data. We place markers to attach the waist of hula-hoop players and the hoop. Four markers are placed to the waist and the hoop respectively so that they can organize a space consisting of these markers. A motion capture system can calculate the center of gravity of these 4-points as a rigid body, and acquire data every 10 milliseconds.

3.4 Analysis System

3.4.1 Feature Extraction

The system detects the hoop state positioned in foremost and rearmost, because motion direction of the waist and hoop changes at these points in time. When the system plots the monitoring data in time series, we can observe the waveform expressing the feature of the repetitive motion. The horizontal axis is indicates passed time, and the vertical axis is the amplitude of the waist and the hoop. Figure 3 shows the hula-hoop data as an example. Large waveform shows the time shift of the waist, and small waveform shows the time shift of the hoop. From Figure 3, the hoop state positioned in foremost is expressed the local maximum point in the waveform. Similarly, its state positioned in rearmost is also expressed the local minimum point in the waveform. The system compares the current data and the latest data, and it judges the large/small relation of Z-values. In the case of the current data is larger than the latest one, when the current data changes smaller than the latest one, the system detects the local maximum point. Similarly, in the case of the current data is smaller than the latest one, when the current data changes larger than the latest one, it detects the local minimum point.

From these points, the system extracts some features. We call a cycle of waist from that the waist is operated foremost to that next motion is operated. We call similarly a cycle of hoop from that the hoop is operated foremost to that next motion is operated. In these cycles, we call a phase that an index showing a position in the cycle. The phase that between the waist and the hoop may have a gap of phase. We regard this gap as phase difference. Therefore, the local maximum/minimum point between the waist and the hoop may have a gap in time perspective. We define this gap as time difference. Further, we express these features above in the waveform. Figure 3 also expresses the hoop cycle and the time difference. This study regards intervals from a local maximum point to a next local maximum point as the hoop cycle, and regards gaps between the local maximum point of the waist and that of the hoop as the time difference. Then, it defines the phase difference as a ratio of the time difference to the hoop cycle. From Figure 3, the hoop cycle can be confirmed to the waist and the hoop, and the time difference can be confirmed between the waist and the hoop. Namely, the hula-hoop performed with the time difference by which the hoop state is delayed than the waist state. Therefore, we try to identify the motion timing of the waist using the phase difference from the hoop phase.

Furthermore, the system observes the hoop height and phase difference at time course. Figure 4 expresses one of these observations in five male subjects. Solid polylines are the hoop height relative to the waist height, and broken polylines are the phase difference. From Figure 4, the phase difference tends to be increased as the hoop height becomes lower. In addition, Table 1 reads a correlation between the hoop height and each feature value based on those subjects. From Table 1, there is larger negatively correlation between the hoop height and the phase difference in common. From this relationship, the system predicts the phase difference in future, and identifies the timing.

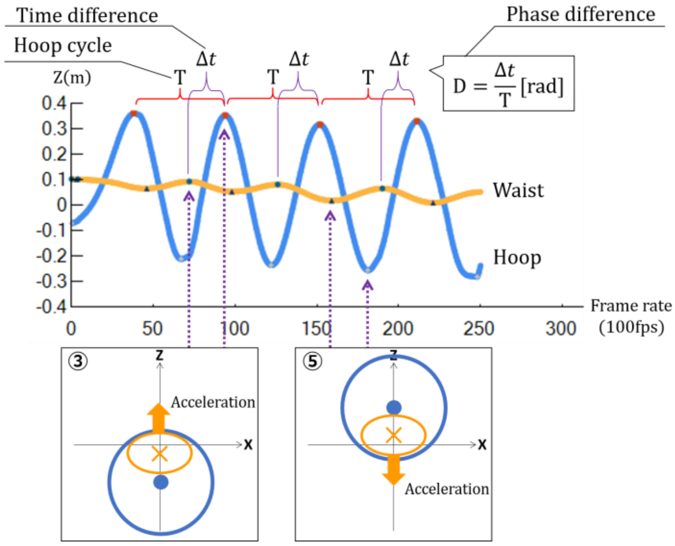

Figure 3. Motion Timing and Phase Difference in Waveform

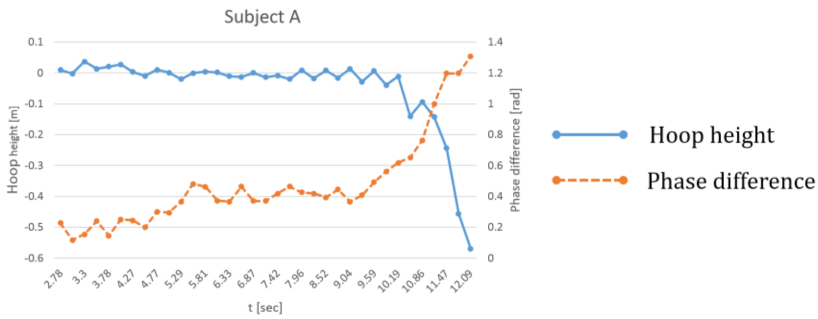

Figure 4. Hoop Height and Phase Difference at Time Course (Subject A)

Table 1. Correlation Coefficient between Hoop Height and Each Feature Value

Subjects	Phase difference	Hoop cycle	Hoop amplitude
A	**-0.88**	-0.62	0.10
B	**-0.88**	-0.60	0.51
C	**-0.92**	0.09	0.43
D	**-0.86**	0.75	0.82
E	**-0.97**	-0.10	0.33

3.4.2 Timing Prediction

The system identifies the hoop phase during hula-hoop. For this proposal, we need to estimate the hoop cycle, because the hoop phase can't be identified without the hoop cycle. Figure 5 illustrates a reason to estimate the hoop cycle. From Figure 5, the system can identify the hoop phase during hula-hoop, and estimate the hoop phase that should operate the waist. Therefore, it identifies the hoop phase from the estimated hoop cycle and provides the timing of the waist motion that is mentioned in previous section as feedback to the learner.

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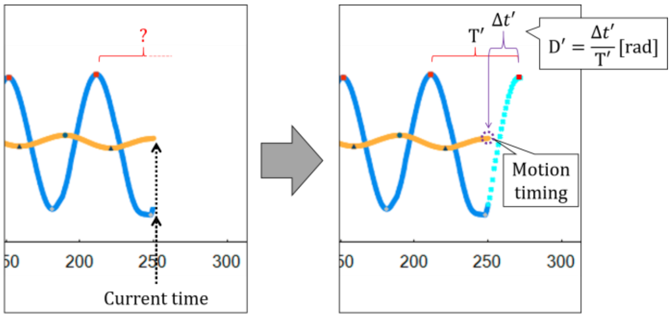
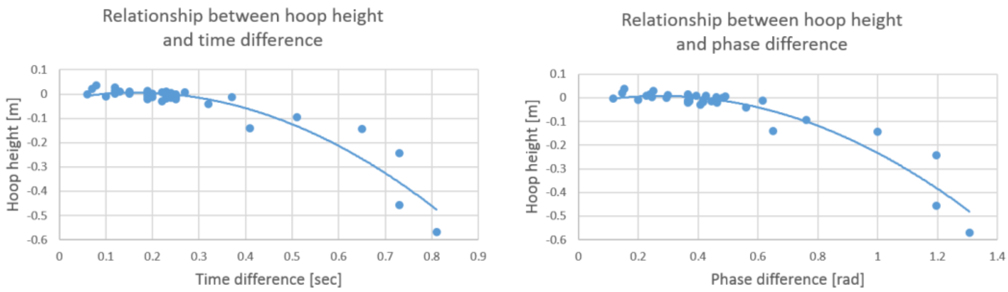


Figure 5. No estimation of Next Cycle (Left) and Estimation of Next Cycle (Right)

In addition, from Figure 5, the system calculates the next hoop cycle from value of the time difference and the phase difference. Therefore, it predicts them in the next cycle using regression analysis. At that time, this study uses a relationship between the hoop height and the phase difference. Value of the hoop height is applied to the hoop height being relative to the waist height. At first, the system acquires a two-dimensional regression formula from the learner’s data by regression analysis. An objective variable is the phase difference, and an explanatory variable is the hoop height. Figure 6 expresses an example on result of regression analysis. ‘R2’ is a coefficient determination. It is accuracy index of approximation and good model that is nearer to a value of one. From Figure 6, the system observes the coefficient determination of a regression formula being near to a value of one. Next, from the result, the system can calculate the next hoop cycle and predict the cycle of the hoop that is falling. It tends to be relatively short in higher position of the hoop and long in lower position of the hoop. Therefore, the system predicts to be shorter the hoop cycle when the hoop height is lower. At that time, this study assumes that players can control most stable the hoop when a value of the hoop height is same as a value of the waist height. From Figure 5, the calculated phase difference is an ideal value for the learner when the value of the hoop height is zero. The system detects the hoop height lower than the waist height as the falling hoop, and estimates the hoop cycle calculable by the ideal value of the phase difference. At this time, it estimates excessively small the value of the hoop cycle while the hoop height is better to be low. At last, it identifies the hoop phase to operate the waist in the next cycle using the predicted phase difference and the estimated the hoop cycle based on the hoop height. Then, when the hoop phase during hula-hoop has arrived the identified hoop phase, it implies to move the waist to learners.



$$y_1 = -3.31x^2 - 2.88x + 0.19$$

$$\mathrm{R2} = 0.88$$

$$y_2 = -4.68x^2 - 4.23x + 0.35$$

$$\mathrm{R2} = 0.87$$

Figure 6. An Example on Result of Regression Analysis (Subject A)

3.5 Feedback System

In this study, the system supports the waist motion of front and back direction. The feedback is desired simple contents so that learners can also understand intuitively during hula-hoop. Figure 7 illustrates a user interface under development. From Figure 7, the left side shows the feedback to be move the waist from front to back and the right side shows the feedback to be move the waist from back to front. The feedback system displays the square in right edge of a screen. The square moves until green line with the lapse of time. When it arrives on green line, it is changed to a triangle. Display position of the square shows an arrival state until the hoop phase to operate the waist. In addition, the system displays two color of the square into red color and blue color. The former shows an operation to backward of the waist, the triangle moves downward. The letter shows an operation to forward of the waist, the triangle moves upward. Therefore, learners operate the waist in accordance with the movement of triangles while watching squares. Thereby, the system can induce learners to predict the motion timing of the waist.

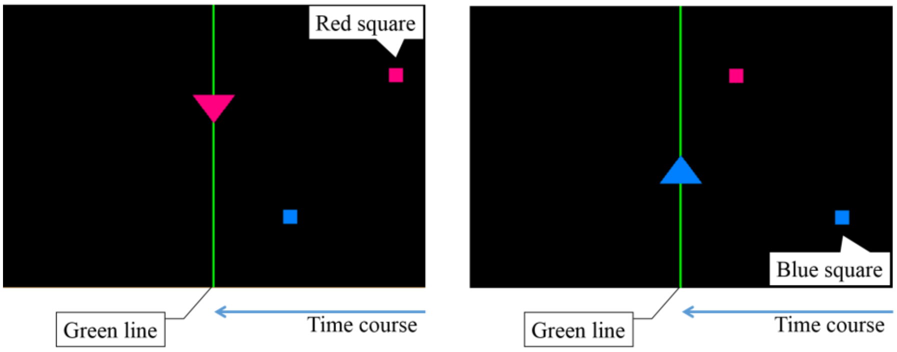


Figure 7. User Interface Under Development

4. SUPPORTING METHOD

4.1 Supporting Scenario

This section describes a supporting scenario. This study aims at acquisition of the timing of body motion for stable hula-hoop exercise by the synchronous learning support. There are a pre-trial phase, a main trial phase, and a post-trial phase in the learning support by this study so that the system needs several accumulated data to create the feedback. Therefore, learners of supporting target in this study is not a novice that can't rotate the hoop but an intermediate-level learner that can rotate the hoop a little. At first, in pre-trial phase, the system observes the learner's hula-hoop and creates a model for the learner from the observation. Next, in main trial, the system provides the feedback to the learner using the model during exercise. The learner acquires a sense of an appropriate operation interval corresponding to the hoop height through the feedback. After then, in post-trial, the learner performs the hula-hoop without the feedback. Therefore, the learner gradually acquires the timing of the hula-hoop by iteration of the main trial and the post-trial.

4.2 System Flow

In this section, this paper describes a system configuration. Figure 8 illustrates our supporting flow in the system. At first, in monitoring system, the system acquires the learner's motion data using motion capture system. Next, in analysis system, it performs the regression analysis from the inputted time series data of the hoop height and the phase difference when it is inputted the monitoring data, and created the learner's model. At this time, if it already creates that, it predicts the phase difference in next cycle corresponding to the hoop height using the time when it detects the local maximum point or the local minimum point. It calculates the next hoop cycle and estimates the hoop cycle required to restore the hoop height when the hoop height is lower than the waist height. Then, it identifies the hoop phase to operate the waist from the predicted phase difference and the estimated hoop cycle. At last, in the feedback system, it displays the feedback animation on screen. Therefore, it repeats these flow and provides the synchronous learning support.

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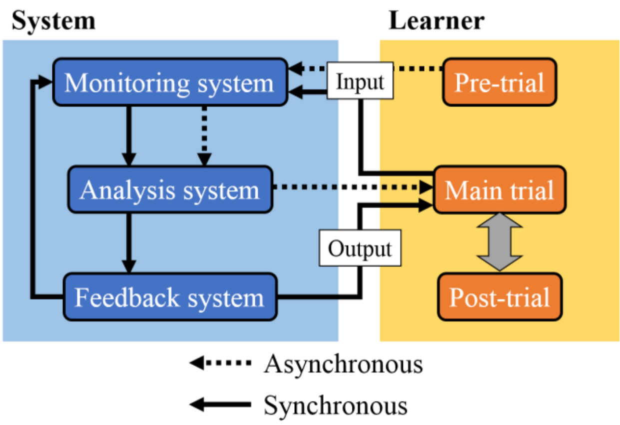

Figure 8. Supporting Flow

5. CONCLUSION

This paper proposed a learning support method based on the timing in repetitive motion using an instrument. Especially for hula-hoop, this study tried to give the feedback to learners during motion in real-time support. Hula-hoop was observed using the motion capture system and motion data was acquired. We focused on the time difference between the waist and the hoop, and estimated the motion timing to adjust the hoop height. In addition, we developed the system for improving.

The system in this paper only implements a supporting function of the timing. We plan to design the total supporting system to combine functions of the spacing and the grading. Further, the system needs to adjust the feedback timing for each learner in terms of synchronous support. Therefore, to implement the adjustment of the feedback timing is made as an issue to be addressed in the future.

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