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A Learning Support System for Integrated Motor Skill by Organized Training Stages

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Abstract: It is effective to use a learning framework when learners acquire a new skill. Jump rope is one of a slightly complex exercise which requires the coordination of each primitive movement and to control a rope. Therefore, this study designs a learning support system using learning stages which shift from primitive training to cooperative training according to learner's performance. The prototype is equipped with 3 functions which detect the feature points, compare the learner's data with an expert's and provide the learner with the visualized information using image processing technique. This paper describes a learning process, methodology and issues encountered.

Keywords: Motor skill, learning support, feedback, image processing

1. Introduction

1.1 Background

Skill learners often need to acquire some techniques using trial and error to execute an unlearned performance. Furukawa (2009) states that it generally is difficult for novices to understand and acquire motor skills. One of the reasons is that some novices make mistakes while executing and controlling their bodies by themselves due to the mental model error. This is one of the problem which makes it difficult for some novices to acquire motor skills. Therefore, this study develops a learning system to support them acquire a skill.

Guthrie (1952) defines a skill as an ability that is learned to reach a decided achievement in advance. It is often accompanied by maximum accuracy while consuming minimum time/energy or both minimum time and energy. Motor skill is a skill in which people execute performance moving their body. For example, in swimming, it is required to move legs, arms, and breathe simultaneously. To acquire the skill and swim smoothly, one needs to learn and train these skills, at first, independently, after then, cooperatively. This study suggests learning stages when novices acquire such skill.

1.2 Jump Rope

Jump rope is one of the well-known exercise all over the world. The characteristic is that anyone can do it alone and it doesn't need a wide space. The notable feature is that combining several motor skills and changing the activity degree can produce many tricks. Gotoda et al. (2010) classified these tricks into two groups; rotate the wrist once per jump (single bounce) and rotate the wrist twice per jump (double bounce). The difference between two groups is the degree of difficulty. Some people who can do the single bounce cannot do the tricks of double bounce. Hence, our supporting targets are those who cannot execute double-under, the most fundamental trick in double bounce.

Fitts et al. (1967) claim that it is important to consider three learning stages; verbal-cognitive, motor and autonomous stages. At first, in verbal-cognitive stage, the problem for a learner is the language and cognition. In case of jump rope, the important things are how to decide the goal, evaluate the performance, control a rope, and pay attention. Secondly, in motor stage, since learners have already solved most of cognitive problems, they focus on more effective organization of motion pattern. In case of hand motion in double-under, learners begin to make an exercise program for rotating the wrist more rapidly than single-under (Yoshioka et al., 2015). By this trial and error, they become able to detect their own error and get self-feedback, hence, their performance is improved rapidly. Finally, autonomous stage means the development of autonomous motion which does not need paying attention to. In case of double-under, one can continue to repeat a set of motion units as long as one has the physical strength. Therefore, this study focuses on novices who belong to the verbal-cognitive or motor stage.

2. Strategy for Jumping Rope

2.1 Primitives and its Relations

Jump rope exercise mainly consists of hand and jump motions. ARSA, which stands for Australian Rope Skipping Association, suggests how to execute the tricks in jump rope for a learner. In double-under instruction by ARSA, there are three primitives of hand motion and three primitives of jump motion. Primitive movements of hand are "rotating the wrist", "quick circular" and "beat of 1, 2". In addition, primitive movements for jump are "jumping high", "not bending at the waist" and "straight knees". Based on these primitive movements, this study examines and considers learners actions.

2.2 Training Stages for Acquisition

This study also interprets from ARSA's suggestion that, there are 4 training stages to acquire double-under. Stage 1 and 2 are basic stages where learners acquire primitive movements independently without a rope. Stage 3 is an advanced stage where they learn to coordinate primitive movements by combining hand motion with jump motion. In this stage, they practice without a rope. Here, considering time course in jump rope exercise, it is an exercise which repeats a set of motion-unit. The goal of the repetitive exercise is to continuously perform. However, if novices practice with a rope at first, it arises a problem which they cannot continue because they have not acquired motor skills for the trick yet. This can lead to failure when they begin to execute. Therefore, in these stages, one of the purpose is that they acquire a form to execute in double-under since they can repeat to execute without a rope. Stage 4 is also an advanced stage where learners try to coordinate primitive movements with a rope.

Meanwhile, this study points at a problem between stage 3 and 4. The difference between them is whether a rope is used or not. However, there is a case that the form of some novices become worse when they have passed stage 3 and try to practice stage 4 at first. One of the reason is that they cannot control a rope. In stage 3, the goal is to acquire the form in double-under without a rope, not to make a model to control with a rope. This study inserts a new stage 3' before proceeding to stage 4. It is also an advanced stage where they learn to coordinate primitive movements with a districted rope. The idea is that they execute double-under with a rope which is rotated on only one side of their body. In other words, a rope doesn't need to pass under their foot. The important thing is that they need to achieve the trajectory of a rope's top observing from their side as drawn like a circular orbit by rotating the wrist. Hence, this study construct 5 training stages by inserting stage 3'.

2.3 Transferring between Stages

It is required to learn how to transfer between stages. This study defines the stage flow based on ARSA. Figure 1 indicates a relationship between training stages. In each stage, there is a function's cycle which transfers from observation to data analysis, stage's decision and suggestion in a system. At first, a learner tries to execute double-under with a rope and without it as a pre-trial, then the system observes, judges and determines the stage. Here, there are some rules to transfer to the other stage. A learner, at first, tries to practice on the stage once at the first stage or the transferred stage, then the system judges the performance and determines the next stage to practice.

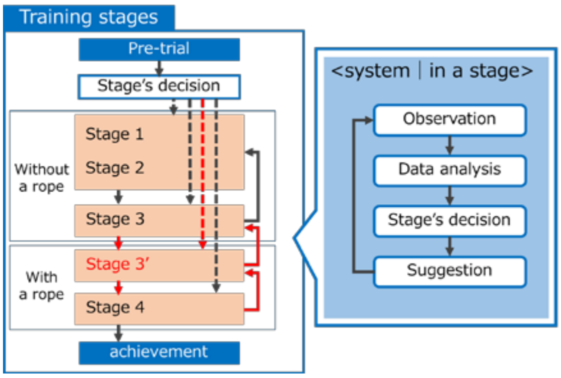

Figure 1. Training stages

Next, this study proposes how to judge each stage. In stage 1, 2 and 3, the system judges by binary method which determines if the learner's data is good or bad per a primitive movement based on reliable ranges calculated by expert's data statistically. In stage 3', the system again uses the binary method to decide whether the rope passes under one's foot while jumping or not. In stage 4, it is difficult to observe the performance because it is not clear if the learner executes double-under or not.

In addition, this study proposes how to transfer to the other stages. Basically, the system transfers from stage 1 to stage 4 in order. However, if a learner cannot master the skill in the stage, it is possible to train in the same stage again or transfer to lower stage. In case of stage 3, Sugawara et al. (2016) indicate that the coordination of primitive movements is required. That is to say, a learner who has been trained in stage 1 and 2 acquires the coordination which consists of primitives in stage 3 although some primitive movements become bad. In addition, if the judgement of the coordination is correct, the system transfers to stage 3'. If not, the system adopts in stage 3 again. In stage 3', if the judgement is that a rope passes under one's foot on all jumps while a learner execution is correct, the system transfers to stage 4. If not and the judgement of the coordination is correct, the system adopts in stage 3' again. Otherwise, the system stays in stage 3. In stage 4, if a learner can execute double-under at least once within 2 trials, the end of this learning support is reached. If not, the system transfers to stage 3' and a learner trains at it again.

3. Methodology

3.1 System Work

In learning process, it needs to judge whether a learner has acquired the skill or not per stage. This study mainly tries to solve it by a parameterized performance for the judgement in jump rope exercise. Hence, this study suggests the way to detect feature points using techniques in image processing.

3.1.1 Viewpoint

Learners need to grasp the way of using their bodies by themselves objectively. Jump rope exercise is an exercise which consists of hand and jump motions. In double-under, by observing from the side of a learner, it regards a motion of rotating the wrist as circular motion. In addition, it regards a motion of jump as vertical motion. Therefore, this study uses the way of observation in two-dimensions using a video camera.

3.1.2 Data Analysis

For detecting body information of a learner, this study uses color recognition. Herewith, it gets several points; head, hand, the top of grip and toe. Using these data, this study calculates reliable ranges that it is possible to execute double-under from the data of experts statistically. This study defines experts as those people who can execute double-under over than 20 times, then gathers the data from 10 such experts. Figure 2 shows a reliable range of "rotating the wrist" as an example. We classified 3 groups;

experts could execute it "under 10 times", "over 10 and under 20 times" or "over 20 times" until failure. Every group consists of over 8 trials data. The results of Figure 2 suggest that those who can execute it more times tend to execute in a smaller radius. However, the target in this study is novices. Therefore, this study adopts the reliable range which experts execute "under 10 times" until failure to judge the novices and similarly adopts the same way for other primitive movements.

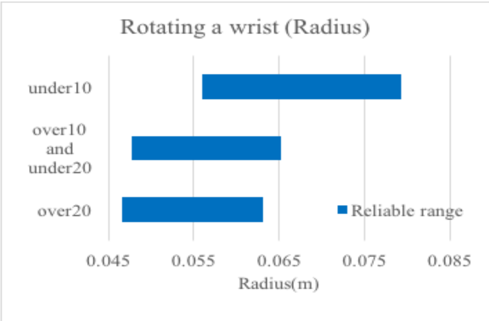

Figure 2. Reliable range of rotating the wrist

3.2 *Learning Process*

To acquire skill, we need to consider learning flow. Figure 3 is a learning process in this study based on Soga et al. (2005). This flow consists of 2 parts; a learner's part and a system's part. In learner's part, there are 3 parts in a cycle; execution which a learner tries to do, recognition which figures out one's error arising from own movement by feedback and improvement in which one takes a strategy for success and acquiring the skill based on recognition. In the system part, there are 3 functions in a cycle; observation of learner's execution, data analysis and indication including the result of analysis as a learning support framework. "n" stands for the number of stages.

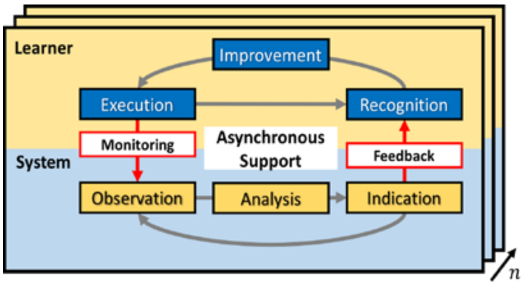

Figure 3. Learning process

3.3 *Timing of Support*

For learning support, we need to consider timing when learners get some information. Kosaka et al (2011) suggested the timing of support. In "synchronized support", learners get support while executing appropriately. The advantage is that learner can fix and improve the motion immediately. The weakness is that a learner cannot get an evaluation of the overall performance. Furthermore, it is not suitable for ballistic exercise. On the other hand, in asynchronous support, the advantage is that a learner can get information of both motion and overall performance. The weakness is that it is possible to lose consciousness in each motion since a learner cannot get some information simultaneously while executing. Therefore, this study adopts "asynchronous support" as the learning support. The reason is that the goal is to acquire double-under skill which consists of some primitive movements and their coordination. Therefore, we need to provide a learner with the information and whole body movement.

4. Designing Issue

4.1 Observation

This study uses OpenCV as techniques of image processing for detecting the feature points. However, it is difficult to track the top of a rope by color recognition because of the speed and the environment. Karungaru et al. (2016) propose a method using particle filter for tracking the feature. Therefore, this study applies color recognition for detecting the feature points, in addition, background subtraction and particle filter for tracking the features.

4.2 Learning Support

It is effective for learning support to consider feedbacks. According to Schmidt (1991), feedback often means information difference between the target value and performance. There are two feedbacks in detail; intrinsic and augmented. The former is the information in which learners recognize their performance by themselves while executing, in case of jump rope, they often get it by visual and auditory sense. The latter is the information which is based on artificial methods, for example coach's voice, observed data and movie. Some novices make miss-recognitions in the intrinsic one. In contrast, augmented feedback is adjusted accurately and objectively. This is information that coaches don't or cannot control. Hence, this study designs augmented feedbacks for a learning support system. Therefore, this system is equipped with visualized feedback. According to Yoshioka et al. (2015), a learning system supplies a learner's current movie attached with target form about hand motion. The purpose is that learners become able to imagine the target model compared with learner's internal model by themselves. The system contains a video of actual performance attached the target points and a model video made by experts. Figure 4 is one of the sample as a feedback video in stage 3'. Stage3' is for those who cannot rotate the wrist twice while jumping with a rope in spite of acquiring ideal form without a rope for double under in stage 3. The video indicates a trajectory (two red circles) and the speed of rotation (a light blue dot moving on the trajectory) to achieve an ideal rotation with a rope while jumping. The target movements are overlapped on learner's result and drawn by image processing. Learners watch it and are given any target values, after that, they make a strategy with moving their bodies by themselves for the next execution.

Figure 4. The feedback video in stage 3'

Moreover, in stage 3 and 3', the coordination between primitive movements is required. The system needs to consider the correlation between them in feedback. Therefore, this study calculates the correlation between them from the result of 10 experts. In Table 1, (h1) and (h2) mean primitives of hand motion (this study treats the parameter of "beat of 1, 2" as binary, then excludes it from this calculation), and (j1), (j2) and (j3) mean primitives of jump motion. In addition, the correlations are combined hand motion with jump motion.

Table 1: The correlation between primitive movements.

Serial number	combination	Correlation coefficient
1	(h2) – (j1)	0.881210473
2	(h1) – (j3)	-0.525911049
3	(h1) – (j1)	0.35485142
4	(h2) – (j2)	-0.335502835
5	(h1) – (j2)	0.221594898
6	(h2) – (j3)	-0.057921484

This study uses these results for a decision of a training way. It expects that a learner in stage 3 or 3' needs to acquire some skills. Although it is not effective for people to train all skills simultaneously, a learner needs to train some skills simultaneously to acquire the coordination. This system decides a training method which a learner should train at first. For example, if (h2) is judged as bad, this study chooses the combination between (h2) and (j1) from 3 choices because we assume that the correlation is higher. Finally, the system provides a learner with a training way for improving the combination.

5. Conclusion

This study proposes the framework of learning support to acquire motor skill in double-under. To achieve this, the study configures learning stages from fundamental training to complex one based on ARSA. Since it is important to connect between the stages, this study adopts the judgement which is determined statistically by the data of learner's performance. Accompanied with this, this study develops the system which is equipped with three functions; observation using image processing, data analysis and indication as feedback. In observation, this study tries to use the technique of color recognition and background subtraction for detecting the body information, and particle filter for tracking feature points. In feedback, this study supplies a learner with the visualized information which is a learner's movie and a model video made by experts for their understanding objectively. In addition, the timing when the feedback is provided to a learner is an asynchronous support. The next issue using this prototype is an evaluation whether the learning framework is effective for novices or not.

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