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Design of Tennis Training with Shot-timing Feedback based on Trajectory Prediction of Ball

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Abstract: Tennis has long history as a famous sport and enhanced health promotion of men and women all ages. In many cases, the style of technical teaching has been a long tradition of face-to-face. On another front, recent seamless bio-feedback technologies enable players to be trained in the acquisition of novice skills without the coach. This paper proposes a design and scenario of practice on their own with training system for tennis skills. One of the basic skills for the novices is to make an appropriate contact with the ball. We focus on skill related to judgment of shot-timing. The system provides the timing feedback based on trajectory prediction of ball. Image-processing module with Open CV preliminarily develops the estimated expression for the ball position by analyzing captured video frames. After that, the system gives color change to the ball according to the position with video projection. Therefore, a player can learn the appropriate shot timing easily. We will evaluate the training efficiency among comparison of practice using system with only one without system from the viewpoint of timing accuracy.

Keywords: Physical education, interactive learning, tennis, bio-feedback system, video projection

1. Introduction

Tennis has much player numbers all over the world. Similarly, in our nation, tennis including soft tennis has been always famous club sport among middle-school and high-school students. Therefore tennis is employed as physical education in a part of some school lessons in addition to lifelong sport among senior for health promotion. Under this background some novice people play tennis for the sheer fun of it, other novice people tackle to technical lesson from the spontaneous motivation of skill upgrade. The traditional way of technical teaching is face-to-face lesson. However, all novices cannot take lessons because a few coaches (e.g. physical education teacher) must limit the number of them for the purpose of keeping a certain level of teaching quality. Thus, when the lesson has many players compared with coaches, practices on their own hold a majority in the training activities.

On the other hand, integrated hardware and enhanced software technologies bring both tiny and high-speed sensing and audio-visual functions in several devices. For example, Eureka Computer Co., Ltd (2010) is calling for “e-Sports Ground” as an entirely-new field of sports entertainment with AR (Augmented Reality) technology with such seamless bio-feedback by using motion-sensor data and video projection. In particular, projector and video camera are distributed at low cost, many school are generally equipped with them. Therefore, combination with them has potential to provide players for a training method without the coach at school and so on.

Thus, we propose a design and scenario of practice on their own with training system for tennis skills. One of the basic skills for the novices is to make an appropriate contact with the ball. We focus on skill related to judgment of shot timing. For example of serve, the timing corresponds to appropriate height of the ball. The system provides the timing feedback based on trajectory prediction of ball. Image-processing module with Open CV preliminarily develops the estimated expression for the ball position by analyzing captured video frames. After that, the system gives color change to the ball according to the position with video projection. Therefore, a player can learn the appropriate shot timing easily. We will evaluate the training efficiency among comparison of practice using system with only one without system from the viewpoint of timing accuracy.

2. Related Research

2.1 The Way of Motor-skill Development

On the basis of Bersteine (1996) idea, it is required to acquire the fundamental skill knowledge about the fusions between how to evaluate several inputs and how to perform their body movements. He discussed such a motor dexterity and its development from the viewpoint of cognitive science and ecological psychology. In the field of such a motor development, following two theories take up initiative.

2.1.1 Fitts & Posner's Three Stage Theory

Fitts & Ponsner (1967) identified three stages of skill learning: “Cognitive”, “Associative”, and “Autonomous” stage. Learners can grow from unskilled performance with lots of errors to skillful performance with few errors. It means that they become more stable movement and better accuracy of timing through these steps. On the first step: “Cognitive” stage, a learner defines the goal of skill and recognizes a strategy of movement patterns which has several component parts for the achievement in her/his head. When a learner gets skill of tennis serve, the simple goal is shooting a static tennis ball in a comfortable position. In this case, a learner should pay attention to the following strategy as this stage during training:

- How to toss the ball in to the air?
  - How high?
  - Which direction?
- How to contact the ball with the racket?
  - Which timing?

Therefore, this stage is High degree of cognitive activity. On the next step: “Associative” stage, a learner links the parts like the abovementioned items into a smooth movement. This stage involves repeated practice by using feedback for the purpose of obtaining unchangeable reaction. Finally, on the last step: “Autonomous” stage, a learner can perform without conscious for the items. Of course, not all learners will reach this stage.

2.1.2 Gentile’s Two Stage Theory

On the other hand, Gentile (1972) proposed two stages skill learning:

- Getting the idea of the movement
- Fixation / Diversification

This idea resembles Fitts & Posner's theory because the former stage corresponds to “Cognitive” stage and the other deals with both “Associative” and “Autonomous” stages. Similarly, on the first stage, learner’s goal is to develop an understanding of movement’s requirements. The additional thing against Fitts & Posner's theory is that a learner has to learn to discriminate between regulatory and non-regulatory conditions. According to the conditions, each skill is described as “Closed Skill” and “Open Skill”. As the second step, on the basis of difference between skills, Fixation means a training of “Closed skill” which refines movement patterns. Conversely, diversification denotes a training of “Open Skill” which adapts movement to conform to ever-changing environmental demands. Thus, in the case of tennis, serve is “Closed Skill” which a learner has self-control in respect to the ball and racket. However, smash is regarded as “Open Skill” because a learner must shot the return-shot ball from the opponent.

2.2 Interactive Learning of Sports Skill for Personal Training

Interactive learning of sports skill is implemented by means of bio-feedback as improvement instruction based on specified activity data. Several advanced studies for personal training obtained significant findings.

Kawagoe et al. (2011) developed the feedback system which visualizes a center of gravity from learner’s motion by using motion capture. A Learner can check her/his center in addition to motion and

posture after the trial. The study focused on the non-supervised / autonomous training based on cycle between personal exercise and reflective learning. The result of experiment for serve skills of novice badminton players shows some effect for understanding the relationship between the center of gravity and the movements of the learners.

On the other hand, Gotoda et al. (2011) proposed real-time coaching between a learner and an expert as supervisor via internet during training. They tackled to remote coaching system of runner's arm-swinging form with wireless sensor devices. The system provides coach for monitoring interface on web browser in real-time. The simple instruction by coach's mouse-click operation among several preset candidates on the browser is transmitted to sensor device as sound feedback. The practical experiment led to the possibility of real-time feedback training system to improve motion patterns based on several obvious problems.

In comparison with these studies using the dedicated devices and sensors, Matsuura et al. (2009) proposed personal web-training system with video recording devices which everyone can get easily (e.g. digital camera, mobile phone integrated with camera etc.). Learners can upload their training video into the community site which has the video-sharing and video-analysis function. The system analyzes human body-motion in the uploaded video by using Open CV and visualized it as a chart upon the video screen layer. Additionally, the system recommends several video candidates as supervised learning material for after the upload and analysis. The candidates are based on all video archives of same type of skill which has uploaded. The framework made users learn without burden.

2.3 Discussion on These Studies

Regarding the novice level in tennis, to make an appropriate contact with the ball is first step up the ladder of skill training for the novices. Both serve and smash which held up as examples are a basic technique with it, and they can practice on their own. Therefore we choose them as targeted skills. Based on Fitts & Ponsner theory, in the case of these skills, strategy of movement patterns in Cognitive stage is simple like abovementioned patterns only from the aspect of contact with proper timing. Thus, the system focuses on supports between Associative and Autonomous stages. However, Gentile theory suggested the consideration of environmental steadiness. In fact, generally, Open Skill: smash is more skillful than Closed Skill: serve. For this reason, we define a flow of two principal stages as learning scenario.

As to the requirement, fundamental idea is to avoid excessive fatigue for novice practice. The demands include the training without attached devices. Moreover, the ideal contact timing does not depend on individuals except for the body-height differences while the control of gravity position based on movement sequence is diversified. Therefore, we chose interactive learning with an image-processing analysis and real-time feedback for the obvious problem.

According to the discussion, we designed two stage learning scenario from Closed Skill: serve to Open Skill: overhead smash. Our system contributes to accomplish the problem of each stage step by step.

3. Learning Scenario

Figure 1 illustrates the learning scenario. On the first step, a learner practices toss which throws the ball overhead before shot training because at least both enough height and straight toss in a vertical direction brings condition to measure the appropriate timing for a learner. Next step, a learner conducts serve training. The system helps this shot timing after self-toss. S/he practices this step over and over until acquisition of correct contact timing. After that, in the Open Skill stage, a step without shot is prepared in similar to Closed Skill. However, the move training represents a completely different approach to it. A learner has to predict where the ball from a toss machine which has a role in opponent will land. Finally, when a learner is ready to handle the movement base on prediction, s/he tries to do smash training with feedback.

At the beginning, we focus on closed skill stage. In the following sections, the system design and experiment s plan concentrating on Closed Skill training will be presented.

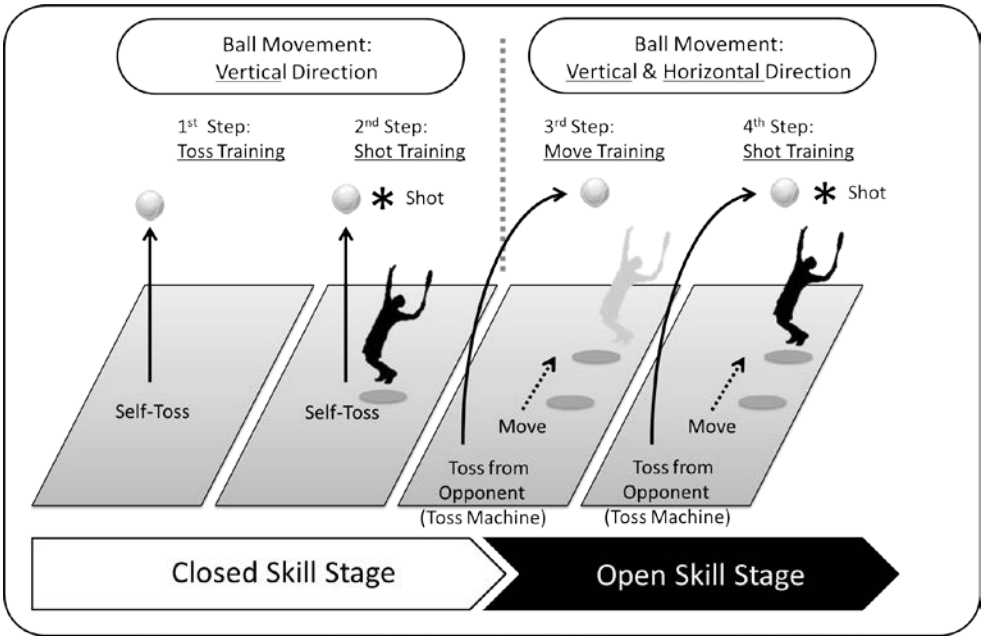

Figure 1. Learning Scenario

4. System Design

Shot-timing feedback is based on trajectory prediction of the tennis ball. The prediction is conducted by analyzing an initial section of captured video frames. Figure 2 shows derivation rule of appropriate contact height which corresponds to the timing. Image-processing module with Open CV analyzes several video frames from release point. The system extracts velocity vector based on interval between frames and develops the estimated expression for the ball position.

Next, as shown in example like Figure 3, height including appropriate contact area is shown as colored ball by video projection. On the basis of the premise that system knows exactly proper contact position including body height and arm length by image processing with Open CV library, the graduated pattern composed several different color bands is provided by analysis vertical movement of the ball along with the predictive trajectory. Moreover, the band width is depended on accuracy because expert can contact it almost exactly within the thin area. Therefore, the width is adjusted in accordance with learner's skill level or learning progress.

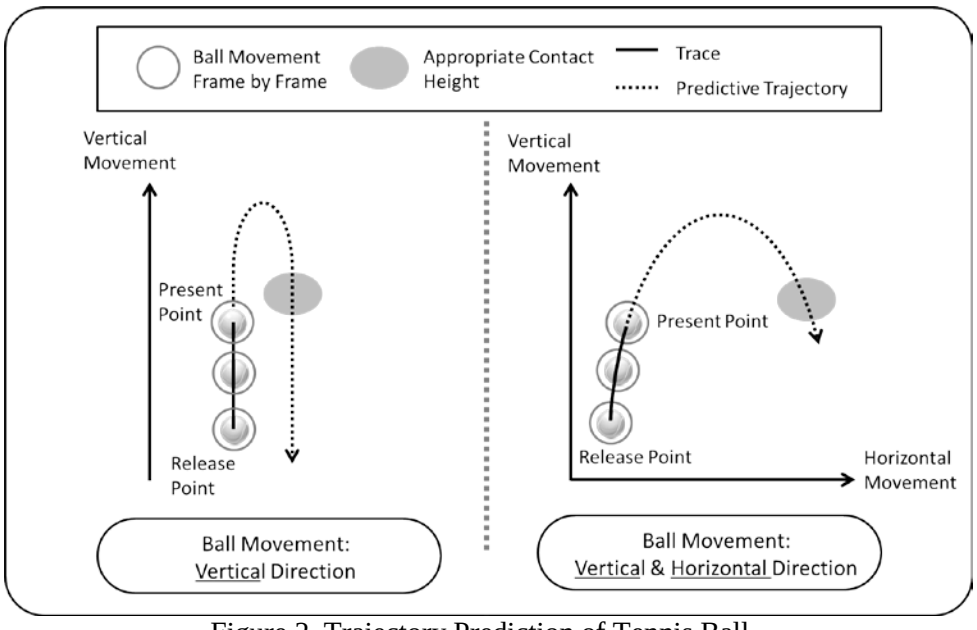

Figure 2. Trajectory Prediction of Tennis Ball

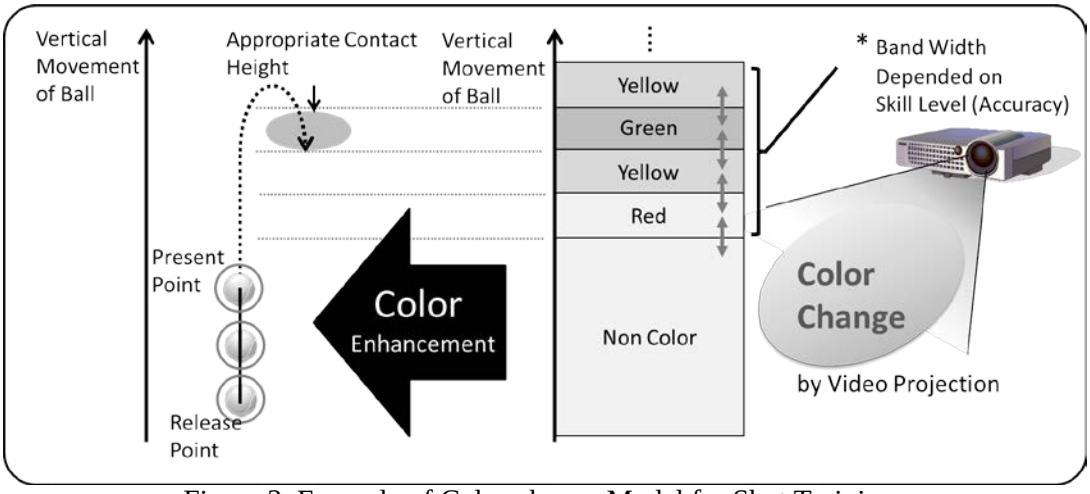

Figure 3. Example of Color-change Model for Shot Training

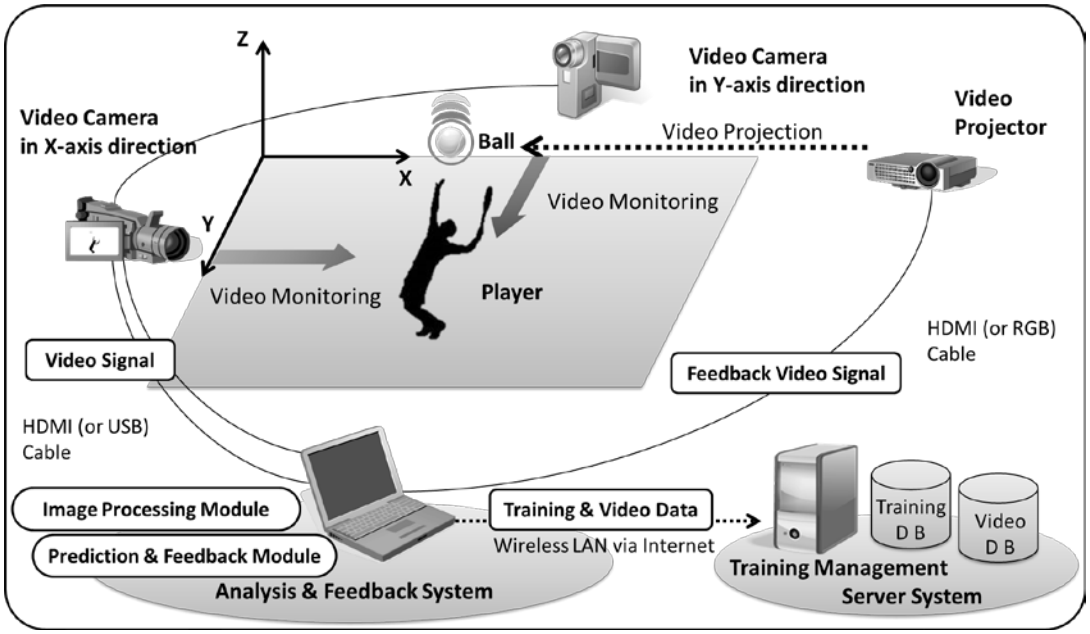

Figure 4. System Configuration (i.e. Closed Skill: Serve)

Figure 4 denotes an overview of system configuration based on these architectures. Monitoring function is set upped composed of two cameras which the X intersects with Y at player's place. Analysis and feedback system runs the image processing, prediction and feedback modules while sending the data to the training-management server.

5. Experiments Plan

Experiments based on our proposal will be conducted under the process like Figure 5. First of all, we will ensure the reliability of training system to establish the support method. Therefore, predictive trajectory of the ball will be compared with the real trajectory to monitor the position precisely for the immediate feedback. Shot timing based on our enhancement model will be compared with real shot timing by experts in the latter evaluation. This focus on an investigation of validity related to feedback. In particular, a color-change order and the band width will be defined by the supervised opinions.

After these preliminary experiments, we are going to evaluate the leaning effect with the established method for novice leaners. In the process of evaluation, timing accuracy is treated as reference index to judge learner's skill level. Therefore, the variation tendency will be investigated through a comparison between novice-player group and expert-player ones of several skill levels. Finally, we will prepare comparative approaches: with the method and without it. The effect difference

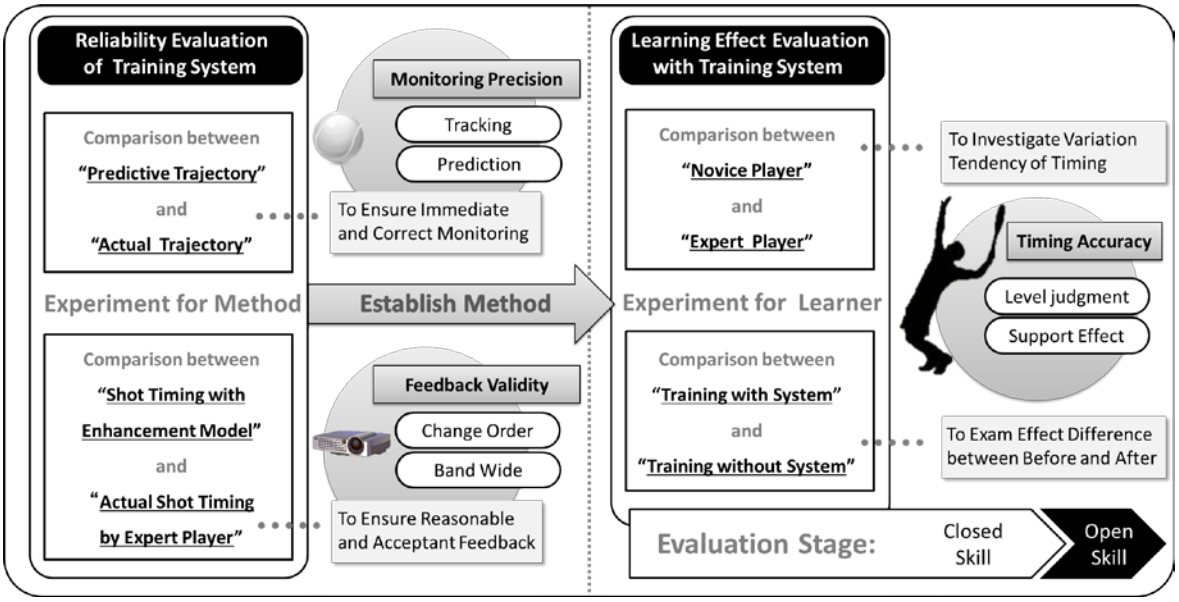

Figure 5. Experiment Process

between before and after will be shown through training results based on each environment. After the experiment regarding Closed Skill, Open Skill stage will be done with improved method.

6. Conclusion

We proposed a real-time feedback system of shot timing in tennis. The appropriate contact area is shown as colored ball by video projection. The graduated pattern composed several different color bands is provided by analysis vertical movement of the ball along with the predictive trajectory. The width is adjusted in accordance with learner's skill level or learning progress. In the near future, we will implement our proposal and conduct the experimentation. Also, we will define concrete patterns of color-change through trial and error. Also, after training experiment of Closed Skill, we will develop additional feedback for smash position in the training of Open Skill.

Acknowledgements

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