A Support System for Improving Shadow Swing Form in Badminton

2310405 Wang Zihao

Badminton is a sport that requires precise and fluid full-body coordination, making it particularly challenging for beginners to master proper swing techniques. Among all badminton strokes, the forehand clear is a fundamental yet difficult skill for beginners to acquire. Traditional training methods often rely on video-based imitation or in-person coaching, which either lack personalization or are not always accessible. To address these limitations, this study proposes a system for supporting the improvement of badminton shadow swing form, specifically focused on the forehand clear motion. The system integrates pose estimation, motion comparison, and multi-modal feedback to enhance the learning experience and performance of beginners.

The proposed system is built upon a two-perspective analysis framework that captures the player's shadow swing from both frontal and lateral views. Using YOLOv11 for pose estimation, the system extracts joint positions from keyframes in the video. Standard motion models were constructed by averaging the key poses of expert players collected from multiple trials. For each user swing, the system identifies corresponding keyframes and applies Procrustes analysis to spatially align the learner's pose with the standard model. By calculating joint-wise deviations and mapping them into a normalized score, the system provides visual and quantitative feedback on form correctness.

A key innovation of this study is the feedback generation mechanism. For each keyframe, a three-column feedback image is created, showing the learner's actual form, a skeleton-based reference from the expert dataset, and a real image of an expert player with similar body type performing the same motion. Arrows and annotations indicate joint deviations and provide textual guidance. These visualizations help beginners identify and correct mistakes in an intuitive way. Due to the high computational cost of virtual video generation, only three keyframes from each perspective are used for comparison, while the frontal keyframe is excluded due to occlusion errors in joint detection.

To further explore the potential of visual feedback, this research also incorporates a simulation-based training method using the open-source UniAnimate model. By inputting a video of expert swing motions and a front-view image of the learner, the system generates a personalized virtual video in which the learner's body performs the expert motion. This enables learners to visually perceive how they would look with ideal form. To manage GPU memory constraints, the expert motion is sub-sampled to approximately 85 frames before feeding into the UniAnimate model.

To evaluate the effectiveness of the proposed methods, a controlled experiment was conducted involving 30 badminton beginners. Participants were randomly divided into three groups: (A) the feedback system group, which used the proposed skeleton-based visual feedback system for practice; (B) the simulation group, which practiced by watching their own virtual videos generated by UniAnimate; and (C) the control group, which learned through conventional expert video tutorials. Each participant performed two rounds of shadow swings before and after a 20-minute practice session. Joint deviations were scored using the system, and improvement was measured as the change in average score between the two rounds.

The experimental results showed that the feedback system group achieved the greatest improvement in both frontal and lateral swing forms. Statistical analysis using the Wilcoxon signed-rank test confirmed the significance of the improvement for "feedback system group" "simulation group" and "control group". Notably, while the simulation group provided a strong sense of embodiment and engagement, its effectiveness in correcting specific motion errors was slightly lower than that of the feedback system. The control group showed the least improvement, suggesting that generic video-based learning is less effective for technical motion refinement.

In addition to objective evaluation, a post-experiment questionnaire was conducted to assess

user experience, perceived effectiveness, and motivation. The feedback system group reported the highest levels of usefulness and satisfaction. Many participants commented that the arrows and step-by-step guidance helped them understand their mistakes. The simulation group also received positive feedback, particularly regarding its novelty and motivational effect. However, some users noted that the visual realism was limited due to the lack of racket rendering and slight deformation in generated avatars. The control group expressed difficulties in identifying their own mistakes when watching expert videos.

This research highlights the importance of personalized, multi-perspective feedback in motor skill acquisition. While virtual simulations offer enhanced engagement, precise and detailed visual cues based on pose estimation proved to be more effective in guiding learners to correct their swing forms. The combination of real-time skeleton feedback and visual self-comparison enables learners to internalize target motions more efficiently.

In conclusion, this study presents a novel badminton training support system that combines pose estimation, visual feedback, and personalized simulation. Through multi-angle analysis and detailed comparison mechanisms, the system helps beginners better understand and improve their swing technique. The experimental results and user feedback support the effectiveness of the approach. By integrating technical rigor with user-centered design, this system offers a promising direction for intelligent sports training systems aimed at novices.

Nonetheless, the study has several limitations. First, the UniAnimate model used in this research cannot generate videos with rackets due to input limitations, and its rendering quality occasionally causes avatar deformation. Second, the current system focuses only on discrete keyframes and lacks dynamic trajectory analysis across frames. Third, although the experiment included a moderate number of participants, longer-term studies are needed to evaluate retention and sustained improvement.

For future work, the system can be enhanced in several ways. First, more advanced video generation models that support high-quality, object-inclusive rendering should be explored to improve the realism of the simulation. Second, dynamic motion trajectory analysis could be incorporated by evaluating continuous pose sequences rather than isolated keyframes. This would enable the system to capture rhythm and temporal coherence, which are important in fluid sports motions like badminton. Third, integrating real-time feedback mechanisms and combining the advantages of both the feedback system and virtual video simulation may provide a hybrid training experience that enhances both immediate correction and motivational impact. Finally, expanding the system to support other badminton techniques such as smashes, drop shots, or footwork, and incorporating hitting practice, would increase the system's utility and training diversity.

Keywords: badminton, shadow swing, pose estimation, motion feedback, virtual simulation, UniAnimate, Procrustes analysis, beginner training system.