Indian Journal of Science and Technology, *Vol 9(45), DOI: 10.17485/ijst/2016/v9i45/106910, December 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Potential and Limitations of Kinect for Badminton Performance Analysis and Profiling

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Abstract

Objectives: Badminton performance analysis and profiling are essential steps in badminton coaching in order to identify the strengths and weaknesses of an athlete. **Methods:** In this paper, we investigated and identified the key potential and limitations of the Microsoft Kinect sensor for badminton performance analysis, particularly on novice badminton player. A survey was conducted during badminton event of SUKMA in order to determine which strokes are important to novice level player, where participants include coaches from different states of Malaysia. The essential strokes were then analyzed by Microsoft Kinect sensor. **Findings:** The survey results indicated that there are four main strokes to be mastered by novice level player, such as clear, net, lift and smash. Moreover, the key selected badminton strokes as identified by expert coaches such as forehand crosscourt lift, backhand touch net, backhand lift, forehand lift, forehand push net, backhand clear, backhand push net, forehand touch net and forehand clear can be measured and analyzed accurately and consistently with Microsoft Kinect sensor. However, the sensor measurements are limited for badminton strokes such as static smash, jump smash and overhead forehand clear. The major reason for such limitation is mainly due to occlusions and loss of acquisition data due to fast moving motion. **Improvement:** Therefore, the current performance analysis algorithm using skeleton information will be incorporated with color information in future to resolve the occlusion issue.

Keywords: Badminton, Depth Map, Kinect, Performance Analysis, Performance Profiling

1. Introduction

In sport science, observable behavior changes from athlete are indeed important in coaching process. In order to improve performance of athlete effectively, the coaching skill relies heavily on performance analysis[1]. Generally, athlete performance profiling is performed to identify the strengths and weaknesses of an athlete. Such valuable technique is often employed to organize training, preparation and the development of an athlete[2]. Moreover, performance profiling can provide insight information on athletes, where a realistic goal setting can be implemented and assist in maximizing the motivation of athletes[3]. Meanwhile, the study by Weston, et al.[4] indicated the athletes' positive perceptions of the impacts of performance profiling. From their work, athletes believed that performance profiling is indeed important to raise self-awareness, self-motivation, assist in deciding the important task to work on, setting goals, performance monitoring and evaluation and responsible for their development. Furthermore, Andrew, et al.[5] found that the majority of coaches praised the usefulness of the performance profiling as part of the wider coaching process. Generally, athlete performance analysis is divided into biomechanical and notational analysis[6]. Biomechanics analysis of human motion is the acquisition, observation and definition of human motion during a certain period of time and afterwards its assessment[7]. Technically, biomechanical analysis technique contributes to identify injurious movements while notational analysis assists to assess physiological and psychological demands of sports.

Badminton is an indoor racquet sport which is played either at a casual or competition level. In Malaysia, badminton is one of the most favorable sports as well as in

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countries such as China, Indonesia, Korea and Denmark, among others. The sport can basically take place with either two opposing players (singles) or opposing pairs (doubles) within a center netted rectangular court. As compared with other racquet sports, such as tennis and squash, badminton is the world's fastest racquet sport in accordance with shuttlecock speed[8]. Moreover, badminton is a highly technique-oriented sport with complicated skills. Generally, a badminton player should be able to strike a shuttlecock with force called 'stroke' which requires elegant and delicate techniques that must be constructed and delivered through precise basic skills, powerful strength and coordination[9]. Over the years, numerous researches have been carried out to analyze the movement of a badminton player, such as badminton smashing[10–13], service[14–16] and swing[17]. However, most of the literatures abovementioned perform computerized analysis on badminton strokes using spatiotemporal (*x*-*y*-*t*) information without depth data. Such phenomenon might result performance degradation in terms of consistency and accuracy. In the real world, human body movements are indeed of 4-dimensional, *x*-*y*-*z*-*t*.

In the last two decades, athlete performance analysis, such as in badminton was mostly qualitative in nature. However, with the proliferation and advancement of computer and communication technologies which is related to input acquisition sensor, computer hardware and algorithms in recent years, computerized human motion analysis for athlete are becoming more popular. These systems are increasingly used to monitor performance of athletes, assess risk of injury and to support coaching activities such as in badminton[10–12,18,19]. However, majority of the approaches consisting of video analysis and adoption of physical body markers have inherently shortcomings. Video analysis technique requires system expert to annotate the videos in order to extract essential contents[20]. In addition, adoption of physical body markers tends to affect the performance of badminton player especially when asked to perform a complicated action[21].

In recent years, consumer grade markerless depth sensor, such as Microsoft Kinect sensor is getting more prevalent due to its inexpensive, reliable and robust algorithms in acquiring depth data. Microsoft Kinect sensor was initially bundled with Xbox 360 game console with the goal to enhance gaming experience. Interestingly, the sensor has attracted massive attentions from computer vision and robotics research community due to its broad application[22]. Recently, there have been several researches on motion analysis using Microsoft Kinect sensor[20,23–26], which is specifically applied on badminton.

In this paper, we investigate the potential and limitations of the Microsoft Kinect sensor for badminton performance analysis, particularly on novice badminton player.

2. Problem and Contribution

The emergence of the Microsoft Kinect sensor and skeleton tracking framework bring huge benefit to human centric computer vision tasks. However, not all badminton strokes can be measured accurately with the sensor. Ting, et al.[20] reported that relative low recognition accuracy was obtained for certain badminton strokes in recognition module which is mainly due to occlusion. Additionally, research works from Obdrzalek, et al.[27] and Wei, et al.[28] concluded the similar problem.

To the best of our knowledge, there has not been a study related with potential and limitation of Microsoft Kinect sensor for movement analysis on badminton. Therefore, our paper serves to provide a study in order to classify types of badminton strokes to be essentially mastered by beginner player, which can be adequately detected and measured by consumer grade depth sensors such as the Microsoft Kinect sensor. We focus only on selected badminton strokes to be essentially mastered by novice player as opined by expert badminton coaches. Our novel contribution is towards quantifying the potential and limitations of Kinect for badminton performance analysis and profiling. Moreover, we analyze performance of the badminton players using our developed algorithms[20].

The rest of the paper is organized as follows: Firstly, we provide an overview of the biomechanics in badminton sport. Secondly, expert badminton coaches' opinions on the most essential badminton strokes to be mastered by novice badminton player. Thirdly, we present the results of our evaluation of the consistency of the selected badminton strokes from badminton players using the Microsoft Kinect sensor, followed by a conclusion on the potential and limitations of Microsoft Kinect for badminton performance analysis and profiling.

3. Striking Skills in Badminton

Badminton requires player striking the shuttlecock called 'stroke'. Table 1 summarizes the range of badminton strokes that can be mastered by badminton players of all level of skills. Key categories of movement are serve, net shot, drop shot, drive, smash, clear, lift, and block[29].

Table 1. Range of badminton strokes

Category	Stokes
Serve	Forehand low, Forehand high, Backhand low, Flick serve
Net shot	Forehand crosscourt, Backhand crosscourt, Forehand touch, Backhand touch, Forehand push, Forehand brush, Backhand push, Backhand brush
Drop shot	Forehand, Forehand overhead, Forehand slice, Backhand, Backhand slice
Drive	Forehand, Backhand
Smash	Static, Jump, Forehand Cross court, Backhand
Clear	Forehand, Overhead, Backhand, Defensive, Attacking, Underarm, Forehand Crosscourt
Lift	Forehand, Backhand, Forehand Crosscourt
Block	Forehand, Backhand, Forehand Crosscourt

4. Expert Opinion of Key Badminton Strokes for Novice

With reference to the defined badminton training model[30], we define a novice player as a player that is not able to carry out the basic skills and footwork repeatedly. In addition, a novice player demonstrates poor shuttlecock striking quality, e.g. a deep clear is not sufficiently high and long; a drop shot is not close to the net. The player had also no prior training in coordination, power, fitness and muscle power. Moreover, a novice player never participated in any formal and/or recreational competition.

In order to determine which strokes are important to novice level player, a survey was conducted during badminton event of SUKMA (Sukan Malaysia) Sarawak XVIII in Sibu, Sarawak to rank the key badminton strokes must essentially to be mastered by novice badminton players. SUKMA is viewed as a professional national level competition in Malaysia. The survey's participants include coaches from different states of Malaysia. The coaches evaluated whether the specific stroke is important for novice level and ranked each category of general and detailed strokes as shown in Table 1. As a result, the following strokes are ranked as the most important to master for a novice level player: clear, net, lift and smash as detailed in Table 2.

Table 2. Overall consistency average similarity index for the selected badminton strokes

Stroke	Average Consistency Similarity Index (%)				
	Right Shoulder Joint	Right Elbow Joint	Right Wrist Joint	Right Hand Joint	Overall Average (%)
Forehand Crosscourt Lift	97.20	86.38	97.99	98.55	**95.03**
Backhand Touch Net	89.99	92.07	97.69	97.84	**94.40**
Backhand Lift	90.36	87.50	98.07	96.77	**93.18**
Forehand Lift	92.64	82.72	98.90	98.40	**93.16**
Forehand Push Net	96.73	78.86	98.04	98.22	**92.96**
Backhand Clear	84.36	90.13	97.16	97.24	**92.22**
Backhand Push Net	78.93	88.47	98.50	99.25	**91.29**
Forehand Touch Net	96.61	76.66	94.34	95.91	**90.88**
Forehand Clear	91.16	82.92	92.83	94.85	**90.44**
Overhead Forehand Clear	81.98	65.30	95.33	94.21	**84.21**
Jump Smash	79.45	66.56	86.24	83.98	**79.06**
Static Smash	76.69	59.70	85.92	88.28	**77.65**

5. Evaluation Results

The key focus of our study is to identify and quantify the potential and limitations of Microsoft Kinect sensor in analyzing and profiling badminton strokes of novice badminton players. In our study, we evaluated the consistency of the depth imaging captured by the Microsoft Kinect sensor for the key badminton strokes to be mastered by a novice level badminton player such as listed in Table 2. The selected badminton strokes are: *Backhand clear*, *backhand lift*, *backhand push net*, *backhand touch net*, *forehand clear*, *forehand crosscourt lift*, *forehand lift*, *forehand push net*, *forehand touch net*, *jump smash*, *overhead forehand clear* and *static smash* as highly ranked by badminton coaches.

To acquire badminton strokes depth map sequences, a right-handed badminton player is instructed to perform the selected badminton strokes for six times (where the first movement serves as reference movement) within three meters from the Microsoft Kinect sensor. Subsequently, algorithms and similarity index formula[20] are employed to perform movement analysis on the collected data. Specifically, our analysis is concentrating on right arm segment (right shoulder joint, right elbow joint, right wrist joint and right hand joint) due to the nature of the selected movements. Then, similarities index of four joints are obtained and overall average is computed for evaluation.

6. Results and Discussions

Table 2 shows the results of Overall Average Consistency Similarity Index (OACSI) for the selected badminton strokes. The Average Consistency Similarity Index (ACSI) for each joint (i.e. right shoulder, right elbow, right wrist and right hand) is attained from the five sample badminton strokes after self-benchmarking activity with the reference stroke. Then, OACSI is computed using the ACSI from each joint. Obviously, *jump smash*, *static smash* and *overhead forehand clear* achieved relative low similarity index as compared to other badminton strokes. The low similarity index may be due to occlusion of the body joint. For instance, the right shoulder and right elbow joints are occluded by forearm segment when the player is performing a vertical swinging motion for *jump* and *static smash*. Besides, the low similarity index can also be attributed to the loss of acquisition data due to fast moving motion. The Microsoft Kinect sensor, which is catered with frame rate of 30, might not be sufficient to capture adequate detail of the fast-moving motion, for instance, smash commonly associated with power and speed. Figure 1 exhibits the inconsistency analysis of right elbow joint for *static smash*.

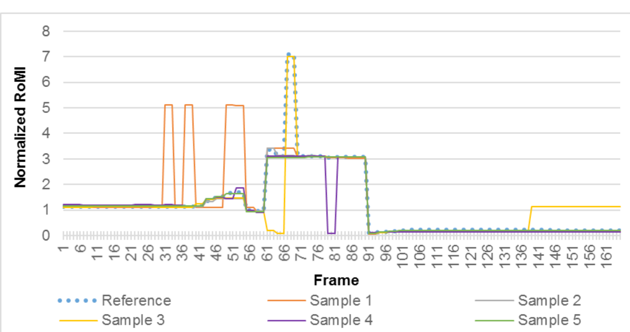

Figure 1. Consistency graph of right elbow joint for static smash.

7. Conclusion

In conclusion, we have successfully identified the key badminton strokes that can be measured and analyzed accurately and consistently with Microsoft Kinect sensor are as *forehand crosscourt lift, backhand touch net, backhand lift, forehand lift, forehand push net, backhand clear, backhand push net, forehand touch net* and *forehand clear*. At the same time, it is also found that Microsoft Kinect sensor measurements are limited for badminton strokes such as *static smash*, *jump smash* and *overhead forehand clear*.

Moving forward, more experimentation with novice players will be carried out to confirm the consistency of Microsoft Kinect sensor for performance analysis such as to include left-hander players. Besides, the current performance analysis algorithm using skeleton information will be incorporated with color information in order to resolve the occlusion issue. Furthermore, we envision ultimately correlating the analysis results with badminton players' biometric data such as heart beat and breathing rates.

8. Acknowledgements

This work was supported by University College of Technology Sarawak research grant.

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