Assessment the Speed-up Detection System for Testing Sprinters’ Performances Using Computer Vision Techniques

Teerawat Kamnardsiri

Received 14 September 2018 • Revised 23 October 2018 • Accepted 24 November 2018

Abstract: Objectives: This paper aims to implement the speed-up detection system for testing sprinters’ performances and also, the system is to assess with the standard video analysis software. Methods/Statistical analysis: This cross-sectional study investigates the relationship between the proposed system and the standard video analysis software (Tracker). Seven athletes (age between 19 to 42) were randomly selected for data collecting. The participants performed a fastest running with static starts at about 25 m. from the Designated point. Descriptive statistics, Cross-tabulation and also Spearman’s Rho were used for statistical analysis. Besides, the root mean square error (RMS Error) and the relative root mean square error (Relative RMS Error) were employed for comparing of both systems. Findings: The results indicated the strong significant relationship between both systems at Spearman’s Rho Correlation > 0.99 at p-value < .0001. The findings, moreover, revealed that the proposed system could be used to evaluate sprinters’ performances accurately. Application/Improvements: the proposed system will be useful in several fields such as biomechanics of sport, physical therapy, rehabilitation, etc.

Keywords: Computer vision, image processing, video analysis, sprinter, speed detection, validity.

INTRODUCTION

Sprint running is one of the Track sport that is a cyclic movement. The speed of a sprinter has to run as fast as possible. There are two main phases in the cyclic running movement as the supporting and the non-supporting phase [1]. In coaching sprinter, it is very difficult to detect instantaneous speed and the maximum speed of the sprinter that is the main problem of coaches. Due to human visual system cannot be detected the instantaneous speed at each period of entirely distance. Many researchers study in the detection of speed, for example, walking and running instantaneous speed detection using an image-processing based technique [2], walking speed detection using an ambient measurement system (AMS) [3], walking and running speed measurement using a low-cost laser [4]. Recently, there are several studied in human motion capture system for sports application, for instance, indoor, outdoor, team, individual of sports such as Track and Field, Tennis, Cycling, Soccer, etc. [5]. Those studies need the system to collect and analyse the performance athletes for developing individual athlete’s training plans. In the traditional method, a stopwatch has been used for measuring the speed by distance/time. However, this method provided just the average of speed, but the results had more errors that were caused by human error [6]. Thus, this paper is to implement the speed-up detection system to test sprinters’ performances, and also the system is to validate with the standard video analysis software.

METHODS

Speed Detection System

Calibration of the Capture Volume

The background video was captured in the movie format (.MOV) at 1280×720 pixels of the resolution, and then the first frame was converted to the image format. There are two marker M1 and M2 in the background image. To initiate the calibration of the proposed system, two steps of mouse click were first:
the designed position at the M1 marker and second: five meters far from the Designed position at the M2. Afterwards, the resolution of the background image was calculated the whole distance of the capture volume.

**Background Subtraction**

To split the human's body, the foreground video was captured in the movie format (.MOV) as well. The background subtracted each frame of the movie. Subtraction value of each pixel \( \text{Body}(x,y) \) was determined the large difference values as 'foreground' whereas, the difference value close to zero as 'background'. A binary image \( \text{Body}(x,y) \) was given by (1).

\[
\text{Body}(x,y) = \begin{cases} 
1 & \text{if } \text{Body}_k(x,y) > \tau \\
0 & \text{otherwise}
\end{cases}
\]  

where, \( \tau \) was the threshold.

**Noise Reduction**

The threshold was used for reducing of noises from each subtracted image which caused by shadows shifting, brightness changing, etc. Hence, the threshold value was determined between 0 and 255 (8-bit images). In this study, the threshold was set at \( \tau = 120 \). Besides, the noises of the subtracted image were eliminated by the two-dimension median filter (2 x 2 adjacent pixels).

**Detection the Starting Point**

The geometric centroid position of the human body or the body's centre of mass (COM) was highlighted to calculate regarding pixels in the horizontal as well as vertical directions. The COM was determined by two-dimensional planar lamina [8]. The body position \( \text{Body}_{\text{position}} \) was given by (2) to (5).

\[
\text{Body}_{\text{position}} = (x_{\text{com}}, y_{\text{com}}) \quad (2)
\]

where,

\[
x_{\text{com}} = \frac{\sum_{k=1}^{N} m_k x_k}{M} \quad (3)
\]

and

\[
y_{\text{com}} = \frac{\sum_{k=1}^{N} m_k y_k}{M} \quad (4)
\]

where,

\[
M = \sum_{k=1}^{N} m_k = \text{totalmass} \quad (5)
\]

The Designated point \( \text{Designated}_{\text{point}} \) was determined by the calibration. Moreover, the starting point \( \text{Starting}_{\text{point}} \) was defined by (6).

\[
\text{Starting}_{\text{point}} = \text{Designated}_{\text{point}} - \text{Body}_{\text{position}} \quad (6)
\]

**Detection Instantaneous Speed**

To obtain instantaneous speed, the COM position in the geometry coordinate system was collected in term of the array. Additionally, the instantaneous speed \( v \) of each step of time \( \text{Timestep} \) was given by (7) to (9).

\[
v_{\text{inx}} = \frac{\hat{x}_{\text{inx}}}{\hat{t}_{\text{inx}}} \quad (7)
\]

where,

\[
\hat{x} = x_{\text{inx}} + \text{Timestep} - x_{\text{inx}} \quad (8)
\]

and

\[
\hat{t} = t_{\text{inx}} + \text{Timestep} - t_{\text{inx}} \quad (9)
\]

**Participants**

Seven elite athletes participated in the fastest running test validity study. Participants were recruited from Chiang Mai University Athletic Club in Chiang Mai, Thailand. The inclusion criteria included a healthy adults age 19 to 42, who could run at the fastest level. The exclusion criteria included uncorrected
visual and vestibular problems and musculoskeletal injury. All participants provided informed consent for participation.

**Protocol**

Running assessments of whole distance, total speed, speed and maximum speed were performed for fast running on the synthetic running track, flat and dry. Length about 25 meters was used for testing. Marker M2 far from M1 (Designated point) equivalent 5 meters. The Starting point for each participant was random between 15-25 meters. The camera was fixed on the tripod which height from the floor about 1.5 meters. The camera position far from the running track about 20 meters and 15 meters from the M1 as shown in Fig. 1.

**Data collection**

Running of participants was recorded with a stationary video camera (Nikon 1 J1, Nikon, Japan) at 60 Hz. A video format is MOV. A resolution of 1280 x 720 pixels was performed for all videos. The participant performed one trial as running at the fastest speed from the starting point to the Designated point.

**Data and Statistical analysis**

Seven videos (MOV format) were collected from the standard video camera were transferred to a personal computer. These videos were then analysed by the proposed system and also Tracker video analysis software (Tracker). The variables such as total distance, total speed, speed and maximum speed were calculated using the proposed system and also the Tracker video analysis software. Additionally,

\[ RMS Error = \sqrt{\frac{1}{N} \sum_{k=1}^{N} (Proposed\ system(s_k) - Tracker(s_k))^2} \]  

\[ Relative\ RMS\ Error = \frac{RMS\ Error}{\sqrt{\frac{1}{N} \sum_{k=1}^{N} (Proposed\ system(s_k))^2}} \]

**Statistical Analyses**

IBM SPSS Statistics 21 for Windows (SPSS Inc., Chicago, IL, USA) was used in this study for the statistical analyses of data, p-value < 0.05 was considered as statistically significant. Descriptive statistics (means, SD and variance) were calculated for the demographic characteristics of participants. Pearson product-moment correlation was employed for calculating the relationship of instantaneous speed data between systems of each participant. Additionally, the Spearman’s Rho correlation coefficients between
the proposed system and Tracker was performed for calculating the relationship of Total Distance (m), Total Time (s), Running Speed (m.s⁻¹) and Maximum Speed (m.s⁻¹).

RESULTS

Descriptive Statistics

Seven participants (four males and three females) completed the fast running without incident. Table 1 shows the demographic characteristics of participants. The average age is 26.00 (SD=10.63, Variance=113). The average weight is 63.14 kg (SD=10.18, Variance=103.81). The average height is 1.74 m (SD=0.04, Variance=0.00). The average Body Mass Index (BMI) is 18.09 kg.m⁻² (SD=2.57, Variance=6.61).

Table 1: Participants’ demographic characteristics

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Height (m)</th>
<th>BMI (kg.m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>male</td>
<td>19</td>
<td>65</td>
<td>1.75</td>
<td>18.57</td>
</tr>
<tr>
<td>T2</td>
<td>male</td>
<td>19</td>
<td>58</td>
<td>1.67</td>
<td>13.77</td>
</tr>
<tr>
<td>T3</td>
<td>male</td>
<td>41</td>
<td>75</td>
<td>1.80</td>
<td>20.83</td>
</tr>
<tr>
<td>T4</td>
<td>male</td>
<td>42</td>
<td>79</td>
<td>1.78</td>
<td>22.19</td>
</tr>
<tr>
<td>T5</td>
<td>female</td>
<td>21</td>
<td>56</td>
<td>1.75</td>
<td>16.00</td>
</tr>
<tr>
<td>T6</td>
<td>female</td>
<td>21</td>
<td>54</td>
<td>1.74</td>
<td>15.52</td>
</tr>
<tr>
<td>T7</td>
<td>female</td>
<td>19</td>
<td>55</td>
<td>1.70</td>
<td>16.18</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>26.00</td>
<td>63.14</td>
<td>1.74</td>
<td>18.09</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>10.63</td>
<td>10.18</td>
<td>0.04</td>
<td>2.57</td>
</tr>
<tr>
<td>Variance</td>
<td></td>
<td>113</td>
<td>103.81</td>
<td>0.00</td>
<td>6.61</td>
</tr>
</tbody>
</table>

The association between the proposed system and Tracker

Table 2 reports the measurement RMS error, Relative RMS Error of each participant and Pearson’ product-moment correlation coefficients between pairs of speed assessment. Overall, the average of RMS Error of the Position was 0.058 m (SD = 0.04), and the average of Relative RMS Error was 0.9%. Furthermore, the average of RMS Error of the speed was 0.572 m.s⁻¹ (SE = 0.128), and the average of Relative RMS Error was 11.6%. Pearson’s product-moment correlation coefficient between both systems of Position (m) data r = 1.000 (p < .0001) and Speed (m.s⁻¹) data r = .975 (p < .0001).

Fig. 2 and Fig. 3 show Bland-Altman plots comparing the running speed measured of the participant of T3 as the highest of Relative RMS Error (13.8%, n=21) and T4 as the lowest of Relative RMS Error (9.3%, n=28), respectively. Besides, a quadratic regression and a linear regression with 95% confidence interval between the two systems were performed. And also, typical curves of the speed and position during sprinting initiation of T3 and T4 were displayed in Fig. 4.

Table 2: The comparison of error between the proposed system and Tracker video analysis tool. Average over the seven participants and standard deviation (S.D.) are shown. RMS error and Relative RMS Error are the root mean squares of the differences between two curves. Pearson’s product-moment correlation coefficient (r) between both systems of Speed (m.s⁻¹) data and Position (m) data for a fastest running condition are reported.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Speed</th>
<th></th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RMS Error (m.s⁻¹)</td>
<td>Relative RMS Error</td>
<td>r</td>
</tr>
<tr>
<td>T1 (n=28)</td>
<td>0.668</td>
<td>11.9%</td>
<td>0.988</td>
</tr>
<tr>
<td>T2 (n=28)</td>
<td>0.607</td>
<td>10.2%</td>
<td>0.900</td>
</tr>
<tr>
<td>T3 (n=21)</td>
<td>0.797</td>
<td>13.8%</td>
<td>0.996</td>
</tr>
<tr>
<td>T4 (n=28)</td>
<td>0.498</td>
<td>9.3%</td>
<td>0.987</td>
</tr>
<tr>
<td>T5 (n=32)</td>
<td>0.529</td>
<td>11.9%</td>
<td>0.978</td>
</tr>
<tr>
<td>T6 (n=35)</td>
<td>0.419</td>
<td>11.5%</td>
<td>0.990</td>
</tr>
<tr>
<td>T7 (n=33)</td>
<td>0.488</td>
<td>12.5%</td>
<td>0.988</td>
</tr>
<tr>
<td>Average</td>
<td>0.572</td>
<td>11.6%</td>
<td>0.975</td>
</tr>
<tr>
<td>SD</td>
<td>0.128</td>
<td>1.5</td>
<td>0.034</td>
</tr>
</tbody>
</table>

Note: All p-value for all the correlations above are < .0001.
Table 3. Spearman’s Rho correlation coefficients between systems (N=7).

<table>
<thead>
<tr>
<th></th>
<th>Proposed system Mean (S.D.)</th>
<th>Tracker Mean (S.D.)</th>
<th>Spearman’s Rho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (m)</td>
<td>21.5 (2.18)</td>
<td>21.13 (2.21)</td>
<td>1.000**</td>
</tr>
<tr>
<td>Time (s)</td>
<td>4.13 (0.60)</td>
<td>4.24 (0.67)</td>
<td>0.991**</td>
</tr>
<tr>
<td>Speed (m.s⁻¹)</td>
<td>5.20 (0.85)</td>
<td>5.13 (0.79)</td>
<td>1.000**</td>
</tr>
<tr>
<td>Maximum Speed (m.s⁻¹)</td>
<td>6.96 (1.01)</td>
<td>7.22 (1.04)</td>
<td>1.000**</td>
</tr>
</tbody>
</table>

Note: **significant relationship to Tracker (p < .0001).

Fig. 2. (a) Bland-Altman plots of the proposed system vs. Tracker of the speed, (b) Quadratic regression plots with 95% confidence intervals of the speed, (c) Bland-Altman plots of the proposed system vs. Tracker of the position and (d) Linear regression plots with 95% confidence intervals of the position, T3 (n=21).

Fig. 3. (a) Bland-Altman plots of the proposed system vs. Tracker of the speed, (b) Quadratic regression plots with 95% confidence intervals of the speed, (c) Bland-Altman plots of the proposed system vs. Tracker of the position and (d) Linear regression plots with 95% confidence intervals of the position, T4 (n=28).
The Speed Detection System Validity

The correlation of the proposed system and Tracker was high and significant when measured all four variables (Total Distance (m), Total Time (s), Running Speed (m.s\(^{-1}\)) and Maximum Speed (m.s\(^{-1}\)), ranging from 0.991 to 1.000. Spearman’s Rho correlation coefficients between the proposed system and Tracker are presented in Table 3.

CONCLUSION AND FUTURE WORKS

The results of this study have demonstrated that the proposed system is a valid assessment tool for measuring fast running in sprinters aged between 19 and 42 years. The long-distance bout 25 meters, especially, showed somewhat good validity. The speed-up detection system for testing sprinters’ performances is advantageous and suitable for roughness measuring speed performance of athletes. Moreover, the proposed system will be useful in several fields such as biomechanics of sport, physical therapy, rehabilitation, etc. Future research should examine whether with the long distance (100 m.) in comparison with the timing gate or stopwatch. Lastly, more care should be taken when testing the fastest running in athletes, who must prepare and warm-up the body before the test.

ACKNOWLEDGEMENTS

This study was supported by the College of Arts, Media and Technology (CAMT), Chiang Mai University, Chiang Mai, Thailand. Besides, the authors would like to thank the Student Development Division of Chiang Mai University for supporting the main stadium and also the Embedded System & Mobile Application Laboratory.

REFERENCES

