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High Speed Motion Tracking for Weightlifting based on Correlation Coefficient Template Matching

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Abstract*— Tracking of motion in weightlifting is a challenging task. This paper presents a method for tracking Weightlifting bar movement of an athlete. The proposed method uses three different template creation techniques for tracking and applies Wilcoxon Signed rank test to evaluate the results. The method was tested with normally captured data (30fps) and data captured in slow motion (100fps) separately. For the normally captured data, combined dynamic templates method has the highest accuracy of 95% in tracking the trajectory. For slow motion data Wilcoxon Signed Rank generated equal results for all three template creation methods.

Index Terms*— Tracking Algorithms, Block Matching Algorithms, Fast Motion Tracking.

I. INTRODUCTION

A sport is a competitive physical activity which contributes to the improvement of physical, social and psychological aspects of life. It also gives entertainment to the participants. Competitiveness of sports is ever increasing and every professional athlete's ultimate aim is winning an international medal like an Olympic gold medal. Therefore, athletes try to improve their techniques in order achieve this goal. Developed countries spend large amounts of money to develop their athlete's techniques. On the contrary, developing countries such as Sri Lanka cannot spend that much of money to improve sports techniques. Therefore such countries need low cost new technologies as an alternative.

The invention of computers has greatly modernized and improved the world of athletics. Computer technology allows for increased accuracy in different sporting events and can be used to correct athlete's bio-mechanics techniques which are difficult to evaluate using naked eye.

Weightlifting is a power sport that is carried out in less than one minute and the athletes need highly accurate technique for reaching their targets. The two competition lifts in order are the "Snatch" and the "Clean and Jerk". This research work mainly concentrates on the snatch. The Snatch requires the dragging of the bar from the bottom to top in 6 phases [1].

Main 3 phases are depicted in Figure 1. Bar moving trajectory and other variant features such as bar travelling distance and velocity can track athlete's technical errors[2][3][4].

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II. WEIGHTLIFTING BAR TRACKING

The major task of this work is to track the weightlifting bar movement of a video sequence. This is achieved by obtaining the interest points of a specific object which is subjected to a particular motion, in two consecutive frames. Continuation of finding the correspondence of the next two consecutive frames, while using the previous result as a new object, makes up the tracking process. In this research work, the tracking object is the Weightlifting bar. Normally weightlifting bar motion is very fast. Due to this fast movement of the weightlifting bar, capturing clear images in the second pull is a challenging task. Therefore, two cameras; one camera with 30fps and the other camera with 100fps, were used in capturing the images. Slow motion mode captures 100fps with 1 second extracting to 12 seconds.

The second pull is the fastest motion area in Weightlifting bar travelling. This section of the video frames has been used in order to decide on a search block size (Figure 2). The maximum bar travelling distance in two consecutive frames is obtained manually and used as the size of the square search block [5][6].

The macro block size is considered as the diameter of the bar. Macro block area of the first frame of the video sequence is selected manually and is considered as the initiating template of the tracking process. The framework of tracking is shown in Figure 3.

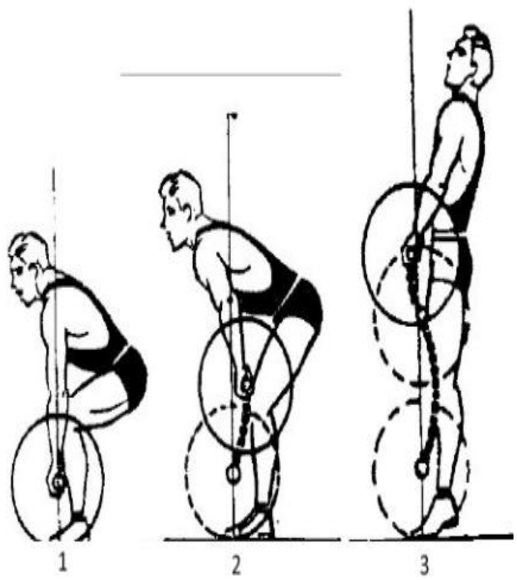

Figure 1- Main three phases of the Snatch

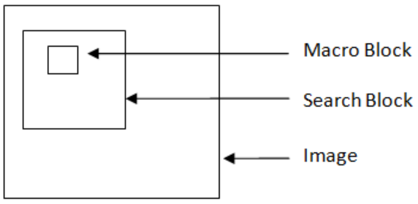

Figure 2- Template Matching Blocks

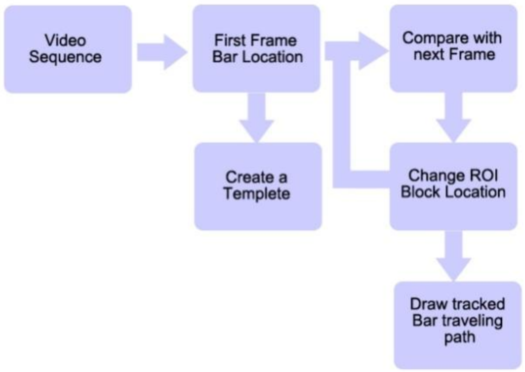

Figure 3- Framework of Tracking moving Weightlifting Bar

A. Templates Creation

Template matching techniques are commonly used in computer vision for object tracking purposes. In a video sequence, the temple from first video frame is selected manually by considering the bar as a template (Figure 4) and three different methods have been used to create the template for the rest of the frames in the sequence:

Figure 4- Manually selected bar First Frame

The template is unchanged for selected video sequence -Constant template matching.

The first video frame's selected template matches with the next video frame. The second frame's best matching area is selected as a new template -Variable template matching.

The Constant template and variable template are combined by taking the average of the two images and the resulting image is used as a template - This template is also changing dynamically.

The video camera is placed perpendicular to the trajectory with a minimum distance of 4 meters, because 4 meters is the minimum range that the camera can be placed to capture the full weightlifting bar trajectory. (Figure 5). When the bar is captured within a range of 4 meters, the size of the bar in the captured image is composed of approximately 20 pixels.

Figure 5-Capturing data in National Weightlifting Championships, Camera is perpendicular to bar motion.

B. Templates Matching Algorithms

Three template matching algorithms were used and tested as discussed below. *(x,y)* is the search block pixel position and *(x',y')* is the macro block pixel positions. *T* is the macro block and *I* is the search block. *w* and *h* are width and height of image.

$$R_{sqdiff}(x,y) = \frac{\sum_{x'y'}\left[T(x',y') - I(x+x',y+y')\right]^2}{\sqrt{\sum_{x'y'}T(x',y')^2\sum_{x'y'}I(x+x',y+y')^2}} \quad (1)$$

Method 1: Square difference matching method matches the squared difference (1). Therefore, a perfect match will give a value of zero and a bad match will give a large value.

$$R_{ccorr}(x,y) = \frac{\sum_{x'y'}\left[T(x',y')I(x+x',y+y')\right]}{\sqrt{\sum_{x'y'}T(x',y')^2\sum_{x'y'}I(x+x',y+y')^2}} \quad (2)$$

Method 2: Cross Correlation matching method multiplicatively matches the template against an image generating a perfect match with a large value and a bad match with a small value or a zero (2).

$$R_{corrcoeff}(x,y) = \frac{\sum_{x'y'}\left[T'(x',y')I'(x+x',y+y')\right]}{\sqrt{\sum_{x'y'}T'(x',y')^2\sum_{x'y'}I'(x+x',y+y')^2}} \quad (3)$$

Where $T'(x',y') = T(x',y') - \frac{1}{wh}\sum_{x'y'}T(x',y')$ and

$$I'(x+x',y+y') = I(x+x',y+y') - \frac{1}{wh}\sum_{x'y'}I(x+x',y+y')$$

Method 3: Correlation coefficient matching method matches a template relative to its mean against an image so a perfect match will provide a value of 1 and a perfect mismatch will provide a value of –1(Equ 3). A value of 0 simply means that there is no correlation.

After testing the above three methods as the matching criteria, Correlation Coefficient based template matching was selected as the best method [7].

III. RESULTS AND DISCUSSION

A simple GUI was designed in order to get the ideal path from a video sequence using the feedbacks from a weightlifting expert. Two trajectories were generated manually by two experts. Two such pairs of trajectories were then compared together to generate one optimal trajectory that was considered as the ground truth. The three trajectories, each taken from three separate automated methods were compared with the ground truth.

Parametric tests cannot be applied to the obtained data sets since the y values are not normally distributed. Therefore, Wilcoxon Signed Rank test is applied to the data set [8]. The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test which can be used to test the median of a single sample and also to obtain the (1-α)% confidence interval for the true median, where α is the significance level of the test. In this analysis, the α is taken as 0.05 and hence 95% confidence intervals are obtained for the median. The obtained 95% confidence intervals for the median of x and y values measured from the three methods were compared [9]. The tracking methods have an acceptable error of ±10 which is half of the size of the bar. 36 observations were obtained on x and y separately. The same test was repeated for 10 slow motion observations. In addition to the Wilcoxon Signed Rank methods, multiple box-plots are also used for graphical comparison of three methods. Tables 1 and 2 give the Wilcoxon Signed Rank results for data captured with normal speed and slow motion data respectively. Figure 6 shows the box-plot comparison of the three methods. All the results were calculated using Minitab Statistical software.

In slow motion results no major difference was obtained from the comparison of the three methods. The results showed that the application of the Wilcoxon Signed Rank generated similar results for all the three methods.

Figure 7 shows the tracking output obtained with the tool developed using the method described above.

TABLE I: WILCOXON SIGNED RANK RESULTS FOR DATA CAPTURED WITH NORMAL SPEED

	N	Estimated Median	Achieved Confidence	Confidence Interval	
				Lower	Upper
M1 dev x	1080	4.00	94.9	3.00	5.50
M1 dev y	1080	-12.00	94.9	-15.50	-8.00
M2 dev x	1080	4.50	94.9	2.50	6.50
M2 dev y	1080	-9.00	94.9	-12.00	-7.00
M3 dev x	1080	5.00	94.9	3.50	7.00
M3 dev y	1080	8.00	94.9	5.50	10.00

TABLE 2: WILCOXON SIGNED RANK RESULTS FOR SLOW MOTION DATA

	N	Estimated Median	Achieved Confidence	Confidence Interval	
				Lower	Upper
M1 dev x	300	-0.50	95.0	-1.00	0.00
M1 dev y	300	0.50	95.0	0.00	1.00
M2 dev x	300	0.00	95.0	-1.00	0.50
M2 dev y	300	-1.00	95.0	-1.50	0.00
M3 dev x	300	0.00	95.0	-0.50	1.00
M3 dev y	300	-1.00	95.0	-2.00	-0.50

IV. CONCLUSION

In this research, different weightlifting bar tracking algorithms were implemented and tested to evaluate the accuracy of each. The datasets obtained from slow motion camera and the normal camera were tested separately and compared against with ground truth. The accuracy gets low in fast image sequences of the video obtained from the normal camera, because the camera tends to capture blurred images when the actual motion fast. For the videos obtained from the normal camera, the combined static and dynamic template method generates good results. The Wilcoxon Signed Rank 95% confidence interval for the median of x and y values measured from the method lie within the -10 to +10 range. The other methods produce confidence intervals outside the -10 to +10 range.

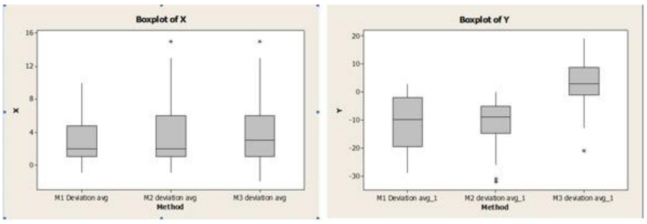

Figure 6: Box-Plots Comparison of the Three Methods

Fig 7- Final Weightlifting Bar Tracking Out put

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