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Abnormal gait detection using Hexagonal method on Model based Front view model

Gait abnormality recognition would be very useful in medical monitoring and surveillance system. In this research, analysis of front view human gait silhouette had been done to investigate the possibility of the method in recognizing abnormality on proposed model-based approach. The model based which utilised hexagonal theorem as feature extraction method is used to produce the vertical angles of both hip and knee for 70 image sequences as feature vectors for both legs for one complete cycle sequences. Consequently, a total of 280 features generated based on four parameters from the lower limb of human body for gait abnormality purpose. Further, the gait features extracted from different gait pattern namely as normal, drunken, dragging and tiptoed is classified as normal or abnormal using ANN and KNN. Improvement findings of classification result for before and after normalisation confirmed that the proposed method suited to be utilized as gait abnormality recognition based on human gait pattern.

Keywords: Hexagonal; abnormal gait; model based; ANN; KNN.

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1. Introduction

Gait analysis and detection usually used as health monitoring and gait rehabilitation in medical work. It also gradually popular used as abnormality movement detection in surveillance system which used as unordinary or suspected gait. Recently, several of human abnormality detection method was perform by many researchers and most of them utilised sensors or marker on their devices. A mobile gait monitoring system based on smart shoes explored by [1] which utilised shoes with equipped ground contact force (GFC) in feet to provide visual information in following a reference normal pattern of GCF. Then, using quite similar type of shoe-integrated system, angular velocities and acceleration measured using gyroscopes and accelerometers as mentions in [2].

Example of task for abnormality detection usage in clinical work elaborated briefly in this literature. Falling possibilities and abnormal of walking pattern discussed by [3] where it related on Zero Moment Point (ZMP) locus captured from signal of low-cost Force Sensitive Resistors (FSRs). Further, frame-to-frame optical flows computation of computer vision approach utilised silhouette-masked flow of motion metrics on histogram form and eigenspace transformation of human silhouettes extraction as explored in [4]. Additionally, model sensitivity of abnormal gait patterns by prediction knee joint contact forces numerical model from TKR's stance phase of subjects gait investigated by [5]. Instability condition gait of Parkinson patient studied by [6] which related on basic, kinematic and kinetic parameters of gait such as cadence, step length, walking speed and mean of stride time while walking involved.

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Further, surveillance and gait monitoring also utilised abnormality detection as part of their new contribution method. As mentioned in [7], a robust vector space embedding of segmented body silhouettes provides from homeomorphisms between 2D lattices and binary shapes provides an idea in detection of unusual movement pattern behaviour in gait study was explored. Nevertheless, abnormal walking types was analyse by [8] with aspect ratio as features which related individual length of leg and height was observed. Consequently, Extreme Learning Machine was used replacing Support Vector Machine as classifier of abnormality gait using pre-normalization of T-Test was explored by [9]. For instance, Discrete Fourier Transform (DFT) method by frequency domain of angle joint as features and coefficient of harmonic has been run by [10] in analyzing an abnormality gait task. In our research work, model based front view gait modelling was proposed which consists of modified human sticks figure with hexagonal method in extracting gait features for abnormality gait detection.

2. Methodology

In this section the method used for front view modelling of human gait is discussed in detail. The overview of the step of procedures is as shown in Figure 1.

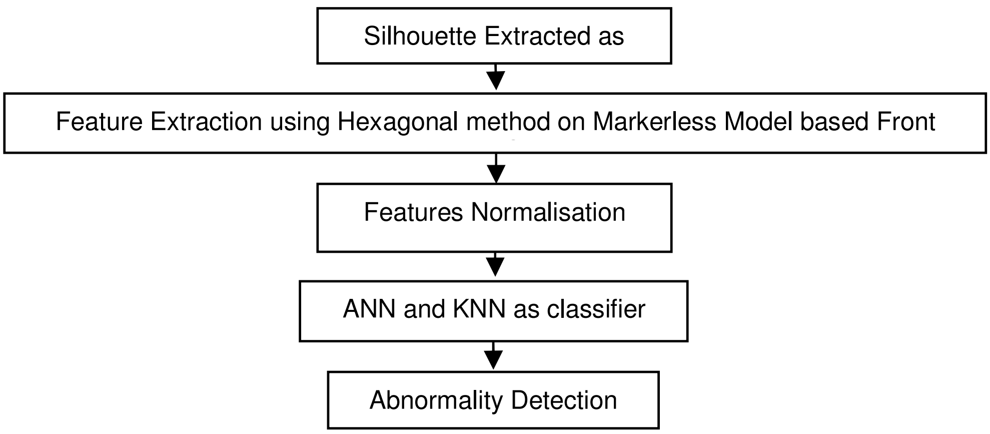


Figure 1: General overview of the step of procedure.

2.1. Human Modelling

Basic of anatomical human body knowledge was utilised in studying human body structure for the gait analysis. For body height H, the vertical position estimation of the neck, shoulder, waist, pelvis, knee, and ankle was set by anatomical data to be $0.870H$, $0.818H$, $0.530H$, $0.480H$, $0.255H$, and $0.030H$, respectively. However, this research will only use body segments related to leg, along with the hip to toe joint from overall of human body as shows in Figure 2. Proposed front view markerless model method previously elaborated in [11] with amendment on features extraction method part from pendulum to hexagonal theory.

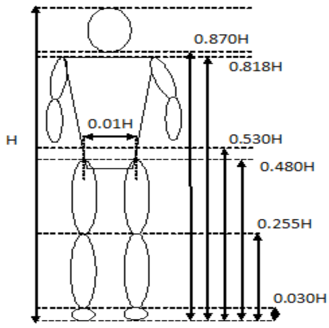


Figure 2: Anatomy of human body for front view

2.2. Thigh and knee model by hexagon theory

An interior angles of a polygon can be defined as the angles inside of a polygon formed by each pair of adjacent sides as elaborated in [12]. The type of hexagonal used is irregular shape angles as shown in Figure 3 which consist of different angles value for each side.

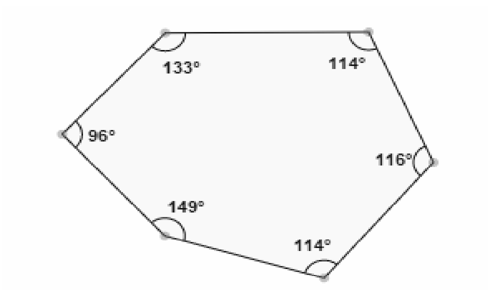


Figure 3: Irregular hexagonal angles

Consequently, in referring Figure 5, edges of the angles between line A2A1 and line A1B can be calculated as in equation (1) for triangular shape with angles and side as in Figure 4.

$$A = \cos^{-1}\left[\frac{b^2 + c^2 - a^2}{2bc}\right] \tag{1}$$

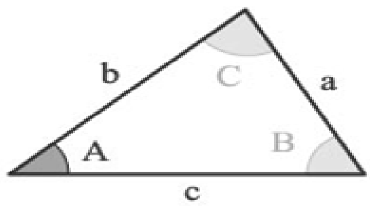


Figure 4: Triangular shape used

Total of 6 edges of the hexagonal is equal to 720 degree state in previous standard equation of hexagonal and then can be elaborated as a formula form as in equation (2).

$$\text{Total of Hexagonal angles} = \theta_{T1} + \theta_{T2} + \theta_{K1} + \theta_{K2} + \theta_{A1} + \theta_{A2} \tag{2}$$

Part of mathematical equation of the angle calculation method can be elaborated as in pseudocode:

Begin of Program
If (slope of AB less than zero)
If (slope of BC less than 0) and (slope of BC greater than slope of AB) then
Angle of Right Knee = 360 – Angle of Right Knee
End
End of Program

2.3. Front view model

The stick figure for front view model comprised of seven joint angles as A1 for left leg hip joint, A2 for right leg hip joint, B for left knee, C for left ankle, D for right knee, E for right ankle and W for hip. As in Figure 5, thigh angle for left leg and right leg is represented by θ_{T1} and θ_{T2} respectively, the angle of the knee by θ_{K1} and θ_{K2}, and the angle of the ankle by θ_{A1} and θ_{A2} which described joint angles of human stick figure from front side view. The additional joints that have been added compared with the side view model are the left and right hip joint, A1 and A2 respectively.

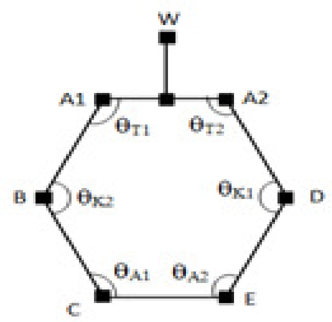
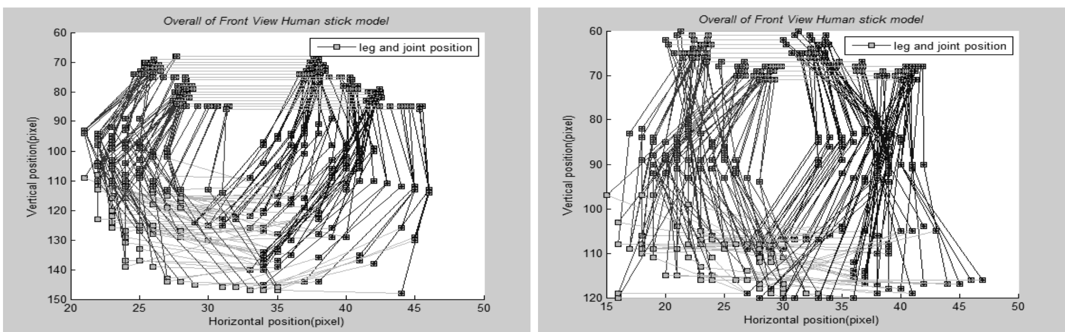


Figure 5: Stick figure for front view leg joint

3. Result

3.1. Front View Gait Modelling

Markerless based front view gait modeling was used in generating gait data for one complete cycle. It consists of gait angles for lower part of human body specifically from thigh to heel. From the model, hexagonal stick figure for one complete sequences of gait cycles was captured as depicted in Figure 6(a) and Figure 6(b) which consists of 70 hexagons for each normal and abnormal gait.



(a) (b)

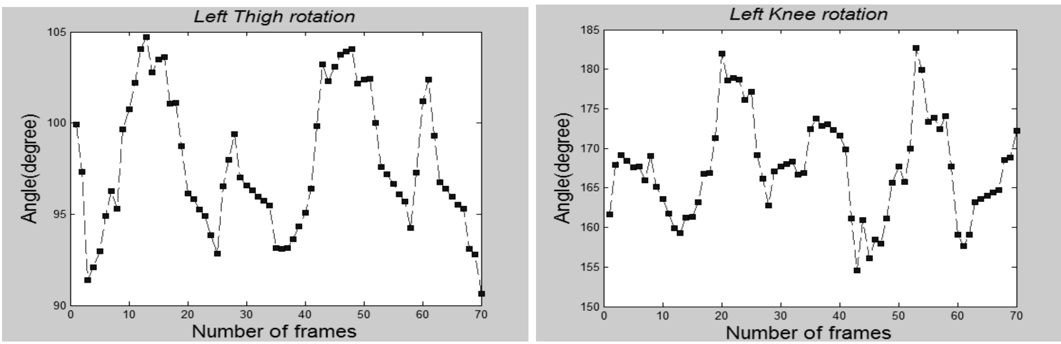
Figure 6: Overall gait sequences for one complete cycle for (a) Normal (b) Abnormal

3.2. Front View Data Extraction and Normalisation

Nineteen set of gait which consists of train and test data respectively divided equally into two sets of input data from extracted gait angles. From the model, 6 parameters extracted which specifically both left and right thigh, knee and ankle rotations namely as ‘data train’ for training and ‘data test’ for testing. In this classification task, only thigh and knee angles for both leg would be used as input features which consists of 70 stick figure in one complete cycles gait, totally 280 features per set. The sample features namely left and right thigh extracted and parts of it plotted as in Figure 7 for complete cycle of gait sequences. Normalise method used are normal shifting phase value (x-axis) into minimum distance between 2 point of difference set, using distance calculation as in equation (3) in reducing gap between gait features.

$$\text{Distance} = \sqrt{(x1 - x2)^2 + (y1 - y2)^2} \quad (3)$$

Where (x_1,y_1) and (x_2,y_2) are the coordinates of the given points for calculated distance.



(a) (b)

Figure 7: Sample of two types of angle features parameters for (a) Left thigh and (b) Left knee

3.3. Abnormal gait classification using Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN) network.

Table 1 and Table 2 tabulated the classification rate based on abnormality gait recognition for hexagonal gait features parameters using two type of neural network used before and after normalisation. KNN utilise Euclidean and Cityblock distance as distance metric whilst ANN sets Scaled Conjugate Gradient (SCG) and Levenberg-Marquadt (LM) optimization method for their training algorithm.

Table 1: Classification rate with feature as input to KNN and ANN before normalise

ACTUAL CATEGORY	PREDICTED CATEGORY (KNN)				PREDICTED CATEGORY (ANN)			
	Euclidean		Cityblock		SCG		LM	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
Normal	8 (100%)	0	8 (100%)	0	7 (88%)	1	7 (88%)	1
Abnormal	3	8 (73%)	3	8 (73%)	3	8 (73%)	2	9 (82%)

Table 2: Classification rate with feature as input to KNN and ANN after normalise

ACTUAL CATEGORY	PREDICTED CATEGORY (KNN)				PREDICTED CATEGORY (ANN)			
	Euclidean		Cityblock		SCG		LM	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
Normal	8 (100%)	0	8 (100%)	0	8 (100%)	0	7 (88%)	1
Abnormal	2	9 (82%)	3	8 (73%)	3	8 (73%)	3	8 (73%)

From the tables, it can be observed that using all four features namely left thigh, left knee, right thigh and right knee in KNN and ANN managed to recognize human gait abnormality with 100 to 73 percent rate using Cityblock, Euclidean, SCG and LM respectively without normalization. Additionally, classification using KNN with Euclidean method leads as highest accuracy rate of abnormality detection with 100 percent and 73 percent compared to ANN. Whilst, for a same method using Cityblock, it increased to 100 percent and 82 percent after normalization. SCG optimization in ANN classifier also shows an improvement with 100 percent and 73 percent. As conclusion, normalization of the features improved the accuracy rate for both type of classifier.

4. Conclusion

Overall, it is observed that the proposed front view model using hexagonal feature extraction method is capable to detect abnormality gait based on experimental task done. This is proven based on the classification rate attained that proved normalization of two features namely left and right thigh can be used to improve detection rate.

Acknowledgment

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