GAIT ANALYSIS USING IMAGE PROCESSING

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ABSTRACT

The way a person walks, called gait, is useful to medical professionals and emergency responders to detect abnormalities and respond immediately. The objective of this project is to develop a methodology to capture the gait of a person from videos and analyze their gait cycle to flag emergency situations like fainting and also perform in-depth analysis to support rehabilitation for walking. Results from the methodology reveal that a person's fall is easily detected as well as gait characteristics like gait type, heel strike, dominant leg are captured effectively.

1. INTRODUCTION

'Gait' is, quite simply, the pattern of how a person walks.Medical professionals can diagnose problems with a person's health from their gait, including if they have neurological or musculoskeletal problems. 'Gait analysis' is a method for identifying biomechanical abnormalities in the gait cycle, i.e. the way a person walks.

A gait cycle can be defined into two phases: swing phase and stance phase. The stance phase begins when the foot first touches the ground through a 'heel-strike' and comprises of all activities till the same foot leaves the ground through a 'toe-off'.It involves 'Initial Double Stance, Initial Single Stance', 'Midstance', 'Terminal Single Stance' and 'Final Double Stance' sub-stages and accounts for 60% of gait cycle. On the other hand, swing phase accounts for remaining 40% of gait cycle occurs when the foot is not in contact with the ground and comprises of 'Initial Swing', 'Mid Swing', 'Terminal Swing'[Fig.1]. Gait analysis provides number of parameters namely, step length, stride length, speed, trunk rotation, and arm swing. A deviation in these parameters are indicative of a person's gait abnormality.

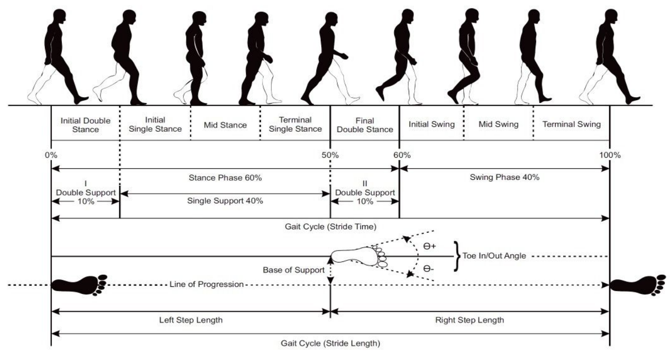

Fig. 1 Stages of Gait cycle of a person

3. LITERATURE

The technological devices used to analyse gait can be broadly classified into wearable sensors(WS) and non-wearable sensors(NWS) which can be further classified into floor sensors(FS) and those based on image processing(IP)[1]. WS are placed on various parts of body and include force sensors (resistive piezoelectric, capacitive[2]), inertial sensors(accelerometers, gyroscopes), goniometers, active markers, electromyography, *etc.*[3][4] FS NWS involves 'floor platforms' and 'pressure measurement' measuring 'ground Reaction Force',viz. force exerted by body on floor[5] IP NWS involves threshold filtering real-time or offline videos either through depth-based measurement[time-of flight, infrared thermography][1] or through simple CCTV footage.

Mario Nieto-Hidalgo et al.[6] analyzed gait for early detection of frailty and senility syndromes using gait analysis. They have extracted the silhouette of the person in the image and used proportions to localize features such as head, torso, hip, legs and heel. Silhouette extraction is employed extensively in the feature extraction domain to detect humans in images. Histogram based edge detection and background subtraction [7], chrominance based method[8], etc. are popular methods of implementing the silhouette extraction. Based on the literature, this project utilizes background subtraction technique and contours for silhouette generation.

4. METHODOLOGY

4.1 Assumption

The proposed algorithm assumes that the person is walking in isolated area, owing to the need to signal alarm in emergency. It also assumes that the background of the scene does not change drastically, Furthermore, the project assumes that subject is in contrast to the background, i.e the background is sufficiently lit. If not, it does give an output with decreased accuracy.

4.2 Dataset

The database referred to test the model is the "Human Identification at a Distance" created by Georgia Institute of Technology's College of COmputing(GVU Center). It consists of video file directories of 20 subjects "walking" with scenes of the type: motion-capture, angle- view indoors, side-view indoors, and angle-view outdoors. For the proposed model, different videos of side-view-outdoors and angle view-outdoors for men & women subjects were tested. In addition, test case videos were recorded by the authors in a corridor environment at Clough Commons at Georgia Tech.

4.3 Algorithm

The algorithm takes video files as input and outputs step length (represented by width of silhouette) and heel points for every frame.

4.3.1 Background subtraction

The proposed project uses background subtraction to isolate the person from the background for gait analysis. Each frame is converted to grayscale and subjected to background subtraction. The method adopted is K-nearest neighbors background subtraction [6]. This method utilizes an adaptive density estimation per pixel to classify the pixel as background or foreground pixel and hence find the moving object in the foreground. The outcome of this operation results in a grayscale mask for the foreground object with predominantly 1 as cleanly classified foreground object and fuzzily classified foreground object in range of 0 - 1.

4.3.2 Bounding Box formation

After background subtraction, any left out grayscale areas in the image frame due to inadequate object against background are reduced by dilating to 1 or 0. This binary mask is used for contour -tracking. Contours can be explained simply as a curve joining all the continuous points (along the boundary), having same color or intensity.'Contour tracking' is a useful tool for shape analysis and object detection and recognition.

All the contours or object boundaries are found and after sorting these contours based on area, the contour with five largest area is used to create a rectangular bounding box since it will consider the entire body of person. It is assumed that the human legs and human torso will contribute to largest contours. Among the largest contours, those which are in 300 pixel proximity are considered to belong to the subject and a bounding box is generated encompassing the close proximity contours.

4.3.3 Feature Extraction

(a) *Feet location*

The bounding box defines the toe of front foot and heel of back foot[Fig.3b Right image]

(b) *Stride length*

'Stride length' is the distance between the successive heel contact points of the same foot, whereas 'step length' is the distance between the heel contact point of one foot and that of the other foot. Here, the width of the bounding box is equivalent to the step length. Hence the total length of two consecutive step length gives stride length.

(c) *Stride time*
'Stride time' is the time required to completely achieve stride length once. This is used for analysis of different types of 'normal gait' as seen in next section.

(d) *Heel-strike, toe-off points:*
The stance phase of gait cycle begins when the foot comes in contact with the ground by striking heel(Heel-strike: Initial Double Stance) and ends with getting off toe(Toe-off:Final Double Stance). The temporal plot of width can be analysed for detection of heel-strike and toe-off time points.

Similarly, there are many other parameters that can be computed, but the proposed project only considers above parameters.

4.4 Experimental Setup:

The proposed project involves testing the designed image processing algorithm for optimization on the reference database with video files for side-outdoors, angle-outdoors. After optimizing the algorithm, test cases are created of 2 female subjects, age 22, for 'normal gait' and all other cases mentioned in next section. The test cases are simulated for multiple readings to remove any subject-specific bias.

5. RESULTS & DISCUSSION

The algorithm was tested for side-outdoor and angle-outdoor conditions on reference database.It was observed in that for angle-outdoor scenes, the crests and troughs were changing in amplitude, increasing if person walking towards camera, decreasing if person walking away from camera.

Analysis of gait involves two sections:

(a)Gait analysis to detect abnormal gait:

The plot of video frame number(as a measure of time) versus stride length for normal gait was studied and compared with that of abnormal gait.The normal gait plot was characterized by a periodic and almost equal amplitude crests and troughs suggesting heel strike of one leg(legs apart) and toe off of opposite leg(legs together) When the legs are close to each other (midstance or midswing), troughs can be observed. When the legs are far apart (Initial stance, Pre-swing, Terminal Swing), crest can be observed.[Fig.2][Fig.3]

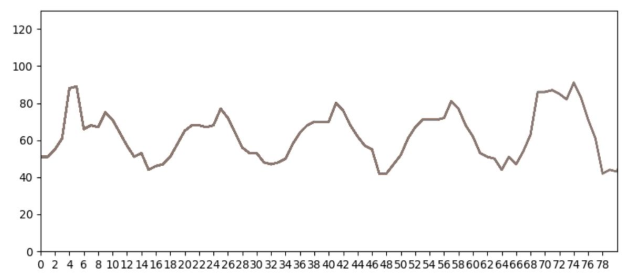

Fig.2:Temporal Plot of stride length for 'Normal Gait'

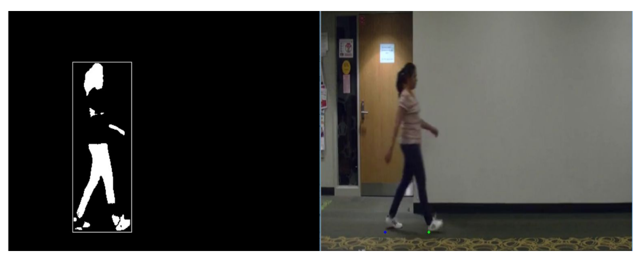

Fig.3:Left image:bounding box tracking, Right image: heel-strike[green] and toe-off[blue]for 'normal' gait

Abnormality cases produced by test subject for proposed project were

1)Subject dragging his leg while walking

2)Subject falling down with a precursor of drifted apart gait.

Case 1 produced results where the plot was still was periodic as the subject was walking, but the well-defined crests in normal gait differed in amplitude at alternate cycle as one leg was being dragged implying difference in motion type of each leg[Fig.4] In Case 2, initially normal gait is observed, then crest height decreases and crest and trough become indistinguishable. Thus, it can be inferred that the subject takes small steps and the falls on the floor resulting in sudden increment in the width of the bounding box, posing a case of fainting [Fig.5][Fig.6].

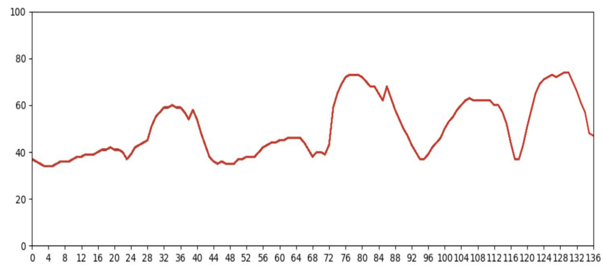

Fig.4: Temporal plot of stride length for Case 1.

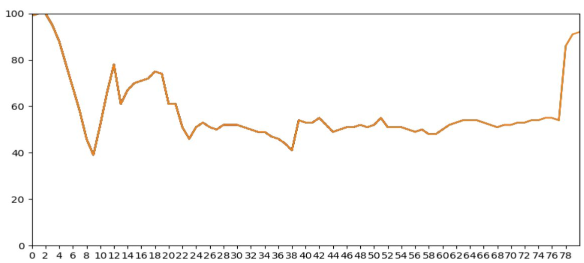

Fig.5: Temporal plot of stride length for Case 2.

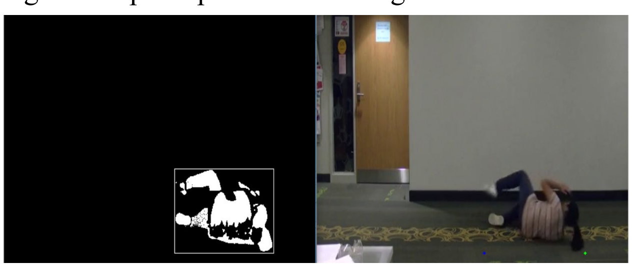

Fig.6 Left image:bounding box tracking,
Right image:tracks body extremes, signals alarm when subject falls down

(b) Gait analysis to detect types of gait.

After detecting abnormality conditions, the project was extended to detect the difference between different types of 'normal' gaits by extracting relevant features from the algorithm.

(1) Detection of the subject jogging:
The motion of a subject jogging over a distance was captured and analysed with normal gait of the same subject[Fig.7]. A reduction in stride time in test case to almost half that of normal gait was observed which validates the gait mechanism of jogging.

(2) Detection of subject marching:
The subject was made to walk by tapping only heels to ground as if she were marching and the gait obtained was compared with normal gait obtained from feet usage[Fig.8]. From empirical data, it was seen that the two peaks seen in normal gait representing heel strike and toe-off movements of one leg while the legs are apart, changed to single peaks representing 'heel strike' movement in the test case as expected.

(3) Detection of dominant foot in normal gait
While extracting 'traditional' features by analysing 'normal gait' of subjects mentioned in previous section, a new feature of 'dominant foot' was observed. Based on the difference in stride length of two legs, one of the foot was observed to take larger strides as compared to other foot, indicating some kind of dominance in gait[Fig.9].This feature needs to be further investigated for more insight.

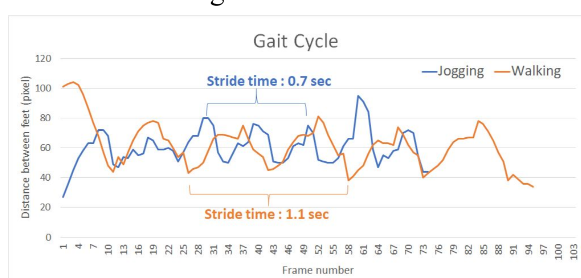

Fig.7 Plot for Case 1.

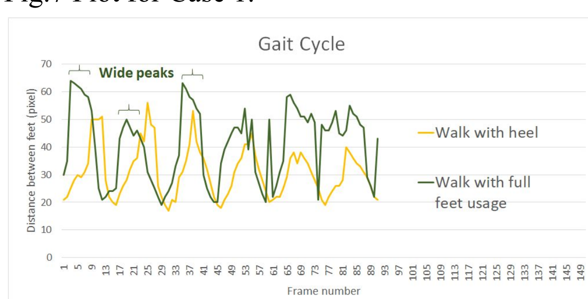

Fig.8 Plot for Case (2)

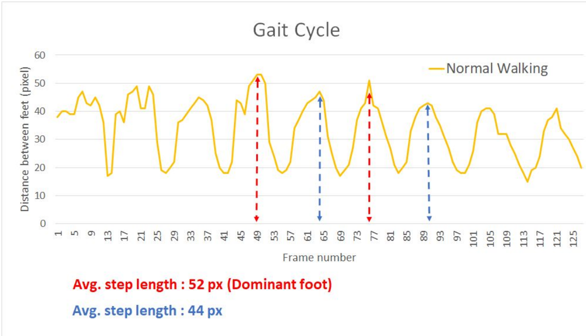

Fig. 9 Plot for Case(3)

6. CONCLUSION

The project extracts the the silhouette of the human body and tracks the feet movement. The proposed algorithm is able to differentiate between abnormal gait behavior and triggering alarm to indicate emergency conditions. It is also able to analyse and validate with literature the different type of 'normal' gaits like walking, jogging, marching,etc. through feature extraction. Thus, the project shows a new direction of applications and analysis of gait using image processing for emergencies in isolated, deserted public spaces as well as medical analysis and rehabilitation.

7. FUTURE WORK

The optimization of algorithm for better shadow removal through improved background noise removal can a further direction of research in signal processing. The project was limited to assumptions mentioned in the previous sections, hence its study can be supported by a larger test dataset of more number of human subjects, also with different physiological, musculoskeletal and cardiovascular conditions. The database for reference can also extended to involve analysis in changing environment or crowdy public spaces, to make it more generalized.

8. REFERENCES

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