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Gait analysis: Approaches and applications

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ABSTRACT

Gait analysis is systematic quantification and evaluation of human walking. It has applications in the field of clinical sciences, video surveillances, rehabilitation therapies, etc. Various state-of-the-science, as well as traditional approaches, have been used for evaluating the gait cycle. This narrative review provides a brief understanding of all such approaches and methods used by scientists and clinicians in India. State-of-the-science approaches include marker based systems, wearable or non-wearable, sensors system, support vector machine, etc. Whereas traditional approaches include observational analysis, videography, etc. 3D gait analysis provides reliable data, however, is currently in limited use due to high instrumentation and maintenance costs involved. Indian scientific community can benefit from traditional approaches which are low-cost, reliable, and can be easy to implement in all sort of set-ups with relative ease.

Keywords: *Orthopedic disorders, Walking pattern, Wearable sensors, Support vector machines, Musculoskeletal disorders.*

1. INTRODUCTION

Every limb in our body has agonist and antagonist muscles, as one muscle contracts, the other one relaxes. This motion is commonly termed as antagonistic motion. The knee joint is a perfect example of it. Study and measurement of body movement during walking of a person can be referred as gait analysis [1]. Recently, gait analysis has been able to attract a tremendous amount of researchers due to its applications especially in the biomedical field and for security purposes. Normal walking of a person can be depicted from the below figure:

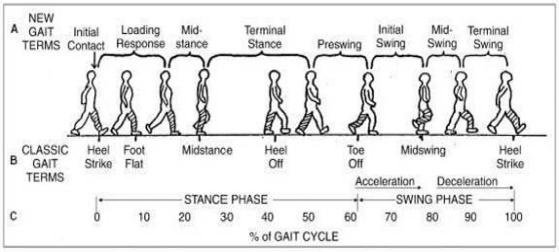

Fig.1: Stages in human walking [1]

As shown in Fig.1, one complete gait of a person mainly consists of two phases i.e. stance phase and swing phase. During these phases activities like heel strike, foot flat, midstance, heel off, toe off, midswing, heel strike occurs. Acceleration of the foot followed by declaration is seen when a person is walking. Abnormal walking may be due to improper co-ordination between joints and limbs resulting normal walking phases are completed properly. Improper co-ordination can be occurred right from birth [seen in cerebral palsy patients], or due to aging effect in humans.

Analyzing this movement and generating meaningful results out of it comes under gait analysis. To analyze these movements different researchers have taken different parameters into considerations. Some of the common parameter to be undertaken while performing gait analysis are calculation knee joint angles, ankle joint angle, hip joint angle, pressure points on the foot, shape analysis, etc. The results generated by taken into considerations the above parameters could in form of graphs, vector files or can be directly fed as a binary video in the database.

The result of gait analysis finds its applications in the fields of biomechanics; it helps an orthopedic physician to examine patients walking pattern and can prove helpful in diagnosis and recovery of the patient. Research to make gait analysis a trusted system for clinical use began in SIAMOC (Italian Society for Clinical Movement Analysis)which promoted a National Consensus Conference which was held in Bologna, Italy, on September 14th, 2013. The purpose of the conference was to produce evidence-based recommendations to assist a) practitioners in managing gait examination and interpreting its results, and b) administrators in defining appropriateness and remuneration [34]. Fig.2 shows a number of research in different biomedical or orthopedic disorders. Most of the Parkinson's and cerebral palsy patients go un-identified; so by examining gait cycle the number of patients can be reduced and measures of precautions can be implemented. Another major application of gait is used by sportspersons. It helps in analyzing proper angles and joint movements in every phase of running or walking. Changes in running patterns are made to have maximum speed while running. Another upcoming application of gait is seen in the identification of humans or for security purposes. Every person can have their own unique walking patterns so storing them initially and using them afterward for identification of persons is attracting eyes of many researchers.

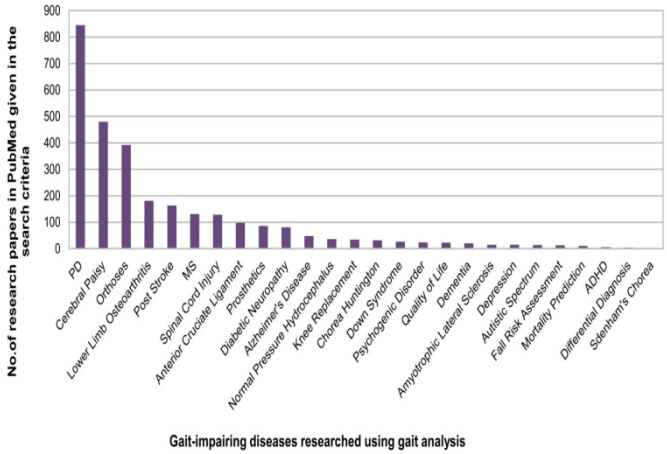

Fig.2: Distribution of research efforts on different gait pathologies for papers published between 1970 and 2016[2]

2. GAIT PARAMETERS

Gait is the study of human walking. Recently people are aware of what is mean by gait and its importance. Since research on gait analysis was started in the 19th century, it has centered on identifying a different parameter that differentiates gait for applying them to various areas like in the clinical field, professional sports training, biometric identification and comparative biomechanics. Kinematic and kinetics these are two major gait parameter distributions. Kinematic involves the study of motions. In the human motion, it is the study of the accelerations, velocities, angles, and positions of body segments and joints during movements. Kinetic is a study of forces, energy, and power of joints during motion. Which parameter to be calculated is depended on the application. In many areas like a border crossing, airport, highly sensitive places and other public places strong need for high-security architecture. Recently deployed different identification methods but they cannot fulfill the modern security needs. Traditional identification technologies are practically infeasible in some areas such as transportation places in metropolitan cities, critical authentication [40]. For instance, for biometric identification is done by getting binary gait silhouette sequences of an authorized human. However, in sports field, a research study may focus on forces and pressure exerted on muscles and joints movement during motion.

Table.1 shows a list of gait cycle parameters extracted for analysis purpose in different applications. The distribution is done in accordance with kinematic parameters and kinetic parameters.

Table.1: Gait parameter distributions

A.	Kinematic parameters		
	a.	Temporal variables	
		1.	Stance time
		2.	Single limb time
		3.	Double support time
		4.	Swing time
		5.	Stride time
		6.	Cadence(step/m)
		7.	Step time
		8.	speed
	b.	Distance variables	
		1.	Stride length
		2.	Step length
		3.	Width of walking
		4.	Step width
		5.	Short step length
		6.	Distance travelled
		7.	Degree of toe out
	c.	Joint angles	
		1.	Hip angle (Sagittal plane)
		2.	Knee angle (Sagittal plane)
		3.	Ankle angle (Sagittal plane)
		4.	Pelvic rotation (Frontal plane)
		5.	Trunk rotation (Frontal plane)
		6.	Femoral rotation (Frontal plane)
B.	Kinetic parameter		
		1.	Joint power
		2.	Muscle torque
		3.	Muscle power
		4.	Ground reaction forces

3. GAIT CYCLE CAPTURING APPROACHES

The capturing of gait cycle requires the movements of joints in the human body to be gathered and stored in a particular pattern. The gathering of movements can be done by various techniques. The historical and previously used technique was using the naked human eye to watch a person walk and analyze information by it. But it is prone to high errors and is not an accurate nor an efficient way to capture gait cycle.

The more efficient and accurate techniques include placing the markers on human joints and then capturing them using image processing, placing sensors that transmit data on the human body, beneath the human foot, etc. Some techniques do not involve any kind of sensors and work on machine learning techniques.

A. Wearable sensors

Sensors which can record or transmit data are placed on required joints of the human body. The recording of data from sensors can result in a quantitative, continuous and efficient gait cycle. Wearable sensors can make gait analysis system portable and can reduce the cumbersome cost of lab setup of gait analysis [2]. Inertial sensors are kind of sensors which can record and transmit the relative movement of its position. These sensors are can be place in different joints of the human body [3]. This sensors are light weight and don't obstruct the walking of humans. The inertial sensor consists of gyroscope and accelerometer, which can transmit data. The data is stored in periodic histograms, which makes it easier to study. Apart from sensors; a questionnaire is been filled out by the person undergoing gait analysis, this helps the select particular joints on which sensors should be placed. Other than just inertial sensors other motion recording sensors [MRS] can also be used [4]. MRS can be placed on arms, hips, ankles. The result is in graphical format with respect to time. Fig.3 shows a typical sensor placed on the human body. A mobile consisting of accelerometer can also be used as a sensor to record joint data. Mobile is attached to trouser pocket position [5].Fig.4. shows a mobile consisting of an accelerometer been attached to the human body during performing gait analysis. As a person walks the accelerometer will record its log in a mobile application. After performing noise cancellation on the logs, the gait cycle can be formed from the data of mobile accelerometer. Low-cost ultrasonic sensors can also be used for this purpose. Ultrasonic transmitter and receiver are used; the reference markers are placed on human body [6]. The transmitter emits ultrasonic waves; these are reflected back from the reference marker on are caught by the receiver; thus the information of the human joint position is obtained. The information gained is continuous and further analysis can be done on it. Fig.5. shows a typical ultrasonic transmitter, receiver and control board and reference marker placed on the human body.

Fig.3: Wearable sensors for gait analysis [4]

Gait analysis also involves the study of force applying areas of the foot. Textile sensor socks in one such sensor which can be worn [7]. It consists of a textile pressure sensor which works like a pressure resistive sensor and it used for finding out pressure in that particular area. Heel contact pressure areas can accurately be measured. Another approach is to use force plate inside the shoes in which the person is walking [8]. The force plate consists of pressure resistive sensors on different parts. Analysis of orthopedic disorders like cerebral palsy and Parkinson's disease can be done through it. The data received from force plates can be sent to another device for its analysis.

Markers can be attached to joints like knee, ankle, hip, etc. These markers can be recognized using image processing techniques. Markers can be active as well as passive [38]. Active markers specifically consist of light emitting diodes (LED) which emit light of their own to the capturing source (camera). And passive markers are made of Scotchlite or radium which is light reflecting materials. These passive markers reflect the incident light directly back to the capturing source(camera).

Fig.4: Use of the mobile accelerometer of gait analysis [5]

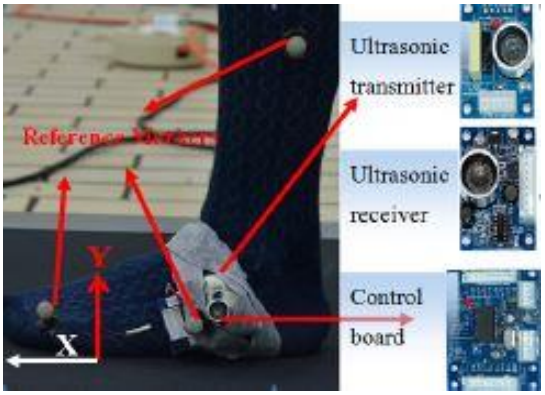

Fig.5: Ultrasonic transmitter, receiver, control board and reference marker[6]

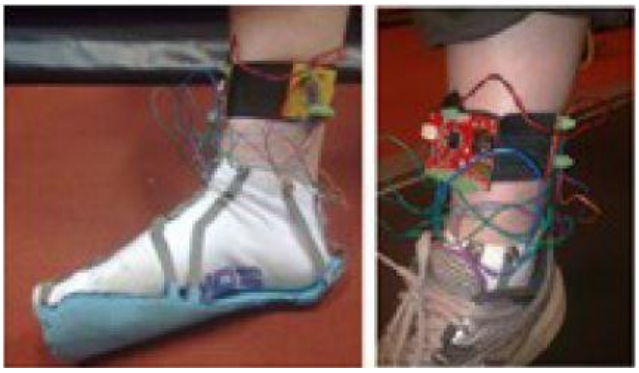

Fig.6: Textile socks sensors[7]

Fig.7: Instrument shoe (a) inertial measurement unit; (b) flexible goniometer; and (c) pressure sensors which are situated inside the insole.[9]

B. Non-wearable sensors

Non-wearable sensor systems can be easy to use and more portable than sensor system. But the accuracy and efficiency can be varied according to the technique used. Shape analysis can be done using silhouette extraction method [10]. The background image is stored in the system; afterward during gait analysis, the background image is subtracted from the image recorded; this results in silhouette representation or shape representation of the human body. The shape of the body can be obtained continuously and can further be stored and analyzed. Fig.8. shows a typical process of extracting silhouette for gait analysis. This process does not require any sensor do be placed on the human body.

Fig.8: Shape analysis (a) background image; (b) original image; and (c) extracted silhouette [10]

Haar classifier can be applied to extracted silhouette to classify between normal and abnormal gait [11]. Haar classifier is pattern matching algorithm which works on a cascade file generated by positive and negative images. Positive images are the set of pattern to be matched and negative images are set of all possible images other than positive images[36]. The positive images are superimposed on all negative images in all possible directions, forming a cascade file of the neural network. The extraction of silhouette can make possible to determine the stride length of a walking person [12]. According to that, one can also identify whether is a person is walking, running or jumping. Mean shift algorithm is used to analyze the speed and to determine the human movements.

Kinect is widely used in the field of virtualization. Kinect was first developed by Microsoft with the motivation of its applications in the field of virtual reality. It consists of ultrasonic and inertial sensors programmed together and the data is sent to other devices. By programming Kinect, it can be used to develop 3D virtual human body [13-14]. By applying supervised learning approach to automatically and accurately extract lower and upper body gait parameters, a 3D virtual skeleton is prepared. This can be formed by a person walking towards the Kinect; it can be online monitored and then notified whether gait cycle is normal or abnormal. The motion can be visualized and stride length and stride velocity can also be obtained. Another marker less system involves mathematical and machine learning techniques for identification of human joints [15]. Initially, the height of a human is determined by silhouette extraction and then the position of different gait parameter like the knee, ankles, etc is determined. General assumption that hip is situated at half of the human height, the knee is situated at three fourth of human height and ankle is situated at 90percent of human height is taken into consideration. Fig.9. shows how different gait parameters are obtained from the extracted silhouette. After obtaining the position of various gait parameters, gait cycle consisting of angles can be generated. But, this system can face problems during occlusion.

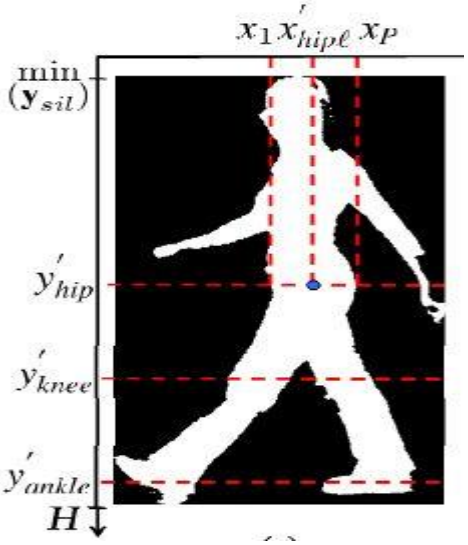

Fig.9: Marker less system using silhouette extraction [15]

A smartfloor concept [16] is also used for gait analysis. The floor is covered with floor sensors; it can record where the foot has been in contact and also measures pressure of the foot imparted on the floor. This data is sent is to other devices online. The floor sensor consists of a special type of piezo pressure resistive sensors. Fig.10. shows a typical floor sensor in place on the floor. The patient is indented to walk on this to generate the gait cycle.

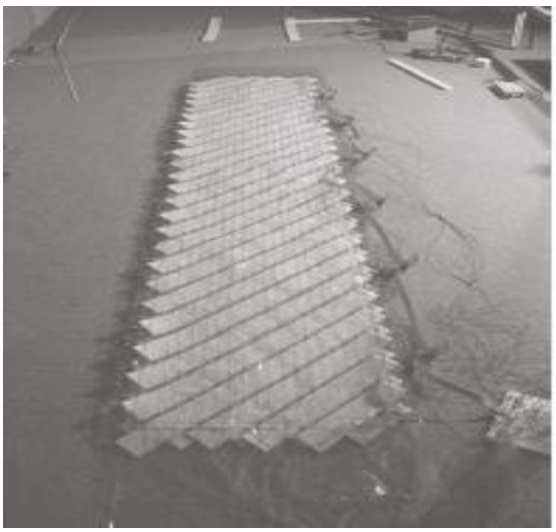

Fig.10: Floor sensor [4]

C. Pros and Cons

All the techniques used for generating gait cycle both wearable sensor systems as well non-wearable sensor system has its own advantages and disadvantages. Table.2. shows pros and cons for wearable sensor techniques [33].

Table.2: Comparison of wearable sensor techniques

Technique	Pros	Cons
Inertial[3]	Light weight	Drifts
Accelerometer[5]	Accurate stride angle	Costly
Ultrasonic[6]	Continuous information	Occlusion
Shoes[7-9]	Pressure areas	Joints angle

The wearable sensors up to a certain extent can give accurate gait cycle results, but on many systems, it is hard to perform the normal walk of a person. The inertial sensors are light weight by the also minute movements of person has a lot of noise in the results; so up to a certain extent accuracy is distorted [3]. The ultrasonic sensors and control board provide a continuous flow of information of stride angles, but one needs to have basic information of operating ultrasonic sensors. The faceplate in textile socks sensors or shoes provide quite accurate results of the heel contact area[9]; but that not the complete gait analysis. The practices currently ongoing in most of the gait lab use one of the above wearable sensor techniques, as results are quite correct.

Table.3. shows pros and cons for non-wearable techniques. These techniques are mostly used for further applications of gait analysis like human identification. This techniques mostly need advanced machine learning algorithms like support vector machines; to identify the gait cycle. The major objective of these techniques is to identify the gait parameter while a person is walking.

Techniques without sensors or markers mostly used the basic technique of silhouette extraction. This technique requires initial background image for the subtraction. All times, this is not possible, so its applications are limited. Whereas, smart floor techniques almost works same as force plate.

Table.3: Comparison of non-wearable sensor techniques

Technique	Pros	Cons
Silhouette[10]	Stride angle	Initial Background
Haar classifier[11]	Identification	Positive Images
Kinect[13]	3D virtual body	Costly
Smart floor[16]	Pressure areas	Joints angle

D. Segmentation of gait cycle

Once a continuous gait cycle is obtained, it needs to be segmented as per required use. The human walking consists of many phases of stance and swing phase[1]. Selection of a single stance and swing phase constitutes a single complete gait cycle. Stride angles and stride velocity needs to be calculated of a particular segmented single gait cycle.

A robust algorithm for gait cycle segmentation is to find out highest and lowest value of the parameter considering it has initial phase and final phase. Peaks in the cycle are detected and an average number of gait cycle is calculated [17]. Based on average gait cycles and segmented peak values, gait cycle as per required threshold value is selected. Segmentation of cycle from extracted silhouette is done by using principal component analysis [18]. A trained database consisting of minimum distance classifier is been developed. The generated sequence of the silhouette is inputted to the principal component analysis database and the minimum distance classifier then segments the gait cycle. The classifier is developed using previously inputted distance samples. Furthermore, different gait parameter can be extracted from silhouette using centroid of the silhouette. The frame is divided into various parts based on the position of the centroid. Analysis can be done of the required gait parameter part. Fig.11. shows such an example of segmenting human gait for various parameters.

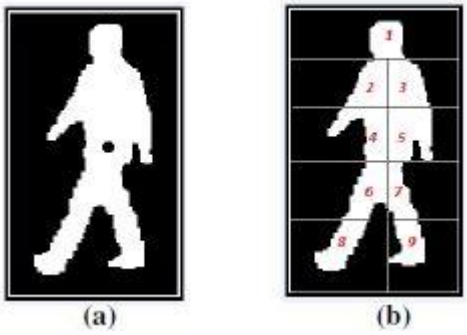

Fig.11: Segmentation of the human Silhouette: (a) Centroid of the Silhouette; (b) 9-segments of the silhouette of a foreground walking person [18]

Based on the extracted silhouette, it is possible to identify human activities like running, walking, jumping, and jogging[19]. After noise cancellation in silhouette Hu-moments algorithm for distorted shapes can identify features in the frame. The considered features are centroid of the silhouette and two leg components. Based on this feature, the sequence is classified in different human activities like running, walking, jumping, etc. Stride length and stride velocity can also be recognized by radio waves [20]. High-end wireless sensors which can receive different frequency of radio waves are used in this technique. This technique is still theoretical and needs to practically implement. Commercial computer software like Kinovea[21] and Dartfish[22]. This software's on been inputted the video feed, outputs the stride angles and stride velocity. This commercial software also has some limitations of background and color constraints.

4. APPLICATIONS

An increasing rise in the application of gait cycle is seen in past few years [23]. Applications of gait cycle are seen in the field of biomedical disorders identifications and human identifications. Gait can be used as an important parameter for security techniques used for human identification. Gait cycle can overcome disadvantages of voice recognition, face recognition, iris recognition and signature recognition [24]. The existing system has many disadvantages like noise due to poor quality; gait analysis can overcome them.

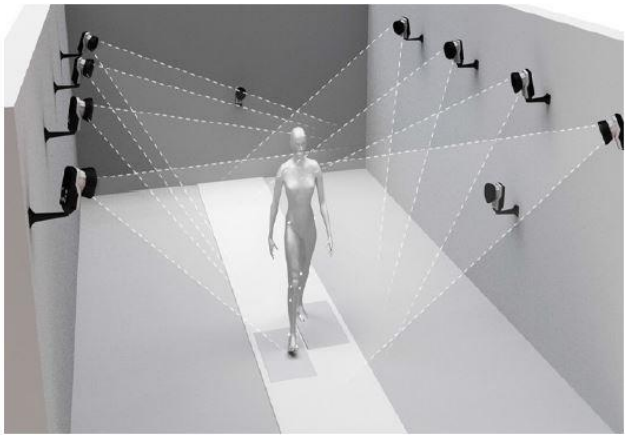

Fig.12. The basic setup for gait analysis [24]

Fig.12. shows a basic setup for gait analysis. Once a gait cycle of a person is recorded and stored, it can be further used to identify the person. The identification of human can be done using deep neural network [25-26]. All recorded gait of different humans is stored in a database. A training neural network is prepared from taking out a major part of all available dataset. The neural network is responsible for matching the inputted pattern with all available dataset. The testing neural network is maintained from the remaining dataset; thus making the system an supervised system. Generally, 70percent of the available dataset is taken for training the neural network and remaining 30percent of the dataset is taken for testing the accuracy of the neural network. Instead of considering entire gait of the human for identification, one can also use only data extracted from joints like joints angle for identification [27]. A joint extraction model is developed before generating a neural network. An also during identification stage before inputting it to the neural network; joint data is extracted. The neural network is the memory-based neural network. In the neural network, the features can store as eigenspace matrix. This eigenspace matrix leads to a feature matrix [28, 39]. The recognition phase in neural network takes place by L2- Norm method in which the inputted sequence or features are matched with all the dataset to find the similar one. Recognition can also be done using features of OpenCV [Open source computer vision]. This enables one to perform operations of image processing in languages like C++, Java, Python, etc. Using OpenCV a stick diagram of the gait cycle can be generated and is stored in the database [29, 37].

Furthermore, using machine learning techniques like Haar classifier [11] or algorithm of K-nearest neighbor can be used. Recognition by the neural network can be done using model-based machine learning algorithms like support vector machines [30-35]. The SVM or support vector machines classifies the gait by using different given parameters and matches them using to which parameters it is most similar to. The features can be extracted also from silhouette or from stick diagrams generated from the gait cycle. By using an algorithm like SVM high accuracy in recognition up to 98percent can be achieved [31].

By using machine learning algorithms of principal component analysis [18] and SVM [31]; gait analysis can be used in real time video surveillance [32]. It is already been started in some countries like Australia and USA on trail basis. Once a dataset containing features of a selected range of humans is generated; then gait analysis is the best option rather than currently being used security features.

The above-listed applications are in the field of human identification; the applications in the field of biomedical disorders are by analyzing the gait parameter according to the disorder.

5. DISCUSSION

Gait analysis can generally be considered as a manner of walking. Assessing the manner of walking can be done by various techniques. The existing techniques follow the flow of capturing the video, extracting silhouette, performing noise elimination, drawing stick diagram (if required), and analyzing the various gait parameters required for the particular application. The techniques used generally fall into two categories i.e. wearable sensors and non-wearable sensor techniques. The wearable sensors techniques need the person to attach a sensor or marker on his body. The sensors like inertial, ultrasonic, accelerometer can transmit the generated data to other devices by means of networking. If markers are used on the human body, then image processing or video processing is the way of obtaining gait cycle. The markers used can be active as well as passive markers. Inertial sensor and accelerometer can also be considered as active markers. The techniques which do not involve any kind of marker system; rely on machine learning algorithms. Mostly all techniques, extract silhouette by removing previously stored background image. This sequence of silhouette can be used to analyze the gait parameter like limbs, knees, ankles, etc from the position of centroid. Some techniques determine the height of the silhouette and then determine the positions of knees, ankles, and hip. Using faceplate consisting of pressure resistive sensors are been used in socks, shoes, and floors to obtain exact information of the heel contact pressure areas. Segmentation of the gait cycle needs to be done before analyzing it. For segmentation, the peak value and average gait cycles are taken into consideration. Some approaches for gait cycle also involves the use of radio waves for gait cycle formation.

Other than orthopedic disorders analysis; gait cycle finds large number of upcoming applications in the field of human identification. By storing the gait cycle in database; it can be used any other time to recognize the person. Neural network are used in these cases,

and algorithms of SVM are mostly used to identify and classify people. Gait is proved to be an better security identification feature than the existing techniques currently been used.

6. CONCLUSION

This paper reviews the existing techniques been used for obtaining gait cycle, performing segmentations and typical application of gait cycle. Although, a lot of research has been done in this field, but then too most of the techniques require high cost for its implementation. Inertial and ultrasonic sensors gives information other than visual output; so interpretation of data is must. In case of marker techniques various cameras and a large setup is used for generated a 3D view of human body. 2D data is appropriate for performing gait analysis and its applications. Low cost solutions for gait analysis are less and needs to be focused. The setups are also large and expensive; so research needs to be done reducing the setup and performing gait analysis by portable devices. More and rapid attention needs to given for application of gait analysis in fields of orthopedic disorders as well as human identification method.

7. ACKNOWLEDGMENT

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8. REFERENCES

[1] https://www.physio-pedia.com/Gait
[2] Shanshan Chen, John Lach, Benny Lo, Guang-Zong Yang, ”Toward Pervasive Gait Analysis With Wearable Sensors: A Systematic Review”,Ieee Journal Of Biomedical And Health Informatics, Vol. 20, No. 6, November 2016.
[3] A.Sant’ Anna, N. Wickstrom, H. Eklund, R.Tranberg, ”A wearable gait analysis system using inertial sensors Part II: Evaluation in a clinical setting”,Proceedings of the International Conference on Bio-Inspired Systems and Signal Processing (pp. 5-14).
[4] Davrondzhon Gafurov and Einar Snekkenes, ”Gait Recognition Using-WearableMotion Recording Sensors”, EURASIP Journal on Advances in Signal Processing Volume 2009, Article ID 415817
[5] Hoang Minh Thang, Vo Quang Viet, Nguyen Thue, Deokjai Choi, ”Gait Identification Using Accelerometer on Mobile Phone”.
[6] Yongbin Qi, Cheong Boon Soh, ErryGunawan, Kay-Soon Low and Rijil Thomas, ”Estimation of Spatial-Temporal Gait Parameters Using a Low-Cost Ultrasonic Motion Analysis System”, Sensors 2014, 14, 15434-15457; doi:10.3390/s140815434 ISSN 1424-8220.
[7] Oren Tirosh, RezaulBegg, Elyse Passmore and NiliKnopp-Steinberg, ”Wearable Textile Sensor Sock For Gait Analysis”, 2013 Seventh Inter-national Conference on Sensing Technology.
[8] Bjoern M. Eskofier, Sunghoon Ivan Lee, Manuela Baron, Andr Simon, Christine F. Martindale, HeikoGabner and JochenKlucken ” An Overview of Smart Shoes in the Internet of Health Things: Gait and Mobility Assessment in Health Promotion and Disease Monitoring”, www.mdpi.com/journal/applsci Appl. Sci. 2017, 7, 986; doi:10.3390/app7100986.
[9] Alvaro Muro-de-la-Herran, Begonya Garcia-Zapirain and Amaia Mendez-Zorrilla, ”Gait Analysis Methods: An Overview of Wearable and Non-Wearable Systems, Highlighting Clinical Applications”, Sensors 2014, 14, 3362-3394; doi:10.3390/s140203362, ISSN 14248220
[10] Liang Wang, Tieniu Tan, Weiming Hu and Huazhong Ning, ”Automatic Gait Recognition based on statistical shape analysis”, IEEE Transactions on Image Processing. Vol. 12, No.9, September 2013.
[11] Ahmad Puad Ismail and NooritawatiMd Tahir, ”Human Gait Silhouettes Extraction Using Haar Cascade Classifier on OpenCV ”, 2017 UKSim-AMSS 19th International Conference on Modeling and Simulation.
[12] Jay Prakash Gupta, Pushkar Dixit, Nishant Singh, Vijay BhaskarAemwal, ”Analysis of Gait Pattern to Recognize the Human Activities”, International Journal of Artificial Intelligence and Interactive Multimedia, Vol. 2. Moshe Gabel, Ran Gilad-Bachrach, Erin Renshaw and AssafSchuster ”Full Body Gait Analysis with Kinect”.
[13] Moshe Gabel, Ran Gilad-Bachrach, Erin Renshaw and AssafSchuster,”Full Body Gait Analysis with Kinect”.
[14] Nguyen-Luc Dao, Yuzhe Zhang, Jianmin Zheng and JianfeiCai, ”Kinect-based Non-intrusive Human Gait Analysis and Visualization”.
[15] Michela Goffredo, John N. Carter and Mark S. Nixon,”2D Markerless Gait Analysis”.
[16] OluwatosinOluwadare, ” Gait Analysis On a smart floor for health monitoring”, The University of Texas at Arlington.
[17] Shuo Jiang, Xingchen Wang, Maria Kyrarini, Axel Graser, ”A Robust Algorithm for Gait Cycle Segmentation”, 2017 25th European Signal Processing Conference (EUSIPCO)
[18] Pranjit Das and SaratSaharia, ”Human Gait Recognition Based on Prin-cipal Component Analysis”, International Journal of Computer Sciences and Engineering Volume-4, Special Issue-7, Dec 2016 ISSN: 2347-2693
[19] Jay Prakash Gupta, Pushkar Dixit, Nishant Singh, Vijay BhaskarAemwal, ”Analysis of Gait Pattern to Recognize the Human Activities”, International Journal of Artificial Intelligence and Interactive Multimedia, Vol. 2.
[20] Chen-Yu Hsu, Yuchen Liu, Zachary Kabelac, Rumen Hristov, Dina Katabi, Christine Liu, ”Extracting Gait Velocity and Stride Length from Surrounding Radio Signals”.
[21] Nur Amirah HanisahHisham, Ahmad Faiz Ahmad Nazri, June Madete, LilikHerawati, Jamaluddin Mahmud, ”Measuring Ankle Angle and Analysis of Walking Gait using Kinovea”, International Medical Device and Technology Conference 2017
[22] SadiqJaferAbbass and Ghaidaa Abdulrahman, ”Kinematic analysis of human gait cycle”, Nahrain University, College of Engineering Journal (NUCEJ) Vol.16 No.2, 2014 pp.208-222
[23] Huiyu Zhou, Huosheng Hu, ”Human motion tracking for rehabilitation-A survey”, Biomedical Signal Processing and Control 3 (2008) 118.

[24] S.Poornima, Shashwat, Dheeraj Malhotra, Neha Verma, "A Survey on Gait Analysis versus other Security Techniques", International Journal of Scientific and Research Publications, Volume 5, Issue 11, November 2015 586 ISSN 2250-3153.
[25] Zifeng Wu, Yongzhen Huang, Liang Wang, Xiaogang Wang, and Tieniu Tan, "Comprehensive Study on Cross-View Gait Based Human Identification with Deep CNNs", IEEE Transactions On Pattern Analysis And Machine Intelligence Doi 10.1109/Tpami.2016.2545669
[26] Muhammad RamzanTalib, Ayesha Shafique, Muhammad KashifHanif, Muhammad UmerSarwar, "Gait Identification using Neural Network", (IJACSA) International Journal of Advanced Computer Science and Applications, Vol.8, No. 9, 2017
[27] Dan Liu, Mao Ye, Xudong Li, Feng Zhang, Lan Lin, "Memory-based Gait Recognition", BMVC 2016 DOI: https://dx.doi.org/10.5244/C.30.82
[28] M. Pushpa Rani and G.Arumugam,"An Efficient Gait Recognition System for Human Identification Using Modified ICA", International Journal of computer science and information technology(IJCSIT), Vol.2, No.1, February 2010.
[29] SwitiKeWatkar and SnehalKathle, "HUMAN GAIT RECOGNITION BY OPENCV", International Journal of Computational Biology ISSN: 2229-6700 and E-ISSN:2229-6719, Volume 3, Issue 1, 2012.
[30] Arun Joshi, Mr. Shashi Bhushan, Ms. Jaspreet Kaur, "GAIT RECOGNITION OF HUMAN USING SVM AND BPNN CLASSIFIERS", International Journal of Computer Science and Mobile Computing, Vol.3 Issue.1, January- 2014.
[31] Deepjoy Das and Dr. SaratSaharia, "Human Gait Analysis And Recognition Using Support Vector Machines".
[32] Sonali Vaidya, Dr. Kamal Shah, "Implementation of Real Time Video Surveillance System using Gait Analysis", International Journal of Scien-tific and Engineering Research, Volume 5, Issue 2, February-2014 ISSN 2229-5518.
[33] DheerajMalhotra,"A Survey on Gait Analysis versus other Security Techniques", International Journal of Scientific and ResearchPublica-tions, Volume 5, Issue 11, November 2015 586.
[34] Maria GraziaBenedetti,"SIAMOC position paper on gait analysis in clinical practice: General requirements, methods and appropriateness. Results of an Italian consensus conference", www.elsevier.com/locate/gaitpost
[35] Ahmed Ismail, "A physics-based statistical model for human gait analysis", Leibniz University at Hannover, Germany.
[36] Mario Nieto-Hidalgo, "Human Gait Silhouettes Extraction Using Haar Cascade Classifier on OpenCV", 19th International Conference on Mod-elling and Simulation.
[37] Mario Nieto-Hidalgo, Francisco Javier Ferrandez-Pastor, Rafael J.Valdivieso-Sarabia, Jeronimo Mora-Pascual ,"Gait analysis using com-puter vision based on cloud platform and mobile device."
[38] Neelesh Kumar, Nissan Kunju, Amod Kumar, "Active marker based kinematic and spatio-temporal gait measurement system using LabView vision", Journal of Scintific and Industrial Research, Vol.69, August 2010.
[39] F.M. Castro, N. Guil, "Automatic learning of gait signatures for people identification."
[40] Nikolaos V. Boulgouris, Dimitrios Hatzinakos,and Konstantinos N. Plataniotis, "Gait Recognition: A challening signal processing technology for biometric Identification" IEEE SIGNAL PROCESSING MAGAZINE NOVEMBER 2005

