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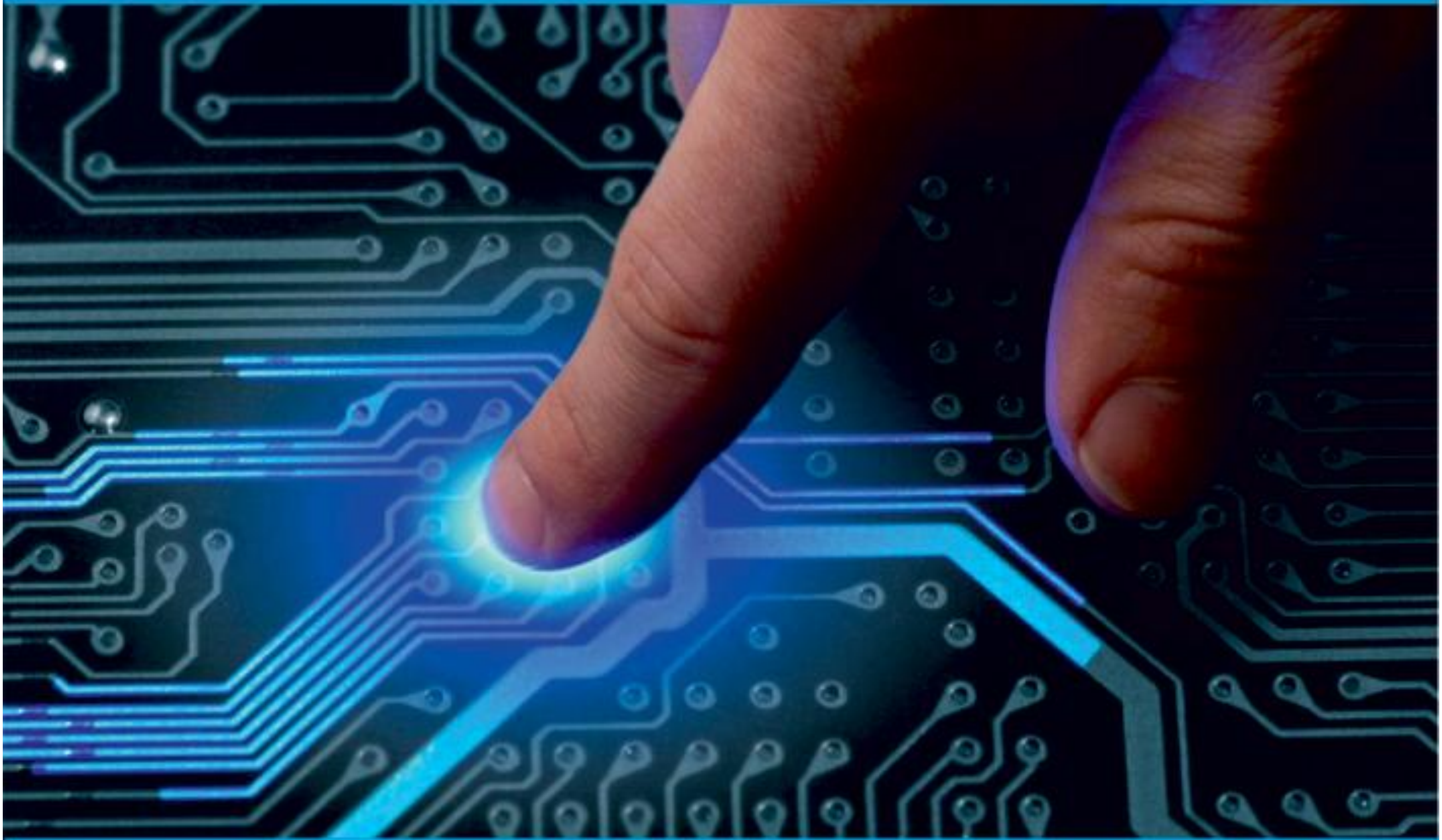

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A Survey on GAIT Analysis

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ABSTRACT: Gait is the form of gesture of the limbs of animals, including humans, during locomotion over a solid substrate. Variety of gaits are used by most animals, selecting gait based on speed, terrain, the need to maneuver, and energetic efficiency. Different species of animal may use different gaits due to differences in anatomy that prevent use of certain gaits, or simply due to evolved innate preferences as a result of habitat differences. Human gait alludes to locomotion achieved through the movement of human limbs. Human gait is manifested as bipedal, biphasic forward propulsion of center of gravity of the human body, in which there are alternate sinuous movements of different segments of the body with least expenditure of energy. In this paper, I am providing a survey on Gait Analysis.

KEYWORDS: Gait Analysis, Human Gait, Parkinson's Disease, Gait Cycle.

I. INTRODUCTION

Gait is the form of gesture of the limbs of animals, including humans, during locomotion over a solid substrate. Variety of gaits are used by most animals, selecting gait based on speed, terrain, the need to maneuver, and energetic efficiency. Differentspecies of animalmay use different gaits due to differences in anatomy that prevent use of certain gaits, or simply due to evolved innate preferences as a result of habitat differences. While various gaits are given precise names, the complexity of biological systems and interacting with the environment make these distinctions 'fuzzy' at best. Gaits are characteristically classified according to footfall patterns, but recent studies often prefer definitions based on mechanics. The term characteristically does not refer to limb-based propulsion through fluid mediums such as water or air, but rather to propulsion across a solid substrate by generating reactive forces against it (which can apply to walking while underwater as well as on land).[1]

Due to the speediness of animal movement, simple direct observation is rarely sufficient to give any insight into the pattern of limb movement. Despiteinitialefforts to classify gaits based on footprints or the sound of footfalls, it was not until Eadweard Muybridge and Étienne-Jules Marey began taking rapid series of photographs that proper scientific examination of gaits could begin.[1]

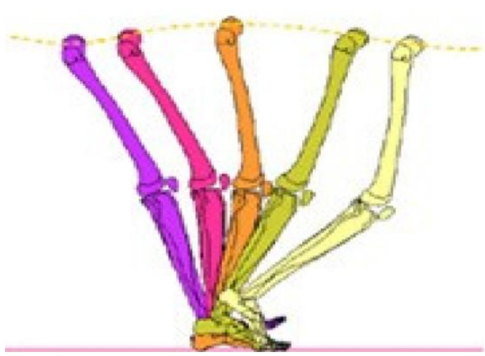

Fig.1.1 Gait Analysis

Human gait alludes to locomotion achieved through the movement of human limbs. Human gait is manifested as bipedal, biphasic forward propulsion of center of gravity of the human body, in which there are alternate sinuous movements of different segments of the body with least expenditure of energy. Differences in limb-movement patterns, overall velocity, forces, kinetic and potential energy cycles, and changes in the contact with the surface (ground, floor, etc.) identifies different gait pattern. Human gaits are the several ways in which a human can move, either naturally or as a result of specialized training.[2]

Gait analysis is the study of human locomotion. In order to examine and quantify how someone walks, it is necessary to isolate the shortest, unique, repeatable task during gait. This task is called the gait cycle. A single gait cycle can be calculated from any gait event to the same subsequent event on the same foot, but the conventional tacit model considers gait cycle is measured from one-foot strike to the subsequent foot strike of the same foot.[4]

Quantifying aspects of the gait cycle, such as time and spatial measures, allow for analysis of gait symmetry, variability and quality.[4]

Since the jobs of weight acceptance, single limb support, and swing limb advancement can only be accomplished successfully if appropriate limb movement patterns occur sequentially and with correct timing, Dr. Perry evolved a systematic method of subdividing the gait cycle to simplify pattern identification and facilitate observational gait analysis. Now known as the *Rancho* classification, in honor of Rancho Los Amigos Medical Center where Dr. Perry and colleagues of the Path kinesiology Service developed this method, it relies on eight subdivisions of the gait cycle, referred to as *phases* of gait. While in general, both phases and periods refer to particular time slices around the gait-cycle unit circle, Perry prefers to use the term "phase" for intervals that have specific functional significance and have a clear relationship to the three identified gait tasks described in the previous section. The Rancho classification provides a framework for functionally organizing the gait cycle harmoniously with the three fundamental gait tasks, and after 30 years of refinement, this approach has proven to be a powerful tool for identifying specific functional deficits or gait impairments during each phase of gait. IGA can be used to measure the magnitude of a functional deficit at a joint by reviewing the kinematic and kinetic data, or abnormal muscle timing by reviewing the EMG. This provides evidence and helps pinpoint the specific region or system most responsible for the overall gait abnormality, and suggests interventions to directly correct the identified functional deficit or gait impairment in each phase.[7]

A **(**bipedal**)** gaitcycle is the time period or series of events or movements during locomotion in which one-foot contacts the ground to when that same foot again contacts the ground, and involves propulsion of the center of gravity in the direction of motion. A single gait cycle is also known as a stride.[5]

Each gait cycle or stride has two phases:

1. **Stance Phase**, the phase throughout which the foot remains in contact with the ground, and the
2. **Swing Phase**, the phase throughout which the foot is not in contact with the ground.

II. LITERATURE REVIEW

Rana Zia Ur Rehman, Christopher Buckley, Maria Encarna Micó-Amigo (2020), proposed the evaluation of Parkinson's disease (PD) utilizing the GAIT analysis system. The study main features: (i) comprehensively quantify a battery of commonly utilized gait digital characteristics (spatiotemporal and signal-based), and (ii) identify the best discriminative characteristics for the optimal classification of PD. Six partial least square discriminant analysis (PLS-DA) models were trained on subsets of 210 characteristics measured in 142 subjects (81 people with PD, 61 controls (CL)). Models accuracy ranged between 70.42-88.73% (AUC: 78.4-94.5%) with a sensitivity of 72.84-90.12% and a specificity of 60.3-86.89%. Signal-based digital gait characteristics independently gave 87.32% accuracy. The most significant characteristics in the classification models were related to root mean square values, power spectral density, step velocity and length, gait regularity and age. This study shows the importance of signal-based gait characteristics in the development of tools to help classify PD in the early stages of the disease.[8]

Juan C. Pérez-Ibarra, Adriano A. G. Siqueira, and Hermano I. Krebs (2020), proposed a novel algorithm that exploits the advantages of the different approaches used for detection of gait events. We built a wearable sensor device with a single IMU placed back of the heel. Three subjects (a healthy subject, a hemiparetic and a myelopathic) worn the devices and performed an experimental protocol with over ground and treadmill walking trials. Algorithms showed a high performance for healthy gait and their suitability for real-time implementations. However, none of the algorithms in the literature could maintain high accuracy during hemiparetic or myelopathic gait. Our algorithm obtained high accuracy for the three subjects: healthy (F1-score: 0.99), hemiparetic (0.97) and myelopathic (0.96). We aim to implement our proposal as part of the control loop of a robot during robotic gait therapy.[9]

Ferdous Ahmed, A S M Hossain Bari, Marina L. Gavrilova (2019), introduce a novel two-layer feature selection framework for emotion classification from a comprehensive list of body movement features. We used the feature selection framework to accurately recognize five basic emotions: happiness, sadness, fear, anger, and neutral. In the first layer, a unique combination of Analysis of Variance (ANOVA) and Multivariate Analysis of Variance (MANOVA) was utilized to eliminate irrelevant features. In the second layer, a binary chromosome-based genetic algorithm was proposed to select a feature subset from the relevant list of features that maximizes the emotion recognition rate. Score and rank-level fusion were applied to further improve the accuracy of the system. The proposed system was validated on proprietary and public datasets, containing 30 subjects. Different action scenarios, such as walking and sitting actions, as well as an action-independent case, were considered. Based on the experimental results, the proposed emotion recognition system achieved a very high emotion recognition rate outperforming all of the state of-the-art methods. The proposed system achieved recognition accuracy of 90.0% during walking, 96.0% during sitting, and 86.66% in an action-independent scenario, demonstrating high accuracy and robustness of the developed method.[10]

Mohanad Hazim Nsaif Al-Mayyahi, Nawaf Hazim Barnouti, Sinan Sameer Mahmood Al-Dabbagh(2019), proposed a method which has been well implemented and tested using CASIA dataset which consists of gait silhouette data of 20 subjects, where each subject offers 12 sequences of gait silhouette images. The algorithm that is proposed has three different stages. The representation stage computes the general average silhouette images to capture and gather the most important information from gait sequence. Then dimensionality reduction stage where PCA technique is applied to extract the most important gait features and greatly reduce the dimension of gait data depending on low frequency information. Furthermore, this approach will increase a discriminating power in the feature space when dealing with low frequency information. Since Low dimensional feature distribution in the feature space is assumed to be Gaussian, thus Euclidean distance is applied for classification and matching process in the classification stage. The experimental results indicate that best identification rate is 90% by representing the images using 50 gait silhouette frames for each and every gait silhouette sequence and 100 × 70 frame size.[11]

Carlos Fernandes, Flora Ferreira, Miguel Gago, Olga Azevedo, Nuno Sousa, Wolfram Erlhagen(2019), evaluated the effectiveness of different machine learning strategies when distinguishing patients with Fabry Disease (FD) from healthy controls based on normalized gait features. Gait features of an individual are affected by physical characteristics including age, height, weight, and gender, as well as walking speed or stride length. Therefore, in order to reduce bias due to inter-subject variations a multiple regression (MR) normalization approach for gait data was performed. Four different machine learning strategies - Support Vector Machines (SVM), Random Forest (RF), Multiple Layer Perceptron (MLPs), and Deep Belief Networks (DBNs) - were employed on raw and normalized gait data. Wearable sensors positioned on both feet were used to acquire the gait data from 36 patients with FD and 34 healthy subjects. Gait normalization using MR revealed significant differences in percentage of stance phase spent in foot flat and pushing (), with FD presenting lower percentages in foot flat and higher in pushing. No significant differences were observed before gait normalization. Support Vector Machine was the superior classifier achieving an FD classification accuracy of 78.21% after gait normalization, compared to 71.96% using raw gait data. Gait normalization improved the performance of all classifiers. To the best of our knowledge, this is the first study on gait classification that includes patients with FD, and our results support the use of gait assess me.[12]

Kosuke Morinaga, Shigekazu Ishihara, Ryuji Miyazaki, Toshio Tsuji, Kotaro Matsuura(2019), developed a computer vision-based bone marker tracking system for Point of Care, that works with common smart-phone or action-cam. With this system, the podiatrist could quantitatively judge problems of bone or joint movement and deformity during gait. The effects of the prescribed insoles are also quantitatively validated with this system. Flatfoot subject showed 10 percent increased the arch angle. High and rigid arch subject shown improvement on reactive control of the arch.[13]

M. Umair Bin Altaf, Taras Butko and Biing-Hwang (Fred) Juang(2015), described the acoustic gaits—the natural human gait quantitative characteristics derived from the sound of footsteps as the person walks normally. We introduce the acoustic gait profile, which is obtained from temporal signal analysis of sound of footsteps collected by microphones and illustrate some of the spatio-temporal gait parameters that can be extracted from the acoustic gait profile by using three temporal signal analysis methods—the squared energy estimate, Hilbert transform and Teager–Kaiser energy operator. Based on the statistical analysis of the parameter estimates, we show that the spatio-temporal parameters and gait characteristics obtained using the acoustic gait profile can consistently and reliably estimate a subset of clinical and biometric gait parameters currently in use for standardized gait assessments. We conclude that the Teager–Kaiser energy operator provides the most consistent gait parameter estimates showing the least variation across different sessions and zones. Acoustic gaits use an inexpensive set of microphones with a computing device as an accurate and un-intrusive gait analysis system. This is in contrast to the expensive and intrusive systems currently used in laboratory gait analysis such as the force plates, pressure mats and wearable sensors, some of which may change the gait parameters that are being measured.[14]

Brooke A. Slavens, Yabo Guan, And Gerald F. Harris(2009), presented a finite element analysis of a commercial forearm crutch for children during gait. The geometric features of the crutch structure were acquired and modeled. The finite element model was created using shell elements based on the frame surfaces. Linear elastic material properties for aluminum alloy were utilized. Upper extremity kinetic data from reciprocal and swing-through gait patterns were applied to the model as boundary conditions and loads. Stress distributions during two gait patterns were determined. Stress distributions during swing-through gait were found to be statistically greater than those during reciprocal gait ($p = 0.01$). This work provides novel quantitative data to improve crutch design and stimulate further analyses of upper extremity joint loads during forearm crutch-assisted gait in children with myelomeningocele (spina bifida).[15]

III. CONCLUSION

The ultimate goal of gait analysis is to provide reliable, objective data on which to base clinical decisions. A gait analysis laboratory requires an interdisciplinary team of individuals with various educational backgrounds who contribute their skills and who need to understand the underlying principles utilized to identify and correct neuromuscular deficiencies. The computer revolution will aid in developing new paradigms for computerized human movement analysis. New experimental techniques will be developed that will allow us to obtain real-time motion measurements. Computer animation techniques will become available to visualize gait data in an intuitive manner. Improvements will be made in our ability to obtain in vivo measurements of muscle function. Advances in both forward and inverse biomechanical models will continue.[16]

Gait as a behavioral biometric trait is a dominating research area because of its unobtrusive and non-perceivable characteristics, which can be suitable for visual surveillance monitoring. This report is an extensive survey of existing research efforts in the area of vision-based gait recognition systems. The article summarized the contribution of various authors in the field of gait analysis. Recently Deep learning has been explored in gait recognition and has achieved promising results, while deep learning required a larger dataset to work.[17]

By studying literature review of GAIT analysis, it is stated that GAIT has already done so much of work in the medical field and the ultimate goal of gait analysis is to provide reliable, objective data on which clinical decisions can be based. The future of gait analysis will require the ability to identify the critical tests, interpret data more quickly, predict the outcome of various clinical procedures, and quantify the outcome. In future, there is still so much of scope in medical field for gait. It is increasingly important that we consider the effectiveness of gait analysis and the role it will play in shaping the outcome of medical care.

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