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Mental Health and Well Being Surveillance Among Children (Abnormal Gait Recognition)

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Abstract— ***Gait recognition methodology used to recognize the person by their walking style. This technique is performed at a distance as video without the cooperation of the person who has to be recognized. Gait recognition have been used in various applications like access control, surveillance and forensics. Gait recognition strategies can be divided into three different techniques based on the setting as machine vision method, floor sensor method and wearable sensor method. In machine vision method, one or more cameras will be used for video capturing for processing the image transformation. This method is also termed as Gait Energy Image since the gait features were extracted from the blurring silhouette image got from the video. In floor sensor method, features of gait will be extracted from the images generated by the sensing floor. Wearable sensor method uses the techniques like gait kinematics, gait kinetics, and electromyography for extracting the gait signatures. Gait recognition is liable to variations, such as view angle, clothing, walking speed, shoes and carrying status. Convolution neural network is used to extract the high level features from less quality video by the following steps: preprocessing the video to obtain the input data. Extracting the features and comparing with pre trained neural network for recognition. A human acknowledgment and recognizable proof is viewed these days as an essential field of research. The most unique parts of human are the ear, odor, heartbeat, voice, the iris, periocular portion of eye, fingerprint, gait, sweat, face, etc,. Without the human interaction to identify a person is quite challenging with low resolution images. Gait recognition is one of the biometric technology which can be used to identify people without their knowledge. The proposed system uses Deep Convolutional Neural Network to extract the gait features of a person by training the neural network architecture with Gait Energy Image.***

Index Terms— ***Gait Recognition; Kinect; Biometric; Model-Based Gait Recognition; Center Of Body Relative Coordinates, Posture-Based Gait Features; Distance-Based Gait Features***

I. INTRODUCTION

Microsoft Kinect is a product used with XBox 360 gaming console, with this device a participant can control games by body motion without carrying any other sensor. Kinect also enables the tracking of different types of information involving for example: the human skeleton, face geometry, and also creating different depths of the captured image.Using Kinect SDK for Windows with a set of APIs provides a very efficient tool to develop a gait recognition application. Different ways of recognizing individuals by their gaits have been widely discussed in the literature for many years. The first work in this area was carried out by psychologists in 1971, when Johansson attached light points to the joints of people's bodies in a dark area. Participants then were asked to walk, run, or ride a bicycle . The results suggested that people can recognize each other by their individual walking styles. Work carried out by Perry in and Kumar et al. in, led to the hypothesis that gait is a characteristic that can be used as a biometric tool to identify people.

Gait recognition approaches can be classified into two models: motion -based (model free), and model-based. Model-based approaches use the structure of the human body and its motion as a model, utilizing information from body parts such as the foot, knee, ankle, hip, wrist shoulder, torso, thigh, head, and hand, for extracting features. Measuring lengths and distances between different parts of the body has been used for constructing gait features. Up to 20 subjects were proposed using simple activity-specific parameters (height, torso length, leg length, and step length) extracted from the double support phase (when both feet are on the ground) of the gait cycle.

Visual analysis of human motion is currently one of the most active research topics in computer vision and has led to several surveys, and biometric-based authentication are emerging as the most reliable solutions. Currently, there are various biometric technologies and systems for authentication, which are either widely used or being developed further. With increasing demand for a visual surveillance system, human identification at a distance has become an urgent need today. Biometrics recognition is a common and very reliable and effective way to authenticate the person based on physiological or behavioral characteristics. It is a science which is being used for detecting and identifying a person. Biometric systems for human identification at distance have an increasing demand in various significant applications.

A physiological characteristic is a relatively stable physical characteristic, such as fingerprint, iris pattern, facial feature, hand, etc. A physical characteristic such as hand, iris, and face have some limitations for identification; if someone wraps the face then it is difficult to identify the person and goggles create problem in iris identification. By using biometrics, it is possible to confirm or establish an individual's identity based on "who she is," rather than by "what she possesses" (e.g., an ID card) or "what she remembers" (e.g., a password). The interest in gait as a biometric is strongly motivated by the need for an automated recognition system for visual surveillance and monitoring applications.

Mental health and well-being surveillance among children encompasses a comprehensive examination of their emotional, psychological, and social states. This process involves ongoing data collection and analysis to assess factors such as emotional resilience, stressors, social interactions, and access to mental health resources. By closely monitoring these aspects, researchers, healthcare professionals, and policymakers gain valuable insights into the prevalence of mental health issues among children, identify potential risk factors, and design targeted interventions. This surveillance is crucial for fostering a supportive environment, early intervention, and the overall well-being of the younger population.

Biometrics is the automated use of physiological or behavioral characteristics to determine or verify identity of a person, the physiological biometrics examines physiological characteristics, like: iris, face , fingerprints, DNA, and hand geometry; the behavioral biometrics examines behavioral issues, such as: voice, signature, and gait. The importance of automatic identification of people has increased during the past decades, especially in high security areas such as airports and banks. Each person has distinguishable unique characteristics that can be used for identification. The science of biometrics uses these unique characteristics to verify and identify the person's identity. Gait recognition is one of the important biometric tools that aims to recognize individuals (from distance) by their style of walking, psychological studies show that people have a reasonable ability to recognize other individuals by the way they walk. A unique advantage of gait, as a biometric measure, is that it potentially offers recognition from a distance at low resolution whilst requiring no user cooperation, whereas other biometrics are likely to require a certain level of cooperation. Gait recognition systems are based on analyzing video sequence recordings. Microsoft has produced a device called the Kinect sensor which supports this kind of analysis, as described below.

In our proposed method we will use a Kinect sensor for constructing 2 sets of dynamic features; the Horizontal Distance Feature (HDF) and the Vertical Distance Feature (VDF). These features are extracted based on data related to the feet, knee, hand, shoulder, hip and height during one gait cycle.

II. PROPOSED METHOD

Our system consists of four stages:

- The creation of an application for skeleton recording.
- Creating a database by recording skeleton information using Kinect.
- The detection of a gait cycle for each subject.
- The extraction of features.

we propose a model for gait recognition based on the skeleton that is provided by the Microsoft Kinect sensor. As explained before, a Kinect sensor supported with its SDK provides a high quality of a human skeleton for up to two persons. Kinect also provides RGB image and depth image, but we used a skeleton model only. In general, our system consists of four stages: firstly the creation of an application for skeleton recording and creating a database by recording skeleton information using Kinect, secondly the detection of a gait cycle for each subject, and thirdly the extraction of features in two different sets: VDF and HDF, this will be described in more details later. Finally, K-Nearest Neighbour (KNN) is used as a classification method.

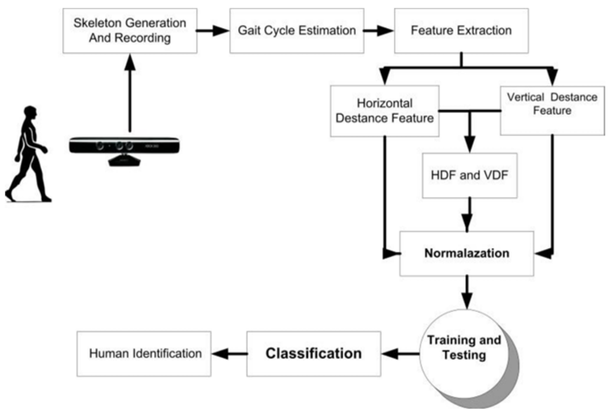

Figure 1. Over view of gait recognition system.

A. System Review

Kinect technology is a human machine interface that has been attracting more interest from researchers. In this paper we propose gait recognition system based on Kinect. Kinect is providing 20 useful points (see Table 1) presenting human skeleton from head over hip to foot more precisely that can have a major role in gait recognition as compared to other types of cameras.

Table 1. Joint points name and numbers.

Joint Number	Joint Name	Joint Number	Joint Name	Joint Number	Joint Name
1	Hip Center	8	Hand Left	15	Ankle Left
2	Spine	9	Shoulder Right	16	Foot Left
3	Shoulder Center	10	Elbow Right	17	Hip Right
4	Head	11	Wrist Right	18	Knee Right
5	Shoulder Left	12	Hand Right	19	Ankle Right
6	Elbow Left	13	Hip Left	20	Foot Right
7	Wrist Left	14	Knee Left		

B. Data Recording

We tested the accuracy of Kinect measurements of distances between Kinect and subject by recording 10 short records for 5 persons at different distances such as 3.5m, 3m and 2.5m. We then compared the accuracy of these distances. We decided the optimum distance between Kinect and the subject to be 2.5m because at this distance the skeleton

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information presents more clearly than at the other distances and provides more than one gait cycle. The height of the Kinect sensor was 0.6m, the angle of the Kinect was 0 degrees and it recorded at approximately 30 frames per second. For the experiment, 20 participants (16 males and 4 females) walked across in the front of the Kinect sensor from right to left at an angle of 90 degree. They were asked to walk normally 10 times, providing a total of 200 records, as shown in figure 2.

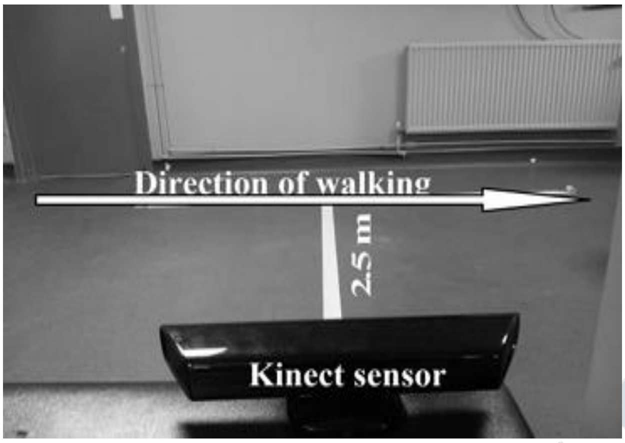

Figure 2: Kinect Sensor

C. Gait Cycle Estimation

The gait cycle refers to the entire sequence of events from the initial contact of one foot with the ground (heel strike) to the subsequent contact of the same foot. It is divided into two main phases: the stance phase and the swing phase. The stance phase constitutes approximately 60% of the cycle and includes several components: the loading response where the foot first contacts the ground, mid-stance where the body passes directly over the supporting limb, terminal stance just before the foot lifts off, and pre-swing where the other foot begins to swing forward. Following the stance phase, the swing phase makes up the remaining 40% of the cycle and includes initial swing where the foot lifts off the ground, mid-swing during continuation of the swing, and terminal swing where the foot prepares to strike the ground again.

Estimating the gait cycle involves various techniques. One approach is to identify points of mid-stance or local minima where both feet are close together, often occurring during mid-stance or the end of the swing phase. Another method involves measuring the distance between the ankles instead of the feet, particularly during the double support phase when both feet are in contact with the ground simultaneously. This method aims to improve accuracy by using the maximum separation between ankles as a reference point.

In terms of terminology, each complete sequence from one heel strike to the next is considered a gait cycle. "Extra steps" may refer to additional steps taken beyond a single gait cycle, indicating ongoing walking beyond the typical cycle.

Understanding the gait cycle and employing precise estimation techniques is crucial for analyzing human locomotion and biomechanics. It allows researchers and practitioners to identify distinct phases and transitions within each cycle, contributing to advancements in gait analysis and rehabilitation strategies.

$$\text{Distance of ankles} = |\, X \text{ right ankle} - X \text{ left ankle}|$$

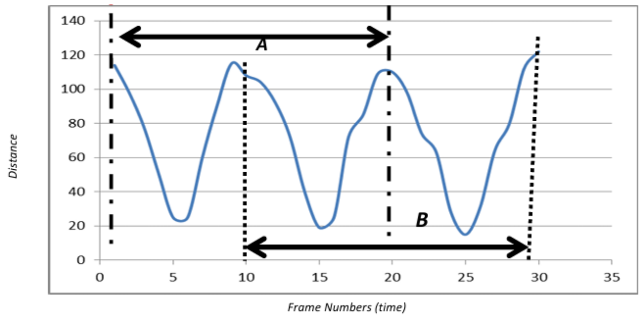

Figure 3: Gait cycle generation.

D. Feature Extraction

In our study, feature extraction differs significantly from conventional camera-based techniques due to our use of Kinect sensors for capturing human skeleton information. The Kinect sensor tracks 20 joint points of the human skeleton, resulting in a dataset that includes X and Y coordinates for each of these 20 joints, totaling 40 attributes. From these, we selected 16 attributes for feature extraction as follows: X and Y coordinates of both ankles, X coordinate of both feet, X coordinate of both knees, X coordinate of both wrists, X coordinate of both shoulders, Y coordinate of the head, Y coordinate of the right wrist, Y coordinate of the right shoulder, and Y coordinate of the center hip.

Based on these joint points, we extracted two sets of dynamic features: Horizontal Distance Features (HDF) and Vertical Distance Features (VDF).

Horizontal Distance Feature (HDF)

The HDF is based on measuring changes in distances between skeleton joints along the X-axis during one gait cycle. We defined four specific features: step length (HD1), distance between right and left knees (HD2), distance between right and left wrists (HD3), and distance between right and left shoulders (HD4), as illustrated in Figure 5 of our study. Instead of using the feet for step length, we utilized the ankles for improved accuracy. For each of these measurements within a gait cycle, we calculated the mean, skewness, and standard deviation. These statistical measures represent the temporal changes of distances across all frames in one gait cycle. The feature vector was constructed using the mean and standard deviation values.

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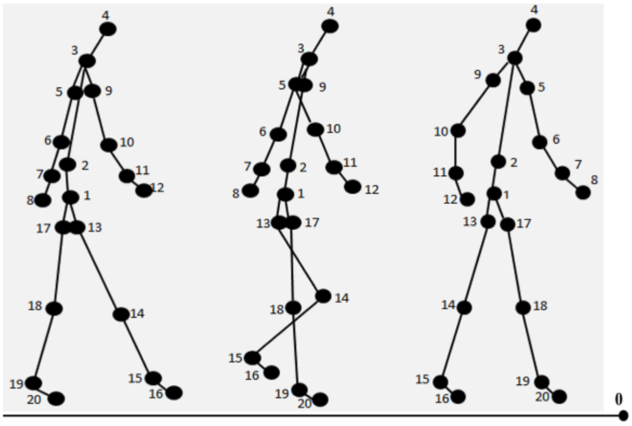

Figure 4: Horizontal and Vertical distances extracted from the skeleton.

HD1= abs (D (Jx (19) - Jx (15)))
HD2= abs (D (Jx (18) - Jx (14)))
HD3= abs (D (Jx (11) - Jx (7)))
HD4= abs (D (Jx (9) - Jx (5)))
MeanH= mean {HD1, HD2, HD3, HD4}
StdH= Std {HD1, HD2, HD3, HD4}
SkwH = Skew {HD1, HD2, HD3, HD4}
HDF = {MeanH, StdH, SkwH}
Where D is distance, Jx is horizontal joint coordinate

Vertical Distance Feature (VDF)

The VDF captures changes in the distance between a skeleton joint and the ground along the Y-axis. We proposed six features to characterize the human body: participant's height (VD1), height of the right wrist (VD2), height of the right shoulder (VD3), heights of the right and left ankles (VD4 and VD5). Similarly, we calculated the mean and standard deviation for each feature across one gait cycle. Additionally, we computed the mean of VD6, which involves the distance between the hip-center and the ground, forming a triangle with the feet. This mean was added to the feature vector.

VD1= D (Jy (4) - Ly (0))
VD2= D (Jy (11) - Ly (0))
VD3= D (Jy (9) - Ly (0))
VD4= D (Jy(19) - Ly (0))
VD5= D (Jy (15) - Ly (0))
VD6= 1/2 *(| Jx(20) – Jx(16)|) * Jy(1)
MeanV= mean {VD1, VD2, VD3, VD4, VD5, VD6}
StdV= Std {VD1, VD2, VD3, VD4, VD5}
VDF = {MeanV,StdV}
Where D is distance, Jy is vertical joint and Ly is land line.

These feature extraction techniques allow us to effectively represent and analyze the dynamics of human movement based on Kinect-derived skeletal data. They contribute to our understanding of gait patterns and can support various applications in biomechanics, healthcare, and rehabilitation.

III. ALGORITHM AND EXPECTED RESULT

A. Algorithm

- Initialize variables: h to 1, s1 to the path of the dataset, df3 to an empty DataFrame with columns 'PersonID', 'MeanV', 'StdV'.
- Start a while loop that iterates from 1 to 5 (inclusive). This loop represents processing the data for each person in the dataset.
- Within the while loop, set s9 to the string representation of the current person number (h), and s7 to the path of the current person's data file.
- Read the current person's data file into a DataFrame df1 using pd.read_csv(). The data file is assumed to be in a semicolon-separated format, with the first column representing the joint number, and the next three columns representing the X, Y, and Z coordinates of the joint.
- Initialize variables: count to 0, i to 0, k to 5, count to the length of df1.
- Start a while loop that iterates while count is greater than i. This loop represents processing each frame of the current person's data.
- Within the inner while loop, calculate the vertical displacement (VD) values for each joint in the current frame. These values are calculated by taking the absolute difference between the Y coordinate of the joint and a reference value (0.6 in this case).
- Calculate the mean (MeanV) and standard deviation (StdV) of the VD values.
- Append the current person number (k), mean VD value, and standard deviation VD value to the df3 DataFrame.
- Increment the count variable by 1, and the i variable by 20.
- After processing all frames for the current person, increment the k variable by 1.
- After processing all persons, write the df3 DataFrame to a CSV file using df3.to_csv().
- The code provided processes the kinect gait raw dataset by calculating the vertical displacement (VD) values for each joint in each frame of each person's data. It then calculates the mean

B. Expected Result

In our study, we utilized a database created from human skeleton information recorded by a Kinect sensor. This dataset includes (x, y) coordinates representing 20 joint points captured from side views of 20 subjects, with 10 recordings per subject. Following data collection, we conducted preprocessing tasks such as data cleaning, gait cycle estimation, and feature extraction. These efforts resulted in two distinct sets of meaningful features prepared for processing by our recognition system.

Our approach employed the K-Nearest Neighbours (KNN) algorithm as a classification method, which relies on

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determining the shortest distance to classify data points. After evaluating K values ranging from 1 to 10, we determined that setting K to 1 provided the optimal recognition rate.

We constructed two sets of feature vectors, namely Horizontal Distance Features (HDF) and Vertical Distance Features (VDF), as detailed previously. Testing our system involved using each set of feature vectors separately, as well as combining HDF and VDF into a single feature vector. When HDF was used alone, it achieved a recognition rate of 56%. In contrast, VDF demonstrated higher accuracy with a recognition rate of 83.5%. Combining HDF and VDF into one feature vector significantly improved the recognition rate to 92% (see Figure 5).

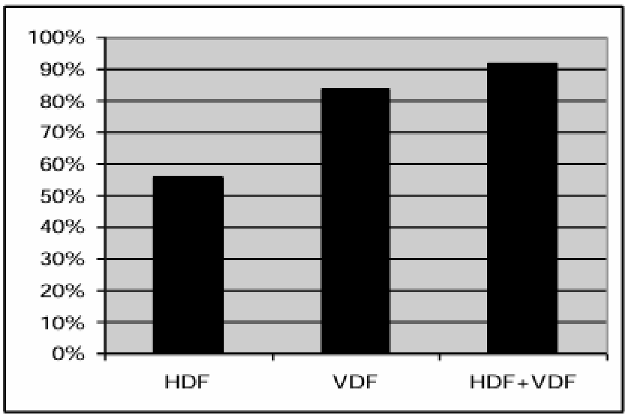

Figure 5: Recognition rate with the feature type.

These results underscore the effectiveness of our feature extraction approach using Kinect-derived skeletal data in enhancing recognition accuracy for gait analysis. The combined feature vector approach harnesses the complementary strengths of HDF and VDF, thereby improving the overall performance of our recognition system.

Calculated efficiency of dataset with confusion matrix.

Output: Accuracy 60%

```
[[257  18   1   1   1 151   0  79  56  24]
 [ 34 202 162   1   1  22   1  18   5   6]
 [  6 120 483  15  36   7   6  10   0   3]
 [  7  19  45 291 137  12  43   2   2   2]
 [  0   7  67 114 238   0  63   0   1   0]
 [176  28   5   2   0 319   0  29  53  23]
 [  1   4  16  25  33   1 586   5   1   8]
 [ 71   4   6   0   3  14   3 427  29   8]
 [ 86   3   0   2   0  41   0  24 279  49]
 [ 61   7   0   0   0  31   1   7 109 465]]
0.6093454732863769
```

Figure 6. Confusion matrix

IV. CONCLUSION

[1] In our study, we introduced a novel gait recognition approach leveraging skeleton point trajectories captured by a Kinect sensor, which offers more robust and detailed skeleton information compared to traditional camera-based methods. Our approach focused on two sets of features: HDF (Horizontal Distance Features) and VDF (Vertical Distance Features). These sets were independently classified using the K-Nearest Neighbors (KNN) algorithm with CityBlock distance function, and subsequently combined into a unified feature set (HDF+VDF). The recognition rates achieved for HDF, VDF, and the combined feature set were 56%, 83.5%, and 92%, respectively. These results demonstrate significant improvement over existing techniques for gait recognition.

[2] Our approach outperformed traditional methods for two main reasons: firstly, by introducing a novel set of features based on vertical distances which cannot be extracted from traditional gait silhouettes; and secondly, by achieving more precise feature point identification compared to techniques relying on conventional cameras.

[3] As gait recognition using Kinect sensors is a relatively emerging field, several challenges remain for future research. Our future work includes expanding the current feature set by extracting new features and exploring different classifiers to further enhance recognition accuracy. We also aim to develop approaches for gender classification based on gait using Kinect sensors, and to address challenges such as the impact of carrying objects or wearing different clothing on normal walking patterns. Additionally, we plan to expand our dataset to include variations in walking direction, angles, and other environmental factors captured by Kinect sensors.

[4] These future research directions aim to advance the capabilities of gait recognition systems using Kinect technology, contributing to improved performance and broader applicability in various real-world scenarios.

[5] Given the increasing demand for long-range human identification in visual surveillance systems, gait has emerged as a promising biometric feature due to its unique behavioral characteristics. Recent studies have demonstrated its potential for effective human recognition.

[6] Advancements in computer vision techniques have enabled automated gait analysis, making real-time applications feasible. Our proposed system has been rigorously tested on gait databases, with extensive experiments conducted on outdoor image sequences showing promising recognition performance.

[7] The approach integrates automatic gait cycle estimation and recognition, ensuring suitability for real-time deployment. Compared to existing methods, our approach achieves highly competitive performance, leveraging temporal dynamics to enhance reliability and robustness in human gait analysis. Through these enhancements, our recognition approach achieves up to 90% accuracy, surpassing earlier developments in the field.

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This method represents a significant advancement in accurately identifying individuals based on their gait, addressing critical challenges in surveillance and security applications effectively.

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