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Original Article

Human Gait Recognition using Discrete Wavelet and Discrete Cosine and Transformation Based Features

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Abstract - *Nowadays, human gait recognition is a popular technique due to security requirements in public places. Gait recognition technique is used to identify a person from his/her walking cycle and cooperation of a human being is not required in this process. In this article, the DWT (Discrete Wavelet Transform) and DCT (Discrete Cosine Transform) feature extraction techniques are considered for extracting the unique properties for gait recognition of an individual. For classification, DT (Decision Tree), RF (Random Forest) and K-NN (K-Nearest Neighbors) are considered in this work, because these classifiers are performing well in the field of pattern recognition research area. The gait cycle has two phases, namely, stance phase and swing phase. Stance phase has included heel strike, foot flat, mid stance, heel off, toe off. Swing phase included acceleration, mid swing, de-acceleration. These both phases are considered in this work to recognize gait of an individual. Information of gait is obtained from different parts of silhouettes. The human silhouette is segmented into seven components namely head, arm, trunk, thigh, front leg, back leg, and foot. People can be recognized by their gait become popular and there are the various reasons such as this can be done remotely, do not need high resolution videos etc. In this article, the authors have considered publicly available dataset, namely CASIA-A gait image dataset for the experimental work. Using features and classification methods considered in this work, the authors have achieved a recognition accuracy of 84.26% with random forest classifier for CASIA-A public dataset.*

Significance of the work *— In this article, the authors have presented DCT and DWT feature extraction techniques and decision tree, random forest and K-NN classification techniques for gait recognition of an individual. The authors have reported a recognition accuracy of 84.26% for CASIA-A public dataset of gait recognition using DCT features and Random Forest classifier.*

Keywords *- DCT, DWT, Decision Tree, GAIT, k-NN, Random Forest.*

I. INTRODUCTION

Gait recognition process is used to identify a person or individual from his/her walking style. Every person has different gait that is useful to recognize an individual. There is also having different recognition methods such as iris scan, face recognition, voice recognition, etc. The gait recognition is useful when any person who carries out an illegal act trying to hide their face by wearing cap and sunglasses. But, in gait recognition natural walking of an individual cannot be hiding. Gait recognition has unique properties such as gait of the individual captured the distance whereas fingerprint and iris scan recognition system cannot be captured from the distance. In gait recognition, the gait of the individual also captured from low quality videos. The gait recognition also works when the face of the individual is hiding because the person can hide his face easily but cannot his walking style [1]. In most of the previous gait recognition approaches standard video cameras were used to take the gait of individual. The disadvantage of standard video cameras was problematic to separation of features for identification [2]. There are various application areas where gait recognition system used such as clinical diagnosis and biometrics. In medical area, gait recognition mostly used in Neurological Disease, Surgery Prognosis and Parkinson Diagnosis. Gait recognition also used to recognize any criminal [3]. Automatic gait recognition in existing work was divided into two approaches that are holistic approach and the model-based approach. The focus of holistic approach to obtain the various statistical features of the individual from his silhouette and these are used to recognize the person [4]. The model free approaches are mostly used today's because these are less exhausted and strong in noise. The human gait features are divided into three parameters temporal, spatial and kinematic parameters. The step length, speed, gait cycle, average stride length is included in the spatial and temporal parameters. And joint angles included in kinematic parameters. The gait cycle of the subject has two phases, namely, stance phase and swing phase. Gait cycle is the time period between two successive hitting of foots of an individual. When the foot is the initial contact with the ground is the beginning of the stance phase [5]. The stoppage of foot contact with the ground is the starting of the swing phase. Stance phase sub-divided into five phase's heel strike, foot flat, mid stance and toe off. The timing between the heel strike and toe off gives the information to survey temporal gait parameters. Heel strike: Heel is striking the floor. Foot Flat: when foot is completely contact with the ground. Mid Stance: It is just the mid of the stance phase. Heel off: It is a component when heel is leaving the ground. Swing phase is sub-divided into three parts: Acceleration: Person tried to accelerate the leg forward. Mid Swing: The leg remains in the centre of the swing phase. De-acceleration: The person tried to stop the leg for a next heel and prepare for the next stance phase [6].

II. MOTIVATION

The strolling style of each individual is a unique feature, and it is hard to duplicate the strolling style of someone else. There are numerous experiments have been done in the earlier year for gait recognition. These days, gait recognition gets so much ubiquity in light of the fact that there is no need of individual touch the machine-like fingerprints or face detection. The other primary reasons gait recognition gets prominence since it works distantly, no need of someone else just the individual required gait style need to perceive (Mantyjarvi et al., 2005).

III. REPORTED WORK

Chattopadhya et al. [7] used kinect RGB-D camera to capture the gait of an individual from the frontal view. They merged depth and color streams from kinect RGB-D camera. Recognition accuracy was 80 percent and performed experiment on 30 subjects where every subject has 30 frames using gait energy image and poses depth volume. Foster et al. [4] tested experiment on 114 subjects and achieved accuracy of 75%. They used masking function to recognize the individuals. The masking function measures area as a time varying signal from a sequence of silhouette. Nickel et al. [8] worked on the extracting gait cycles of the individual gait data. They used Hidden Markov Models technique to recognize the walking style of subject and used accelerometer for gait recognition. They considered 48 subjects' dataset for their experimental work. Han and Bhanu [9] used spatio-temporal technique which was gait energy image. They combined statistical gait features of real and synthetic templates for gait recognition and for experimental work they considered public dataset namely, USF HumanID database. Yu et al. [10] have proposed a framework to compare the performance of various gait recognition techniques. Middleton et al. [11] used a floor sensor system for gait recognition of the person. The cost of those sensors was low, and they performed experiments on the 14 individuals. The stride length, stride cadence and time features were extracted, and sensors were arranged in a 3m by 0.5mm rectangular strip. They achieved accuracy of 80%. Johnston and Wesis [12] designed a smart watch for the recognition of gait of a person or individual. The main advantage of smart watch-based gait recognition system was that every person wears own watch at any location. So, the location provides the information of the user. Huang [13] used a statistical method to recognize the walking of individual which is the feature extraction method. This method extracts features from spatial and temporal templates.

Xu and Zhang [14] suggested a fuzzy principal component analysis to extract gait energy image. The first step was captured the image and got gait energy image and after that extracted fuzzy components and they used neural network classifier for feature classification. They tested experimental work on public dataset namely, CASIA database. Otero [15] suggested continuous wave radar system for recognition of gait. When any person walks, he produced Doppler signature which was used for the detection and classification of an individual. The various components of person produced various Doppler signature. The Continuous Wave Radar system was cheaper which the main advantage of this system was. Begg and Kamruzzaman [16] proposed a machine learning technique for recognition of gait. They have used three gait evaluation features that are temporal/spatial, kinetic and kinematics. They have performed a test on 24 individuals where 12 were young and 12 were elder. They have achieved a recognition accuracy of 91.7%. Baker [17] discussed about the history of gait recognition before the arrival of modern computers. He discussed the gait history from 384-322 BCE to 1926- 2000. At 384-322 BCE, the researcher Aristotle who was the citizen of Greece discussed about the human and animals' motion of movements. In most of the gait recognition technique, two types of approaches used that is model based and model free techniques. Model free technique is depending on the data gathered from the silhouette and in model based focused on joint angles of the person. The silhouette of the person extracted from the video which was recorded by surveillance cameras. The model free approach was mostly used today's because those were less exhausted and strong in noise [18].

IV. PHASES OF GAIT RECOGNITION SYSTEM

In this article, the authors have considered two feature extraction methods and three classification models for the gait recognition of an individual. The feature extraction methods are, namely, DWT (Discrete Wavelet Transform) and DCT (Discrete Cosine Transform). The classification methods used in this work are Decision Tree, Random Forest and K-NN. Fig. 1 depicts about the gait recognition process which consists of the various phases, namely, data acquisition, feature extraction, dimension reduction and classification.

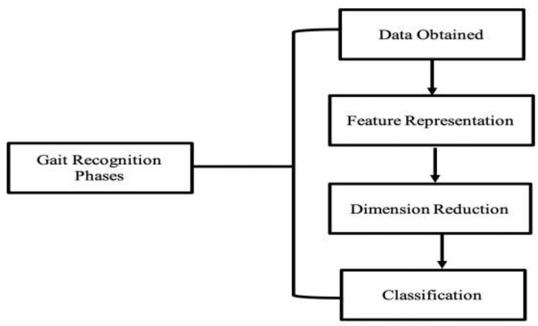

Fig. 1 Gait Recognition Phases

In gait recognition process, initially step is a data acquisition phase. In this phase, the data is collected using camera, floor sensors, accelerometer, or radar. To capture the videos of subject, cameras are positioned at some meter distance from the subject. Then the human gait data is recorded in video, which is further used to recognize individual. Many sensors of gait system are deployed for floor to collect human gait data like OR6-7 platforms, sensor mat, load cells, EMFi floor etc. The interval of time present between acceleration values in the resultant acceleration signal is not equal at every point of time. Therefore, the signal is interpolated to produce equal time intervals (Han and Bhanu, 2005) and after this the level of fluctuation present in the signal is reduced with the help of moving average filters. The second step of gait recognition is feature extraction. The main aim of this phase is to depict a process of entire movement and shape of the silhouette image of a person. Feature extraction phase is very important phase for gait recognition because efficiency of the gait recognition system is depending upon the quality of the feature set. In this article, the authors have considered two feature extraction methods, namely, DWT (Discrete Wavelet Transform) and DCT (Discrete Cosine Transform). The last phase is the classification, which is used to measure to similarity between stored feature set and candidate feature set of a gait. In this work, the authors have considered three classification techniques, namely, Decision Tree, Random Forest and K-NN [1].

A. Pre-Processing

Pre-processing consists of various techniques that increased the quality of the digital image and remove the unnecessary data from the image. The various pre-processing techniques are such as distribution linearization, spatial digital filtering, contrast enhancement and image subtraction [19]. Pre-processing is a combination of various functions used to enhance the quality of image. The pre-processing has six steps, first step is capturing the original image, second step is converting the original image into binary image, third step is spoofed the edges of an image, fourth step is detection of key points, fifth step is coordinate system and last step is central part of the image [20].

B. Feature Extraction and Selection

Feature extraction is the important step of the gait recognition system. This step of the gait recognition technique explains the subject and assistance of the gait procedure. Feature extraction phase is used to extract the unique properties for gait recognition. This is the first step for feature representation that is feature extraction. Here, the authors discussed two feature extraction methods, namely, DWT (Discrete Wavelet Transform) and DCT (Discrete Cosine Transform).

DWT (Discrete Wavelet Transform) is one of the important feature extraction methods that are used for image compression and signal processing. To decrease the data dimensionality and for noise filtration, we acquire DWT technique and therefore we retain a series of low dimensional gait feature [21]. A DWT based latest image coding standard developed by the committee of JPEG is JPEG-2000. It is used to fragment a signal into various functions and those functions are referred to as wavelets. In the latest era 2D-DWT is introduced to perform the basic operations for image processing. A signal is partitioned into low pass components by using DWT. In DWT, one can apply the low pass and high pass filter on the image [22]. The low pass filter provides horizontal approximation and high pass filter provide horizontal detail of the image. After this process on the horizontal approximation one can apply the low and high pass filter.

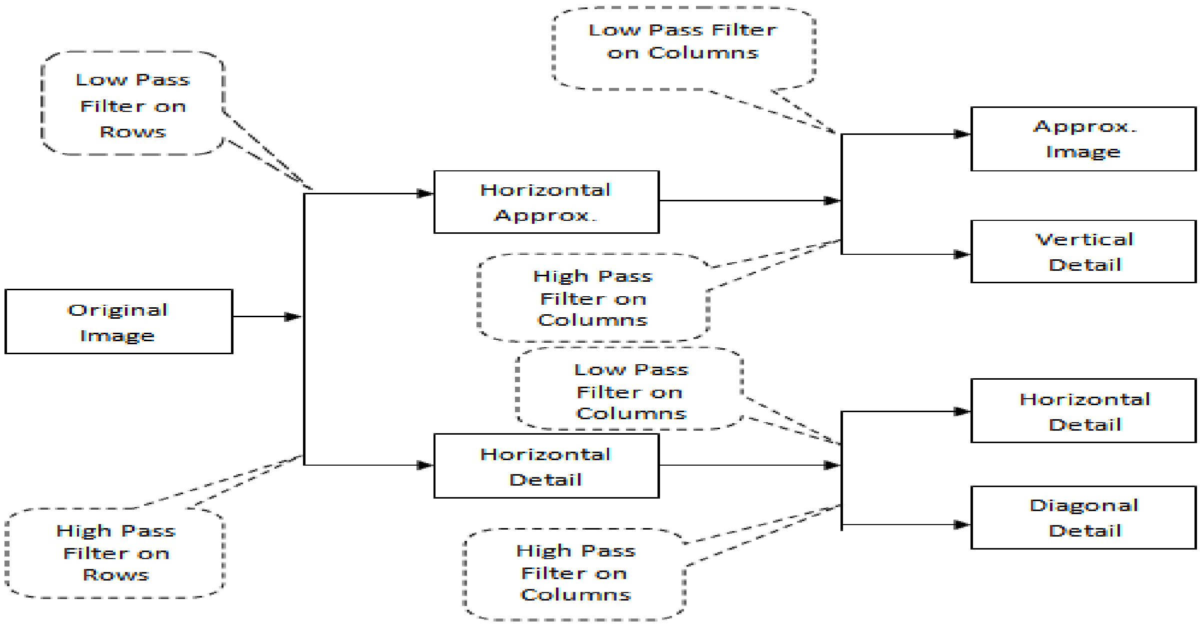

Fig. 2 Discrete Wavelet Transform

DCT (Discrete Cosine Transform) is used to extract the frequency domain information from the gait energy image. To differentiate the various frequency domain components of gait silhouette has successfully applied. DCT is one of the most popular feature extraction techniques because it is uncomplicated for implementation and in the comparison with other methods it is fast. DCT has ability to remove the redundancy from the signals. This method is most popular in the area of image processing and pattern recognition [23]. DCT method was suggested by Ahmed, Natrajan and Rao in 1970s. DCT method is quite the alteration of real signals, and those real signals are included in the frequency domain.

C. Classification

In this article, three classification models, namely, Decision Tree, K-NN and Random Forest are considered for gait recognition based on DCT and DWT features. Decision Trees is an approach of classification method where data set divided into smaller segments that is depends on a set of tests and it is divide every branch in the tree. The tree has a parent node, child nodes and terminal nodes. The root node is only one also called parent node and two or more child nodes, also called internal node and descendants. The terminal nodes are leaf nodes, which has not any other nodes [24]. The decision tree has various types such as homogeneous decision tree, uni-variate decision tree, multi-variate decision tree and hybrid decision tree. Uni-variate decision tree is a method where the region of every descendant in the tree described by the result of the test which passes at every child node. When the result of the test received, the data is divided into two or more segments, and this will happen till the leaf nodes are not received [25]. The main difference between multivariate decision tree and uni-variate decision tree, is that the multivariate decision tree dividing test at every vertex for multiple feature and uni-variate decision tree dividing test for every vertex for single feature [24]. The random forest technique depends on, the multiple decision trees were combined, where selection of fewer portion of components was accumulated method similarly needed training sample to build the application like other techniques such as regression and classification techniques. Random Forest method has not included trimming of the trees. Alternatively, random forest method makes a huge combination of unrelated trees and the result of those unrelated trees merged with configuration of generalized predictor [26]. Random forest technique is an entity that induced one or more decision trees [27]. In several classification techniques, Random Forest is well planned and robust technique. Random forest technique depends basically on bootstrap-aggregating.

V. EXPERIMENTAL RESULTS

In this section, the authors have presented experimental results for the CASIA-A public dataset of gait recognition. In this dataset, there are 20 classes, and each class has 12 image sequences. 4 sequences for each of the three directions, i.e., parallel, 45 degrees and 90 degrees to the image plane. The length of each sequence is not identical for the variation of the walker's speed, but it must range from 37 to 127. Recognition results using DWT and DCT features are depicted in Table I.

Table 1. Recognition results using DCT and DWT features

Feature Extraction Technique	Performance Evaluation Parameter	Classification Techniques		
		K-NN	Decision Tree	Random Forest
DWT	Recognition Accuracy	62.10%	68.29%	82.24%
	False Acceptance Rate	61.19%	67.12%	82.14%
	False Rejection Rate	0.17%	0.14%	0.11%
DCT	Recognition Accuracy	64.10%	71.12%	84.26%
	False Acceptance Rate	63.70%	71.06%	84.06%
	False Rejection Rate	0.14%	0.12%	0.09%

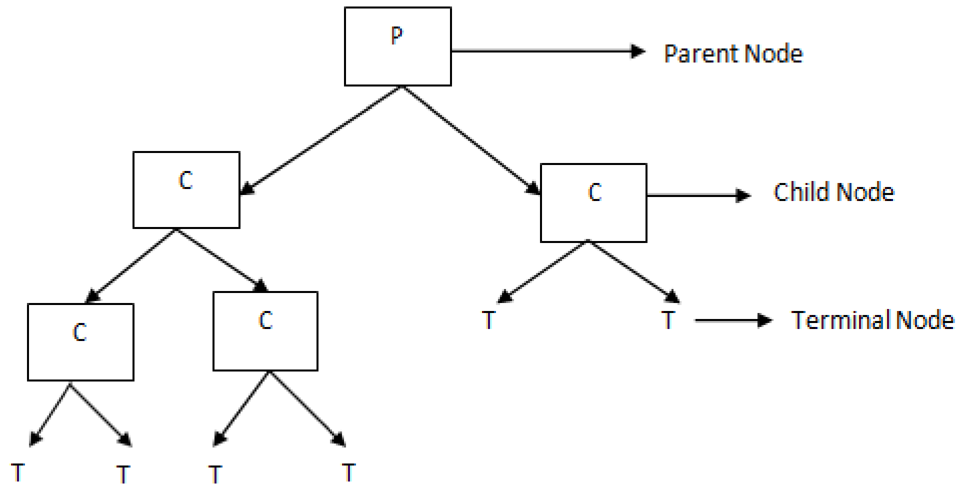

Fig. 3 Decision tree

VI. COMPARATIVE STUDY WITH THE STATE-OF-THE-ART WORK

In this section, the authors have presented a comparison between the proposed methodology and existing methodologies. As one can see that the proposed technique is performing better than all other existing methodologies as depicted in Table II.

Table 2. Comparison of the proposed methodology with existing methodologies

Feature Extraction Technique	Performance Evaluation Parameter	Classification Techniques		
		K-NN	Decision Tree	Random Forest
DWT	Recognition Accuracy	62.10%	68.29%	82.24%
	False Acceptance Rate	61.19%	67.12%	82.14%
	False Rejection Rate	0.17%	0.14%	0.11%
DCT	Recognition Accuracy	64.10%	71.12%	84.26%
	False Acceptance Rate	63.70%	71.06%	84.06%
	False Rejection Rate	0.14%	0.12%	0.09%

VII. CONCLUSION

In this article, the authors have presented DCT and DWT feature extraction techniques and decision tree, random forest and K-NN classification techniques for gait recognition of an individual. Swing and Stance phases of gait cycle are also explained. There are various application areas where gait recognition system used such as clinical diagnosis, biometric and justice system etc. The authors have reported a recognition accuracy of 84.26% for CASIA-A public dataset of gait recognition using DCT features and Random Forest classifier. Gait recognition technique becomes popular day by day as it works remotely. So, in future work, the most efficient techniques must be proposed for human gait recognition to achieve acceptable recognition accuracy.

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