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Feature Extraction Technique for Human Gait Video Analysis

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Abstract: This analysis is to compare the PCA, KPCA, LDA, ICA, LBP and LDP technique and suggestion on suitable techniques for gait analysis on children and adult; for both normal and with impairment. This study reviewed journal and studys in the area of computer sciences. All studys were restricted to english publications only. Study that discussed on gait video analysis, gait recognition and feature extraction techniques has been analysed. Any study related to PCA, KPCA, LDA, ICA, LBP and LDP techniques were also included in this analysis. Document that >2009 based on date of publication were excluded from this analysis. The comparison of the six techniques has been made based on the researchers comments and suggestions in the study reviewed. The comparison has been divided into 3 categories which are the advantages, disadvantages and similarity. The 5 features has been chosen as techniques that are related to the gait parameters. We have found that all techniques can handle the spatio temporal data. Spatio-temporal data is a calculation based on gait parameter such as velocity, cadence, time, stride duration, stride length, step width. Based on the spatio temporal data, the techniques can map the data either in linear structure or nonlinear structure. Linear structure means the technique has map the data in a straight line while for nonlinear structure the techniques can map the data into non straight line or curvy lines. There are two types of feature which are local feature and global feature. Local features extracted salient point in the input domain while global features extracted from the complete gait image. This study can be enhance by comparing more techniques available and perform an experiment on those techniques to obtain more precise result.

Key words: Adult's gait, children's gait, feature extraction, linear structure, presice result

INTRODUCTION

Gait is a daily movement and many elements influenced the gait for example age, weight and possible gait disorders (Karg *et al*., 2010). Similar to fingerprint, each individual's gait is unique. According to Pushparani and Sasikala (2012) gait recognition is a new biometric approach, the objective is to recognize human by their walking style. Defining the gait is a very challenging task. Walking for human is an easy process and it comprises significant information such as health, age, gender and emotion (Jabid *et al*., 2010). Human's gait analysis involves with challenging issues because of the self-occlusion and highly flexible structure of the human body.

Most of the gait characteristic that were extracted from video could consist of repeated or unessential steps for the recognition task. Therefore, it is crucial to use a suitable feature extraction strategy to recognise the gait. In this study we try to understand the feature extraction technique based on studys reviewed. The comparison of the feature extraction techniques is based on comments and suggestions in the reviewed study. We will suggest the best technique for gait video feature extraction based on the gathered information.

Background of the problem: Gait analysis is a technique to understand the way of human's walk or stand. There are variances in the way human walks where these can be an important remark in terms of recognizing a human. Gait video analysis can be an important assessment tool where it helps to reveal the human gait abnormalities. By using one human walk even in the complex background image in the video timeline it will produce important data between the most match frames. There are lots of techniques that can be used to extract the features in the video to recognize a gait. Worapan stated that up to now, there are no standard methods to extract gait features. Each technique has different functionality, advantages and disadvantages. According to Karg *et al*. (2010), gait extraction is complicated because video recordings of gait patterns are categorized by time dependence, nonlinearities, high variability and high dimensionality. By choosing the unsuitable technique, it will impact the

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accuracy of gait recognition. This study is to suggest the best feature extraction technique in gait video analysis based on comparison of each technique.

Objectives of the study: The study was conducted to find the suitable feature extraction technique for gait video analysis for different type of human gaits. In this study, six techniques has been compared which are the Principal Component Analysis (PCA) Kernel Principal Component Analysis (KPCA), Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA), Local Binary Pattern (LBP) and as Local Directional Pattern (LDP). The objectives of this study can be defined as:

- To compare the advantages and disadvantages of each technique
- To suggest an appropriate technique for each gait analysis
- To suggest the best technique for video gait analysis

For the study, a thorough literature review has been done on the pertinent areas.

Gait video analysis: Human movement handles various details where it can be evaluated in many techniques. Human movement can be processes through video analysis. Computer vision method can be used to recognize the way human walk by recognizing the gait movement in the human (Pang *et al*., 2010). The human skeleton brings movement details about human joints and the silhouette brings details about border movement of human body. Furthermore gray-level and binary images consist of various details on human movement. Tracking and recognizing are almost linked because tracking commonly starts with recognizing gait (Lee *et al*., 2014). Two main materials in video image data used for trail gait are image features and shape. Image features refer to the texture or color and shape is the evaluations based on frame and inter frame data. The shape produces movement pattern. The information obtained on image attributes and data movement will be integrated to produce more powerful results (Lee *et al*., 2014).

Feature extraction: Essential features extraction from gait structure is important in gait analysis process (Gaba and Ahuja, 2014). According to Karg *et al*. (2010), the gait feature extraction is very complex because gait pattern are categorized by time dependence, nonlinearities, high variability and high dimensionality. Feature extraction is the method where the important point can be selected and it is effective to capture the gait characteristic (Gaba and Ahuja, 2014). The meaning of feature extraction is input data transform or change into particular parameters or features (Gaba and Ahuja, 2014). Usually, a huge number of features are selected to avoid from loss of significant gait information. Tafazzoli *et al*. (2015) Stated that many gait feature extraction could be repeated or unessential to the recognition task if lacking of enrolling a suitable feature extraction strategy.

Principal Component Analysis (PCA): Principal component analysis is a technique used for data dimensionality minimization (Sangari and Mathivanan, 2011; Ali, 2013) and analyse the connection among a set of connected variables and it also known as Eigen analysis. PCA take out the main difference in the feature vector and allows precise transformation of the data to be produced from only a few of the selected features values, therefore reduced the amount of computation needed. Karg *et al*. (2010) stated that PCA is becoming more powerful for high dimensionality of the original space and by adding more kinematic parameters, the correctness of PCA slightly increases (Karg *et al*., 2010). In also mentioned that PCA is a direct method and does not acquire underlying nonlinearities into account. According to Sangari and Mathivanan (2011) PCA is simple and a convenient method to help solve problems. PCA saves the most information by simplifying the data through dimensionality reduction and save the original signal information as much as possible (Sangari and Mathivanan, 2011; Ali, 2013). PCA technique use feature images reduction without losing much information (Ali, 2013). The advantage of using PCA technique is it reduces the feature area element by evaluating the input differences.

According to Zia *et al*. (2014), the most common silhouette features extraction technique for human activity video analysis is by using the PCA. The PCA technique is commonly used for human recognition by comparing gaits characteristic with known database. Kumar *et al*. (2012) claims that PCA objective is to select a subspace in which the rebuild error can be minimized or equivalently, the variance of the total projected data points can be maximized.

In a study by Jalal *et al*. (2012), they studied PCA and ICA feature in their experiment to compare both techniques against their proposed R transformation feature. Jalal *et al*. (2012) found that PCA is a robust technique to extract direct structure from the most dimensional input data sets. Beside used for data compression, PCA also keep as much information by decreasing the number of elements. Therefore, PCA is the best performance to represent data in straightforward and reduced form.

PCA can only generate linear subspace feature extraction where it is not suitable for the most complex and nonlinear data distribution compared to Kernel Principal Component Analysis (KPCA) (Tafazzoli *et al*., 2014, 2015). KPCA can capture the higher order data available in a dataset and produced nonlinear subspaces for good feature extraction. Mantri *et al*. (2014) claims that PCA tends to perform better than Linear Discriminant Analysis (LDA) if the number of samples per class is relatively. Both LDA and PCA are usually used in combination such as PCA for dimensionality reduction followed by an LDA.

Kernel Principal Component Analysis (KPCA): According to Karg *et al*. (2010) kernel principal component analysis is an extension of nonlinear PCA and its benefits which are eigenvectors nonlinearity and the maximum of eigenvectors number. KPCA can detect nonlinear structures from input space. Feature vectors symbolized as low dimension space of eigenvector. In Karg *et al*. (2010) they reviewed the PCA and KPCA and found that by using some nonlinear map, KPCA will plot the input data into part of feature area and later conduct the PCA on the plotted data. It is usually unrealistic computation to perform PCA directly in the feature area due to the high dimensionality of the feature space. KPCA let PCA used kernel methods and formulate it as the identical kernel eigenvalue problem. Even though KPCA commonly used in data analysis but KPCA unable to find out nonlinear data structure if it ruins by outliers. According to Karg *et al*. (2010) PCA unable to represent unrevealed structure while KPCA able to select the nonlinear features for complicated data.

Tafazzoli *et al*. (2015) mentioned that KPCA objective is to control highly complicated nonlinear data issues and produced nonlinear subspaces. Tafazzoli *et al*. (2015) Chose KPCA as a better feature extraction in their researche. In another study by Jha and Hayashi (2014) focused on the KPCA performance improvement in feature extraction technique for chemical vapor class recognition. KPCA seek much of nonlinear Principal Component (PC) direction in feature area. By leaving more PC direction of lower difference, KPCA gives better chances to discard the noise element in the data sets. For a noisy data set it is good to use KPCA feature extraction. In conclusion the researchers in Jha and Hayashi (2014) proposed the selection of optimal kernel function for KPCA method as an effective feature extraction approach in highly noisy background condition for chemical vapor class recognition.

In a study by Chen *et al*. (2011), they developed computer observation for gait analysis using KPCA. These help the clinical to evaluate Parkinson Disease (PD). They used KPCA-based technique to extract gait criteria from the continuous gait video frames from the non-PD controls, "Drug-On" PD patients and "Drug-Off" PD patients. KPCA-based and PCA-based have been examined for their potential to recognize and classify the gait of "non-PD" controls and the PD patients in various states. The KPCA method was verified to be powerful feature extraction compared to traditional image area and PCA technique in categorizing "Drug-Off/ On" PD and "Non-PD" patients. KPCA technique only requires a decorated corridor setup and digital camera. KPCA gives a low cost solution to researchers and clinicians because KPCA technique requires only easy-to-use and cheaper appliance to calculate the kinematic gait criteria that has been extracted (Chen *et al*., 2011).

Linear Discriminant Analysis (LDA): Linear discriminant analysis is also closely related to PCA where both algorithms are based on linear transformations and try to perform data classification in given image. According to Kumar *et al*. (2012) and Dhere (2015) LDA is generally famous for the data classification into same class and between other classes. LDA maximizes within class scatter matrix concurrently minimize the within class scatter matrix. Dhere (2015) stated that LDA is a statistical approach for classifying samples of unknown classes based on training samples with known classes. LDA is an approach used to overcome dimensionality reduction where it is used mainly in the small sample size problem. This can be an issue in a large set of data. According to Katiyar *et al*. (2011) there are 2 main benefit of using LDA. First benefit is LDA minimize the dimension of gait feature where this is very practical aspect in real time application. Second benefit is LDA maximize a margin between gait features from different subject and minimize the gap of gait feature that belong to the same subject. According to Mantri *et al*. (2014) the disadvantage of the original LDA is that at least one non-singular scatter matrix is required for computation. This condition fails when there are insufficient numbers of samples in the data set for example the data dimension generally exceeds the number of available data values.

Kumar *et al*. (2012) Made the comparison for PCA and LDA. The LDA suffers from the small sample size problem that provides singularity characteristics or the scatter matrix. This method performs better in high dimensionality. It reduces error rate and complexity by selecting only limited neighbours for each point (Kumar *et al*., 2012). Karg *et al*. (2010) stated that the performance of PCA and LDA were depends on the number of features relative to the number of instances in the training set. In Karg *et al.* (2010), even though PCA is an unsupervised technique, the performance of PCA was better than LDA if the number of features is large compared to the number of instances in the training set. In contrast to algorithms based on PCA, LDA considers class membership for dimension reduction. The main idea of LDA is to separate class means of the projected directions well while achieving a small variance around these means. Like PCA, the derived features of LDA are linear combinations of the original data (Karg *et al.*, 2010). LDA is a supervised method using only known class label (Kumar *et al.*, 2012; Dhere, 2015). PCA minimize the feature area less efficient for a minor kinematic parameters compared to LDA (Karg *et al.*, 2010).

Independent Component Analysis (ICA): Independent component analysis is an important unsupervised technique to extract the independent features from the high dimensional data. Arunasakthi and Priya (2014) stated that the main aim of ICA is to retrieve the independent data given from the observation that are linearly dependent on another data. According to Zia *et al.* (2014) ICA is a technique to solve a blind source separation problem. ICA objective is to decompose the perceived data into a direct combination of some unknown statistically independent basis and their combined matrix. ICA uses higher order statistics, therefore provides more powerful data representation. Referring to Zia *et al.* (2014) the used of local feature extraction technique such as Local Binary Pattern (LBP) and Independent Component Analysis (ICA) can obtain more powerful human activity features. ICA is a higher order data method than PCA (Zia *et al.*, 2014). ICA produces local features and it improved recognition performance over PCA for human movement recognition (Zia *et al.*, 2014).

In a study by Jalal *et al.* (2012) applied LDA on the PC features value using depth silhouette and found that some human movement like sitting down or boxing were mixed partially and all the features were not seem to be well separated. They later use ICA and the IC features of depth images to recognize different activities to extract the local features. They found that a number of activities were partially separated such as walking, running and boxing as compared to LDA on PC features. However, pair of movements such as clapping and sitting down were very near to each other where the low recognition rate is caused by the overlap in the data among the sample of different movement (Jalal *et al.*, 2012). Arunasakthi and Priya (2014) presented the various techniques to reduce the dimensions of the original data. They claimed from their survey, LDA and PCA are the powerful techniques to handle the linear types of data while Independent Component Analysis (ICA) is effectively worked on nonlinear data.

Local Binary Pattern (LBP): Dhere (2015) stated that local binary pattern is a very good technique of feature description. The LBP operator was originally designed for texture description and it has proven to be highly discriminative. LBP is suitable for demanding image analysis tasks because its invariance to monotonic grey level changes and computational efficiency. The recognition rates of the LBP maintain high level under the effect of localization (Dhere, 2015). According to Zia *et al.* (2014), LBP was introduced originally for the purpose of texture analysis and its features represent more detailed local features than ICA. LBP focused on extracting pixel features independent of illumination. The LBP characteristic is likely to be stronger due to their acceptance towards lighting changes and their computational accessibility.

Local Directional Pattern (LDP): In Taskeed the improved LBP was renamed as local directional pattern. The LDP features also have the tolerance against illumination changes like LBP but LDP become more robust features than LBP as they include the angle for every pixel. In a study of Zia *et al.* (2014) they have adopted the LDP features to depth silhouettes of human gait for more robust gait recognition and they proposed LDP-PCA features for gait recognition. LBP and ICA also emphasis on local features while the LDP features emphasis on the local features considering the gradient information of the depth silhouettes and giving of good intolerance over common and uncommon gait patterns.

According to Zia *et al.* (2014), the PCA features usually find the direction of the high covariance lies in the input data and hence PCA on LDP should provide more robust features than the other approaches for gait recognition. Zia *et al.* (2014), they have concluded the proposed LDP-PCA approach outperforms all other methods in gait recognition. However, according to Sivapalan (2014) LDP is not suitable to use in 3D data application. Thus, the LDP feature vector need to be optimized dimensionally without the loss of gait information in order to extend it to 3D (Sivapalan, 2014).

MATERIALS AND METHODS

This study reviewed journal and studys in the area of computer sciences. The searched database and number of studies selected are shown in Table 1. All

Table 1: Database of the paper reviewed articles

Database searched	Articles selected for each database
IEEE	7
Springer	6
ACM, sage pub	2
CiteSeerX	1
Proquest	1
Semanticscholar	1
Ijesit	1
Globaljournals	1
IJSER	1
Airccse	1
Eprints	1
Sersc	1

studies were restricted to english publications only. Key criteria were used to select studys for inclusion or exclusion in the literature review. Following are the inclusion and exclusion criteria for this searches.

Inclusion criteria are studys that discussed on gait video analysis, gait recognition and feature extraction techniques. Also included are some studies that contain the details or information that might be relevant for gait. Any study related to PCA, KPCA, LDA, ICA, LBP and LDP techniques were also included. The exclusion criterion is the documents that are <2009 based on date of publication were excluded.

RESULTS ANS DISCUSSION

Anaysis and finding: The comparison of the six techniques has been made based on the researchers comments and suggestions in the study reviewed. The comparison has been divided into 3 categories which are the advantages, disadvantages and similarity. The 5 features in the similarity Table 2 has been chosen as techniques that are related to the gait parameters. Based on the similarity table all techniques can handle the spatio temporal data. Spatio-temporal data is a calculation based on gait parameter such as velocity, cadence, time, stride duration, stride length, step width. Based on the spatio temporal data, the techniques can map the data either in linear structure or nonlinear structure. Linear structure means the technique has map the data in a straight line while for nonlinear structure the techniques can map the data into non straight line or curvy lines. There are two types of feature which are local feature and global feature. Local features extracted salient point in the input domain while global features extracted from the complete gait image.

Table 3 shows the advantages of each technique. All techniques are compared based on its robustness in computation, how they outperform other technique, the type of data and it computational time/cost. Table 4 shows the disadvantages of each technique in terms of data handling, performance and efficiency in performing its task and the computational time.

Table 2: Similarity of the technique

	Similarity				
Technique	Spatio-temporal data	Linear structure	Nonlinear structure	Local features	Global feature
PCA	✓	✓			✓
KPCA	✓		✓		✓
LDA	✓	✓		✓	✓
ICA	✓		✓	✓	
LBP	✓		✓	✓	
LDP	✓		✓	✓	

The objective of this study is to suggest the suitable feature extraction technique for gait video analysis of the different group of people. We grouped them as normal children gait, normal adult gait, brain-impaired adult gait and brain-impaired children gait. The suggestions are made based on the comparison of the techniques discussed earlier.

Normal adult can walk in a consistent speed and length. In this situation, stride frequency, the speed and the width of the step can be distinguished to recognize normal adult. Based on the stride length, stride frequency and speed, these parameters can also easily differentiate between adult and children. Since, PCA is an efficient tool for spatio-temporal data mining, therefore PCA is recommended for normal adult gait video analysis. Adult with impaired brain will walked more slowly or inconsistently where this video will contain many noise and abnormal gait pattern. LDP is the more suitable technique for Brain-impaired Adult Gait video analysis because it gives better accuracy for noisy data or condition and also better intolerance for normal and abnormal gait structure.

It is very difficult to extract feature for children in a video where this will lead to many discrepancy and noisy data compared to adult video. The suitable technique for normal children gait video analysis is the KPCA because it can detect nonlinear structures from input space, handle highly complicated nonlinear data distributions and good feature extraction technique for noisy dataset. Children with impaired brain have many stereotype gaits like pacing, jumping, hopping, skipping and spinning. It is the most difficult to capture a video for this category of children where they have difficulty in coordination and gross motor function which impact gait. Thus, we can use silhouette as a feature extraction for brain-impaired Children Gait Video analysis by using LDP technique where LDP emphasize on the local features where it consider the angle of the silhouettes where it gives possibility of good sensitivity over normal and abnormal condition.

Table 3: Comparisons on advantages of the techniques

Technique	Advantages: Robust	Out perform	Data	Computational cost/time
PCA	Powerful for the high dimensionality original space Powerful method for extracting linear structure	Perform well than LDA if the number of feature is large than the number of instances in the training set	Can use to compress the data without much loss of information Can handle small as well as large scale data	Reduce amount of computation needed Low space and low memory where it will run fast for GEI
KPCA	Capture higher order statistics Produce nonlinear subspaces for better feature extraction	Better than PCA in noisy data feature extraction		Low cost solution Easy-to-use and inexpensive tool
LDA	More robust to the statistical parameters of all joint angles Popular for the classification of data into within class and between classes	Better than PCA for a multi-clas classification task More efficient in minimizing the feature space for small number of kinematic parameters compared to PCA	Maximize a margin between gait features from different subject and as well as to minimize the distance of gait feature tha belong to the same subject	Special reduce gait feature elements where it is very practical feature in real time application
ICA	More powerful to human activity by using local feature extraction More powerful in representing the data via higher order statistics compared to PCA	Better than PCA to provide more powerful data representation ICA is a higher order statistical approach compared to PCA Powerful in human activity features	Decompose the perceived data into a direct combination of some unknown statistically independent basis and their combined matrix	
LBP	LBP features stronger due their acceptance against illumination changes and their computational accessibility Very good technique of feature description. Initially LBP was designed for texture description	The LBP features is more detail local features because it focused on extract the pixel features which free of illumination compared to ICA	Proven to be highly discriminative and because its invariance to monotonic grey level changes and computational efficiency which makes it suitable for demanding image analysis tasks	Traditional LBP techniques are improved results in classification accuracy and fast process Computational simplicity
LDP	Focus on the local features and gives the potential of better intolerance over normal and abnormal gait patterns	Better than LBP as they gives better accuracy under noisy conditions Powerful than LBP since it include the lighting data for every pixel		

Table 4: Comparisons on the disadvantages of the techniques

Technique	Disadvantages: Data	Performance	Computational time
PCA	Unsuitable for complicated and nonlinear data distributions Does not obtain hidden nonlinearities into account	Less efficient in extracting related temporal information from time series compared to applying basic statistical parameters	PCA technique require longer system time to compute using silhouettes-based system
KPCA	Sensitive to outliers If the data ruin by outliers, KPCA fails to discover nonlinear data structure	Less efficient compared to PCA Not necessary perform well in real world task	-
LDA	If insufficient numbers of samples in the data set, this condition fails	Reduces the feature space less efficient if the number of kinematic parameters increase compared to PCA	-
ICA	Not robust in illumination and pose changed	-	-
LBP	Invariant to grey level channel	Perform less efficient for noisy condition such as lighting changes	-
LDP	Does not fit for application used 3D data because it can loss information	-	Computation process is slower as LDP represent each pixel as eight bit binary code

CONCLUSION

All six techniques discussed in this study are able to handle the spatio-temporal data. Spatio-temporal parameters can be made with simple methods or tools. According to most of the survey Arunasakthi and Priya (2014) has concluded where the nonlinear techniques are efficient compared with the linear technique because most of the real world data are in nonlinear form. In video gait analysis, it is difficult to get a person who can walk in a same stride length, step width and speed especially for children and people who were brain impaired. In this case, we need to choose an optimal technique to deal with the nonlinear data structure. In this study, 4 techniques are identified as the nonlinear structures which are KPCA, ICA, LBP and LDP. Between these 4 techniques only ICA, LBP and LDP are extracting local features. Zia *et al*. (2014) stated that by using local features extraction approach, we can obtain more robust in human activity features. Kusakunniran *et al.* (2010) Added that the local feature is more powerful under noise situation and it is controllable because it doesn't need any camera calibration and complex multi-camera system (Kusakunniran *et al.*, 2013). As a conclusion, based on the study reviewed that has been carried out, I will suggest LDP is the best technique for gait analysis feature extraction. LDP features emphasis on the local features considering the gradient information better than ICA and LBP local feature extraction. LDP features focus on the local features where it gives the potential of better intolerance over normal and abnormal gait patterns. LDP is better than LBP because it provides better accuracy for noisy condition especially in lighting changes. LDP features also tolerate with anti-illumination and the feature is more powerful compared to LBP since it also include the angle data for every pixel.

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