Human Identification and Verification using Gait Analysis and Facial Recognition

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***Abstract*—The COVID-19 pandemic has emphasized the need for contactless technology, particularly in the domain of access control. However, traditional methods such as fingerprint scanning and facial recognition are faced with challenges due to the need for physical contact and increased cost to set up. In this paper, we propose a novel access control system that leverages the power of contactless technologies: gait analysis and facial recognition. Our system aims to create a custom and unique dataset of Gait Energy Images (GEI) by capturing the energy images of the subject from the depth-capturing feature of the KINECT (version 2) camera, set up perpendicular to the subject walking and superimposing the 20 caught frames over a span of 20 seconds and pairing this information with facial recognition performed through only a regular camera placed at the end of the path, whose faces are stored as embeddings along with the superimposed images of that particular subject in the database. The combination of gait analysis and facial recognition provides increased accuracy (89% combined accuracy of the system) and reduced cost of setup than compared to other high-end and complex setups, with mounts, rails, accelerometers, gyroscopes, pedometer and multiple depth sensing cameras. This approach is unique and cost effective in the current market.**

***Index Terms*—Gait analysis, Kinect, Facial recognition, Embeddings, CNN**

I. Introduction

We are living in an era where technology has taken over almost every aspect of our daily lives. One such area where technology has made a huge impact is in the field of biometric identifications, which has become a widely used solution for access control. The use of biometric features such as fingerprint recognition and facial and retinal scans has become increasingly popular in recent years. However, a new and innovative solution has come to the forefront, specifically in the area of gait analysis. This technology, which has previously been utilized primarily in the medical field for managing patients with walking disorders, has now caught the attention of the security and access control industry.

In recent times, institutions and organizations have been implementing biometric-based attendance tracking systems to recognize and authenticate individuals through fingerprint scanners. However, with the outbreak of the COVID-19 pandemic, the preference for contactless solutions has increased, and this is where gait analysis comes into play. The idea of using gait analysis for access control purposes provides a touchless solution for authentication, which not only enhances the overall security but also reduces the risk of spreading infections.

In this paper, we present a detailed overview of the concept of an access control system based on gait analysis. Our proposed solution aims to provide a state-of-the-art technology that is secure, efficient, and user-friendly. We believe that the use of gait analysis for access control purposes has the potential to bring about a new era of security and convenience in the industry.

II. Related work

The field of gait analysis has been extensively researched and applied in the medical and fitness industries. In the medical industry, gait analysis has been utilized for various purposes such as gait classification, fall detection and prevention, injury avoidance, and rehabilitation. Researchers have also investigated the use of gait analysis for posture and gait improvement, as well as for monitoring fitness levels and studying sports biomechanics in the fitness industry[7]. Recent studies have explored combining gait analysis with facial recognition for added security and other applications. The existing body of work in this field demonstrates the potential for gait analysis to be used in a variety of industries, with numerous practical applications in the security domain. Recently, majority of the researchers have tried to use a moving Kinect that requires an expensive set up and a large room.[2] The novelty of this project, is cost cutting by placing the Kinect in a distance of 7ft from the subject walking into the frame of the Kinect. The approach we have used is different from what other researches have used, we have captured 20 frames of the gait energy image in a span of 20 seconds and overlapped the frames. The pace and style of walk is different for every frame.

A. Gait Energy Image

Gait energy image (GEI) is a biometric feature extraction technique that captures a person's walking pattern from a video sequence. It is widely used in the security domain for surveillance, access control, and identity verification. The GEI is a two-dimensional image that represents the energy distribution of a person's gait cycle. In this technical reference work section, we will discuss the GEI technique and its applications in the security domain.

1) Applications in the Security Domain: The GEI technique has several applications in the security domain, including access control, and identity verification.

2) Access Control: Access control systems can also use the GEI technique to confirm an individual's identity before allowing them entry to a secure area. To grant or refuse access, a person's gait pattern can be recorded and compared to a database of people who are allowed. This strategy adopted by us is helpful when conventional biometric methods, like iris or fingerprint recognition, may not be appropriate, like in outdoor settings where these methods may be impacted by environmental factors.

3) Identity Verification: A person's gait pattern may be used as a secondary authentication element when using the GEI technique for identity verification. A person's gait pattern, for instance, can be used in addition to a password or a smart card in a two-factor authentication system to add an extra layer of protection.

B. Gait-Cycle

The gait cycle is divided into two components. The first is the stance phase, which covers 60% of the cycle and consists of four parts: load response, intermediate stance, final stance and forward swing. The second component is the swing phase, which covers 0% of the cycle and is divided into three parts (initial swing, middle swing and final swing)[1]. Gait cycle can be detected based on two main techniques. The first technique is the double support phase, where both feet move away from each other. The second technique is the mid-stance or local minima, where the distance between the two feet is at the minimum[10]. Double support phase technique is used to detect the gait cycle and the distance between the ankles is measured instead of feet for better accuracy[1]. In [1,3] method is based on hip-thigh angular motion, where the hip-thigh angular motion is defined as a Fourier series. In [9],gait information image (GII) is derived from the frames in one gait cycle and two features named gait information image with energy feature (GII-EF) and gait information image with sigmoid feature (GII-SF).

C. Embeddings for facial recognition

SHow a paper not using embeddings and say we're using embeddings.

Utilizing embedded face recognition in security systems has a number of benefits, one of which is contactless authentication. This means that users can be recognized without the use of tools like keycards or passwords or direct physical interaction. This is crucial in places like hospitals and airports where cleanliness and safety are of the highest importance. Facial recognition embeddings can also be used for surveillance, providing real-time tracking and identifying of people in public areas.

The robustness of facial identification embeddings is another benefit. Systems for face recognition that employ embeddings can take into consideration changes in lighting, facial expressions, and other elements that may have an impact on the recognition's accuracy. The system can learn and adapt over time, increasing its accuracy and dependability, thanks to the use of deep learning algorithms in generating these embeddings. Furthermore, the numerical values that make up the embeddings cannot be read by humans, making it difficult for attackers to alter or reverse-engineer them. This makes using facial recognition embeddings to verify identities in a variety of applications a safe and trustworthy choice.

An open-source tool for Python called the Facial Recognition library offers simple APIs for face analysis, face analysis, and face detection. It produces embeddings for facial identification that can be applied in a variety of ways using deep learning algorithms. Developers can quickly begin using facial recognition thanks to the library's pre-trained models for face detection and classification.

III. Model

Convolutional Neural Networks (CNNs) have been widely used in gait analysis due to their ability to effectively extract relevant features from 2D and 3D gait data. Here are a few reasons why CNNs are considered the best models for gait analysis:

1) Ability to handle high-dimensional data: Gait analysis involves processing high-dimensional data, such as motion capture data, which can be difficult to analyze using traditional machine learning models. CNNs are well-suited to handle this type of data, as they can learn and extract patterns from large amounts of data.

2) Robustness to variations in gait: Gait analysis involves analyzing the subtle differences in movement patterns between individuals. CNNs are robust to variations in gait, as they can learn features that are invariant to small changes in the data.

3) Transfer learning: CNNs can be pre-trained on large datasets, such as ImageNet, and then fine-tuned for specific gait analysis tasks. This allows for the transfer of knowledge from one domain to another, which can improve the performance of the model on smaller datasets.

4) Localization of features: CNNs are capable of localizing features within an image, which is important in gait analysis. This allows researchers to identify specific joints or body segments that are relevant to a particular gait analysis task.

Overall, the ability of CNNs to handle high-dimensional data, their robustness to variations in gait, transfer learning capabilities, and feature localization make them the best models for gait analysis compared to other models.

Our code uses a pre-trained Keras model for image classification. First, the code imports the necessary libraries including Keras, NumPy, and PIL (Python Imaging Library). Then, it loads the pre-trained model and labels from the files "keras_Model.h5" and "labels.txt", respectively. Next, the code creates a NumPy array with the correct dimensions for the input image. The size of the array is determined by the dimensions of the input image (224x224 pixels), the number of channels (3, for RGB), and the number of images to be processed at once (1 in this case). The code then loads the input image and resizes it to be at least 224x224 pixels using the ImageOps module. The image is then converted to a NumPy array and normalized to values between -1 and 1. Finally, the image is loaded into the NumPy array and passed through the pre-trained model using the predict() method. The code then selects the class with the highest predicted probability using the argmax() method, and prints the predicted class name and confidence score. This code can be used to quickly and easily classify images using a pre-trained Keras model, and can be easily modified to work with different models and datasets.

TABLE I
MODEL:"SEQUENTIAL_4"

Layer(type)	Output Shape	Param #
sequential_1(Sequential)	(None,1280)	(410208)
sequential_3(Sequential)	(None,4)	(128500)

Total params: 528,708

trainable params: 524,628

Non-trainable params: 14,080

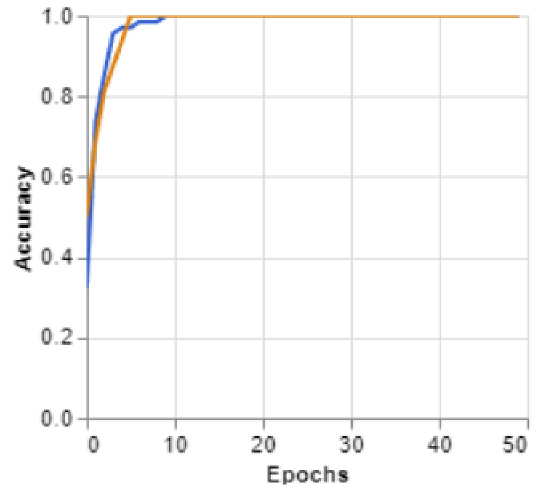

Fig. 1. Accuracy vs Epochs

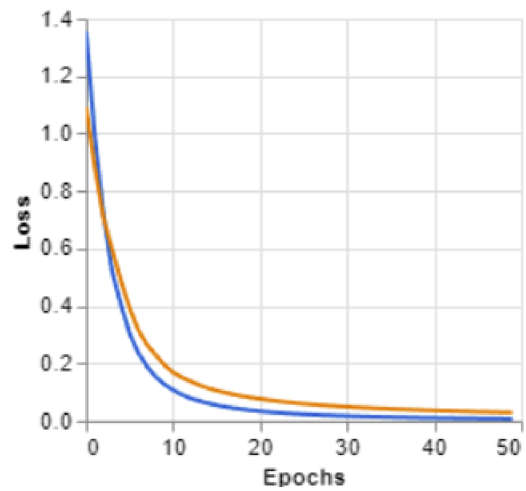

Fig. 2. Loss vs Epochs

IV. METHODOLOGY

We implemented a comprehensive three-phase approach to effectively address the issue at hand. During the initial phase, our primary focus was to capture the gait images using the Kinect depth camera and facial images with a regular webcam. Moving forward to phase two, our team worked on the preprocessing of the recorded images, where we leveraged advanced image processing techniques in Python to develop our own customized version of the gait energy image. We also extracted crucial and significant features from the images and created embeddings for each recorded face.

In the final phase of the project, we moved towards a live implementation phase where our model is actively capturing the subject's face and generating the energy image. The model then performs a database lookup to determine if a match is present. In the event of a match, access is granted; otherwise, the system rejects the request with an "Unknown" message. This approach allows us to ensure the highest levels of security and safety for our users.

A. Phase - I (Recording Phase)

- In the phase of recording the gait cycle of an individual, a Kinect depth camera was used to capture a clip of the person walking within the frame. To communicate with the camera and record each frame, Matlab was used as the primary tool. Matlab was specifically selected because of its powerful image processing capabilities and ease of use for recording and manipulating individual images.
- Each frame was recorded as an individual image, which was then stored for further processing. The recording process was carefully monitored to ensure that the gait cycle of the person was captured accurately, with a focus on capturing the entire cycle from start to finish.Each frame was superimposed one on top of the other to form the gait image, i.e unique to a particular individual. The

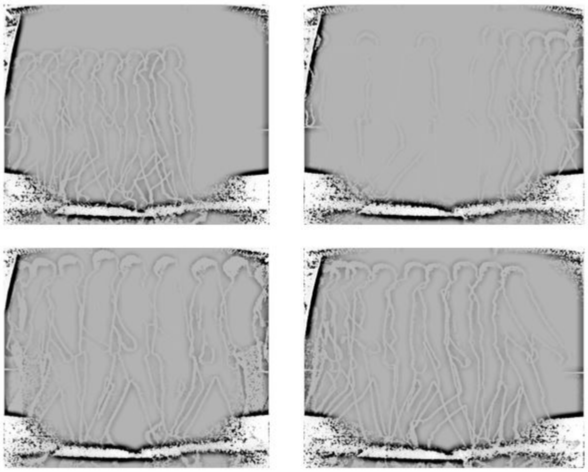

Fig. 3. Energy Images captured during recording

recorded images were used to extract and analyze the various gait parameters that are unique to each person, such as stride length, speed, and stride time, which could be observed in the combined image.

- The process of recording the gait cycle of an individual using a Kinect depth camera and Matlab was a critical step in the development of a biometric access control system based on gait analysis. The information obtained from the recorded images would be used to train the model and develop a gait signature for each individual, which would then be used to authenticate and grant or deny access.

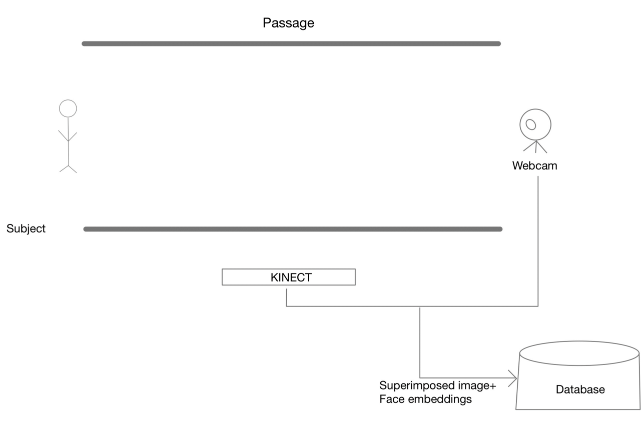

Fig. 4. setup view

- The process of capturing the faces of individuals who are to be given access involved several steps. First, a regular camera was used to capture about 15 images of each person's face, with slight variations in each image. This was done to ensure that the model had different angles and perspectives to identify the person more easily. The captured images were then stored in a directory with a unique name or identifier for each person, to facilitate identification in the later step.
- The directory was organized in such a way that each person's images were stored together, with the directory name being the same as the unique identifier of the person. This unique identifier could be the person's name or any other identifier that was unique to each individual.
- This process of capturing faces using a regular camera was an important step in the development of an access control system using facial recognition technology. The captured images would be used to train the model and develop a facial signature for each individual, which would then be used to authenticate and grant or deny access. By capturing multiple images with slight variations, the model was able to learn different angles and perspectives, making the identification process more reliable and accurate.

B. Phase - II (Preprocessing)

- The preprocessing step in this facial recognition system involves narrowing in on the faces in each image using the facial recognition library. This is done to ensure that only the relevant information is processed, reducing the overall computational complexity of the system. After narrowing in on the faces, the system then creates encodings of each face. These encodings are essentially mathematical representations of the facial features that can be used for comparison and recognition purposes. Finally, the encodings are stored in a pickle file for easy access and retrieval in later stages of the recognition process. This pickle file acts as a database of sorts, containing all the relevant information about the individuals whose faces have been encoded. The preprocessing step is crucial in ensuring that the facial recognition system is able to perform accurate and efficient comparisons in later stages.
- For the gait recognition system, this stage involves combining all the individual frames of a person walking into a single image by superimposing them together. Using libraries such as Pillow and OpenCV in Python, we can process these images and produce a final gait energy image that is unique to every human. To achieve this, we first invert the colors of the image, making the silhouette of the person stand out more clearly from the background. By using this technique, we create an identifying image that captures the person's unique way of walking. The final product of this image processing is the gait energy image, which can be used for various purposes, including human identification, tracking, and surveillance.

C. Phase - III (Live)

The Live phase of the project involves utilizing the information and encodings stored in the pickle file to perform real-time facial recognition. Here's how the process works:

- Acquire an image of a person's face using a camera or image source.
- Preprocess the image by narrowing in on the face using the facial recognition library.
- Create an encoding of the face using the same process as in the preprocessing step.
- Compare the newly created encoding to the encodings stored in the pickle file.
- Based on the comparison, the system will either recognize the person as a known individual or label them as unknown.

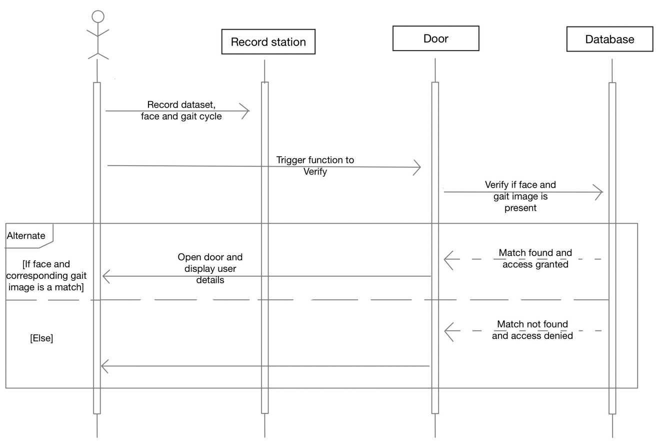

Fig. 5. Data flow in live phase

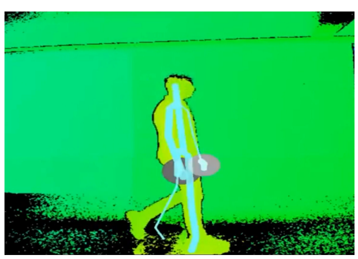

Fig. 6. GEI taken from kinect

- In the event of a recognition, the system may perform additional actions, such as granting access or displaying information about the recognized individual. The accuracy of the facial recognition system will depend on the quality of the encodings stored in the pickle file, as well as the quality of the comparisons performed in this phase. To ensure the best possible results, it is important to ensure that the encodings stored in the pickle file are accurate and up-to-date, and to perform frequent checks and updates as necessary.
- In the final stage of gait analysis, we feed the processed image into our Convolutional Neural Network (CNN) model, which has been specifically trained for each member of our group. By analyzing the unique features of the gait energy image, the model can determine the identity of the person in the input image. However, if the model is not able to confidently match the input image with any of the individuals in our dataset, the output will be "unknown person identified." This is because the model can only recognize individuals who are part of our dataset. To improve the accuracy of our system, we set a certain threshold that must be crossed in order for the model to confidently identify an individual. If the threshold is not crossed, we assume that the input image is of an unknown person. By using this approach, we can create a highly effective and accurate system for human identification and tracking.

V. Future Scope

The future scope of the project could involve exploring new techniques and technologies to accurately identify a person's gait, even when they are wearing attire that makes it difficult to do so. This could involve leveraging advanced computer vision and machine learning algorithms that are trained on a diverse range of data sets that include different types of clothing and walking patterns.

Additionally, the project could involve conducting more extensive research into the factors that influence a person's gait and how they are impacted by different types of attire. This could include collaborating with experts in biomechanics and related fields to better understand the mechanics of walking and how it is influenced by clothing.

Overall, the potential applications of this project are wide-ranging and could have implications for fields such as security, healthcare, and even fashion design. For example, accurate gait identification could be used for security and surveillance purposes, while understanding how clothing affects gait could inform the design of more ergonomic and comfortable clothing.

VI. Evaluation

The evaluation metrics for custom facial recognition software play a critical role in determining the software's effectiveness and suitability for specific applications. The most commonly used evaluation metrics include True Positive Rate (TPR), False Positive Rate (FPR), and Receiver Operating Characteristic (ROC) curve. TPR measures the proportion of positive cases that are correctly identified by the software, while FPR measures the proportion of negative cases that are incorrectly identified as positive. The ROC curve is a graphical representation of TPR and FPR, which provides a visual representation of the software's performance. Other metrics that can be used to evaluate custom facial recognition software include accuracy, precision, recall, and F1-score. These metrics should be chosen based on the specific requirements and constraints of the application, and should be measured and analyzed in controlled and consistent conditions to ensure reliable results.With our facial recognition model we achieved a TPR value of 0.8, FPR of 0.2.

TABLE II
SYSTEM ACCURACY TABLE FOR FACIAL RECOGNITION(FR) AND GAIT RECOGNITION(GR)

	TPR	FPR
FR	0.80	0.20
GR	0.98	0.02
	0.62	.04

VII. CONCLUSION

In conclusion, gait analysis is a promising technology that has the potential to revolutionize the field of biometric identification and access control. With the increasing demand for contactless solutions, especially in light of the COVID-19 pandemic, gait analysis provides a secure and efficient touchless solution for authentication. This technology, which has previously been used primarily in the medical field, has now caught the attention of the security and access control industry. Our proposed access control system based on gait analysis aims to provide a state-of-the-art technology that is both secure and user-friendly. We believe that the use of gait analysis for access control purposes has the potential to bring about a new era of security and convenience in the industry, and we are excited about the future possibilities in this field.

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