Purdue Polytechnic/Northwest - Team 48

Gait Analysis

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OBJECTIVE

This project is meant to determine the feasibility of providing forensic investigators with a new method of evidence collection, specifically by use of gait analysis. The research will determine whether gait is consistent enough to be deemed unique- if successful, a program will be developed using machine learning models to determine how accurately an individual's gait can be classified.

This project was conducted in tandem with students and faculty at Purdue Northwest.

[1] Luo, Jing & Zhang, Jianliang & Zi, Chunyuan & Niu, Ying & Tian, Huixin & Xiu, Chunbo. (2015). Gait Recognition Using GEI and AFDEI. International Journal of Optics. 2015. 1-5. 10.1155/2015/763908.
[2] GaitDataset. (2021, May 25). Kaggle. https://www.kaggle.com/datasets/adammika/gaitdataset

Figure 1: Early exploration of skeletal tracking

PROBLEM AND BACKGROUND

Our problem originates with a speaker at Purdue Northwest who claimed that they could reliably determine a person's gait for forensic use. Our customer, a professor at the Purdue Northwest campus, was skeptical of the speaker's claim and wanted a senior design group to see if forensic use of gait analysis was possible.

Gait analysis already has some use in the sports and health fields. This often relates to improving performance or lowering the risk of injury. It has been noted that personal and environmental factors have some effect on a person's gait. Personal factors relate to body proportions, age, walking speed, injury, and hand preference, while environmental factors include footwear, the physical location a person is in, what a person is carrying, etc.

Some use of gait as an identifier has been done in the 2000s and early 2010s. In these cases, analysis was performed by hand by podiatrists, making them subject to possible biases and inaccuracies. Our goal is to use machine learning to perform more accurate analysis.

CONCEPTS AND EXPERIMENTATION

The project's early design and development phase began with exploring skeletal and silhouette tracking; two separate methods of positioning a frame onto an individual. The skeletal tracking model was tested with varied camera angles which resulted in inconsistent stride lengths as well as failure to properly detect subjects. Eventually, using a static human model in 3D modeling software and using our skeletal tracking algorithm on it still resulted in differing measurements, leading to skeletal tracking being deemed as unusable. Silhouette tracking was explored by attempting to calculate gait characteristics on an open dataset. Unfortunately, this also led to failure as the program could not detect positions correctly (i.e toe of left foot to heel of right foot), causing it to be ruled out.

Eventually the project settled on the concept of GEIs (Gait Energy Images) to be used as a classification metric. GEIs are the average of all silhouettes of an individual in one gait cycle. This would let an individual's GEI be compared to others, which would help determine if gait was truly unique to an individual. From there, the machine learning model could try to classify GEIs to the individual to the best of its ability. If the accuracy is high enough, it could be reasonably proven that a person could be identified from their walking gait. The GEIs for the machine learning model were created from a dataset [2] which contained silhouetted images of individuals and their walking gait. These images were combined together to create a GEI, as seen in Figure 4.

FINAL DESIGN

Figure 2: Graph showing accuracy of CNN

```
#Load Image
image_path = 'image_you_want_to_test.jpg'
predict_and_reject(model, image_path, confidence_threshold=0.85)

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 146ms/step
Unknown subject detected.
```

Figure 3: Program using CNN to identify a singular GEI

Figure 4: Example GEI [1] vs GEI from dataset

TESTING RESULTS

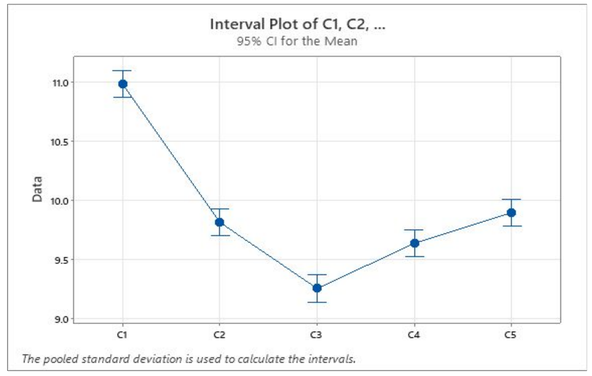

Figure 5: ANOVA of a section of used dataset

CONCLUSION AND RECOMMENDATIONS

Our model supports the theory that a person can be identified based on their walking gait.

Within the scope of our model, we were able to predict a person's walking gait with around 80% accuracy. We were not able to eliminate false positive identifications. Gait was found to be fairly repeatable between instances of a person walking. Gait was found to be unique between different people.

We had the most success with Gait Energy Images (GEI) over other image analysis methods. A CNN trained with a validation set, 50 epochs, Adam optimizer, learning rate scheduler, and categorical cross entropy was found to yield the best results over other models tested.

For future research, we recommend testing other machine learning models and algorithms such as ResNet-50, MobileNetV2, ArcFace, or Triplet Loss. We also recommend conducting testing in a real world scenario that includes changing camera angles and un-ideal footage, which will prevent potential bias from familiarity in an artificial environment.