A Pervasive and Sensor-Free Deep Learning System for Parkinsonian Gait Analysis

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INTRODUCTION

Aim

To identify whether Parkinson’s Gait can be cost-effectively analyzed rather than using expensive gait analysis labs.

END-GOAL

Pervasively monitor the effects of medication on Parkinsonian Gait to enable ‘precision medicine’.

Current Approach

Limitations and Our Contribution

Clinical:
- Gait Labs: Using Vicon systems. (> $50,000)
- Non-clinical:
- Sensors: Body attached accelerometers.

Limitation:
- Current solutions require additional hardware to analyze and limit analysis on already collected data.
- Our contribution:
- A Deep-Learning system capable of identifying Parkinson’s Gait on ‘any’ recorded video.

METHODOLOGY

Deep Learning based extraction

1. Frame Extractor
2. Skeleton Calculator
3. Gait Feature Analyzer
4. Gait Classifier

Summary

Our Deep-Learning based gait-analysis system has 4 modules:
1. Frame Extractor:
   - Extract frames from videos using OpenCV.
2. Skeleton Calculator:
   - Use Deep-Learning to calculate joint positions.
3. Gait Feature Analyzer:
   - Gait features are extracted from Deep-Learning output using traditional Machine Learning/Signal Analysis.
4. Gait Classifier:
   - A decision tree classifier is trained to classify the gait as Parkinsonian or non-Parkinsonian.

SUMMARY

Healthy Gait Behavior

Parkinson’s Gait Behavior

Healthy Gait
- Right and Left ankle movements have a steady mean displacement from torso
- Average gait cycle is approximately 1s
- Right and Left ankle movements have equal strides

Parkinson’s Gait
- Right and Left ankle movements have a smaller but steady mean displacement from torso
- Average gait cycle varies
- Right and Left ankle movements have unequal strides

CONCLUSION

We contribute the following towards a novel gait-analysis system:
- Using Deep-Learning methods, we accurately extract joint positions, infer gait features and classify the gait as Parkinsonian or Healthy.
- We normalize the noisy signals for efficient feature analysis (accounting for challenges such as camera angle invariance.)
- Test our 20 YouTube videos (16 Parkinsonian Gait + 13 Non-parkinsonian gait) and obtained 100% accuracy in healthy gait detection and 93% in parkinsonian gait detection.

Societal Impact

- Save thousands of dollars in buying expensive Vicon cameras.
- Able to analyze already existing videos.

Future Work

- Analyze other features of Parkinson’s Gait such as bradykinesia, spasticity and tremor.

MISCELLANEOUS

Feature Extraction Equations

\[ l_{amp} = \text{Left ankle} \quad R_{amp} = \text{Right ankle} \]

\[ 3 \text{ features} = f_{\text{step}} \cdot f_{\text{slow}} \cdot f_{\text{amp}} \]

Shuffling Steps:

\[ f_{\text{step}} = \text{amp}[\text{Lankle}] + \text{amp}[\text{Rankle}] \]

Slow Gait:

\[ f_{\text{slow}} = \# \text{ double support detections} \times 1.00 \]

Asymmetric Steps:

\[ f_{\text{amp}} = \text{amp}[\text{Lankle}] - \text{amp}[\text{Rankle}] \]

Dataset Specifications

The videos we analyzed (smartphone, surveillance and webcam) were lower in quality than professional Vicon Cameras - but still gave us meaningful results.

CAMERAS

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LITERATURE CITED