

Objective: Walking (gait) is a crucial motor function, and is frequently assessed as a component of clinical examination and subsequent patient management. However, the assessment of gait is often conducted in confined conditions, such as within a corridor or on a ward, and furthermore judgements are typically highly subjective in character, making them variable and unreliable.

Background: Today's widespread availability of tablets and smartphones allows high quality video to be acquired easily and quickly in clinics. We show that such video, of patients walking up and down a corridor during clinical assessment of the UPDRS (Unified Parkinson's Disease Rating Scale), can be used to reliably extract step frequency, which correlates inversely with disease severity.

Methods: The computer vision technique of pose estimation was used to track body parts throughout a video, and from this extract multiple periodic time series related to gait were extracted. Identification of steps was done using peak detection, optimised for this application. The final estimate of gait step frequency is arrived at by Bayesian estimation using a conjugate prior for normal likelihood with unknown mean and unknown variance.

Results: This work utilised a dataset of videos recorded during motor examinations conducted by trained assessors using the MDS-UPDRS rating scale. For a subset of these videos the step frequency was manually labelled, these labels were used as ground truth to calibrate both the peak detection algorithm and the prior. The method was then applied to the entire dataset of videos, allowing us to correlate step frequencies to the MDS-UPDRS severity ratings assigned by assessors at gait examinations.

Conclusions: Automated analysis of a single monocular video provides good estimation of a key parameter of motor dysfunction. Unlike previous works based on multiple views, or expensive bespoke equipment, our method dovetails with current assessment methods, so is easily integrated into clinical workflows.

Methods

Fig 1: Signal extraction process example. **a)** Video clip of a Parkinson's Disease patient walking towards the camera. **b)** Body keypoints are identified using the pose estimation system OpenPose [1]. **c)** From these keypoints three features are extracted; the vertical angle of the body (top row), the ratio of left:right leg minus the ratio of right:left leg [2] (middle row), and the horizontal angle of the line between ankles (bottom row). **d)** The sequential frames of the video clip are used to construct three periodic signals, these signals are independently standardised (mean = 0, standard deviation = 1).

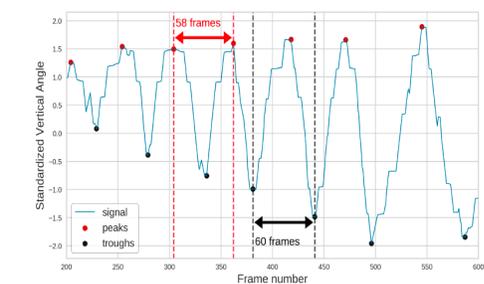
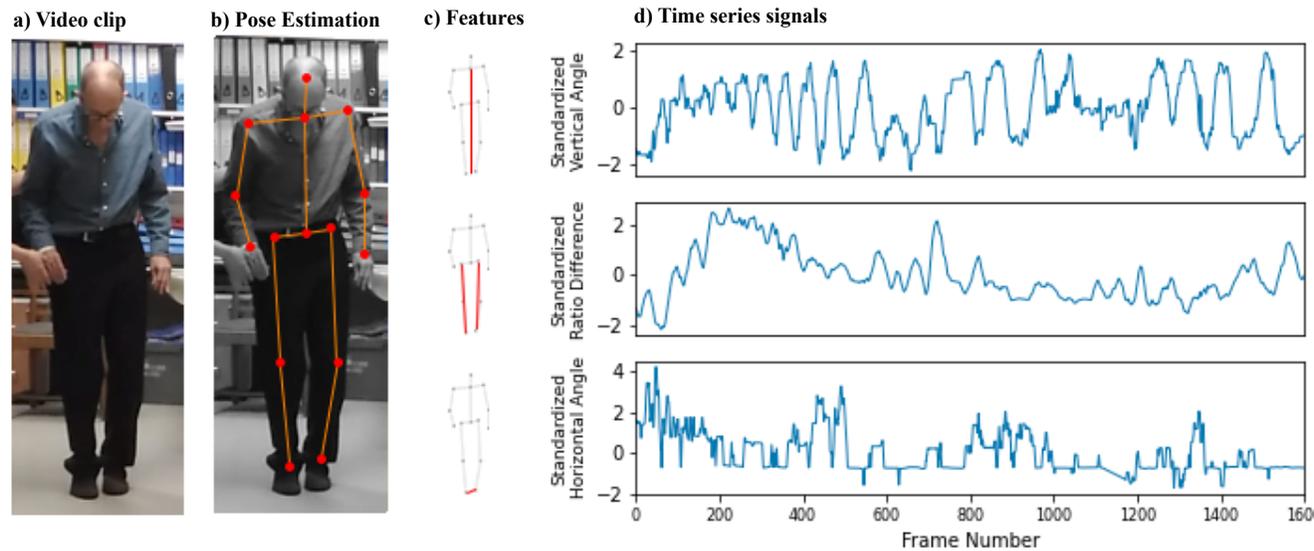
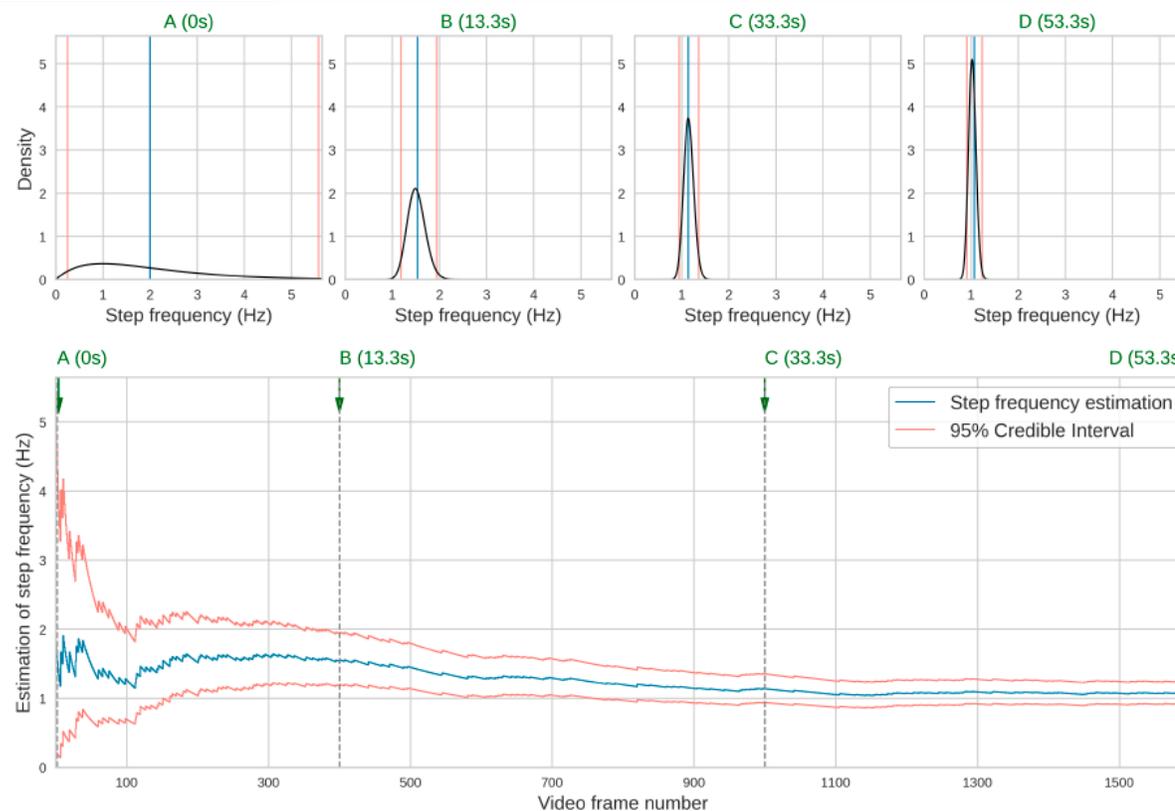


Fig 2: Step detection on a vertical angle of the body signal (standardised) from a video clip recorded at 30 frames per second. Peaks and troughs correspond to the frame when a foot is at rest on the ground.

Fig 3: Process of Bayesian updating, with Poisson likelihood and conjugate prior gamma model, of the rate of step occurrence for a video recorded at 30 frames per second. The prior gamma distribution has parameters $\alpha=2$, $\beta=1$, giving step frequency of 2Hz, with a credible interval covering a range of plausible human step frequency, 0.24-5.57Hz (A). By the end of the video (53.3 seconds) the posterior gamma distribution parameters are $\alpha=117$, $\beta=161$, giving a step frequency of 1.06Hz, and the credible interval has narrowed to 0.91-1.23Hz (D).



Results

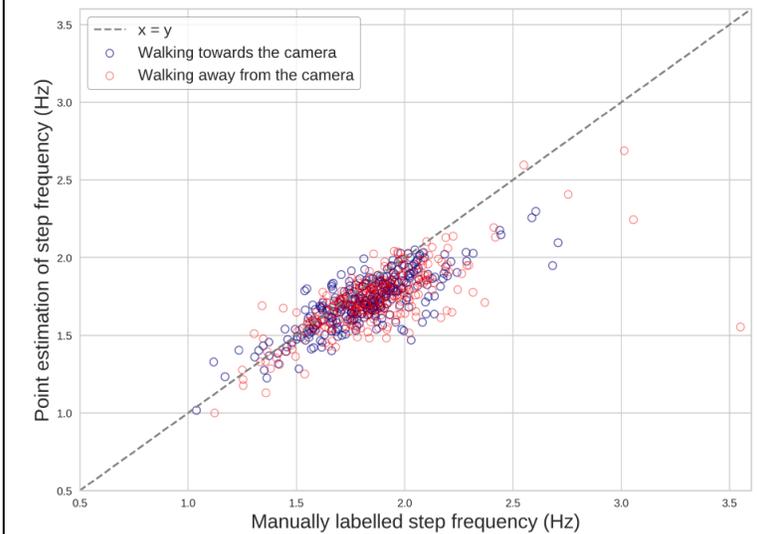


Fig 4: Relationship between the manually labelled and point estimation of step frequency from 593 video clips from the test dataset. The Pearson correlation coefficient is 0.758 that was significant (p-value < 0.001).

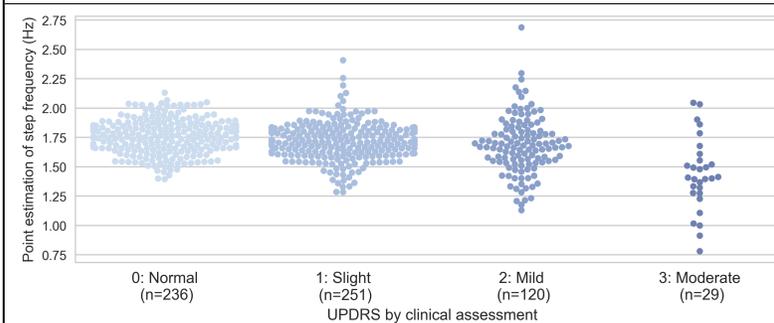


Fig 5: Point estimation of step frequency against MDS-UPDRS ratings for the 636 video clips in the dataset for which such ratings were available. The Pearson Correlation coefficient was -0.280 and significant (p-value < 0.001).

Conclusion

We demonstrate that gait cadence can be measured robustly with short monocular video clips recorded within a standard clinical setting, using a calculation method that is transparent and interpretable.

References

- [1] Cao, Z., Hidalgo Martinez, G., Simon, T., Wei, S. and Sheikh, Y. A. (2019). Openpose: Realtime multi-person 2d pose estimation using part affinity fields. *IEEE Transactions on Pattern Analysis and Machine Intelligence*.
- [2] Sato, Kenichiro, Nagashima, Yu, Mano, Tatsuo, Iwata, Atsushi and Toda, Tatsushi. (2019). Quantifying normal and parkinsonian gait features from home movies: Practical application of a deep learning based 2d pose estimator. *PLoS one 14(11)*, e0223549.