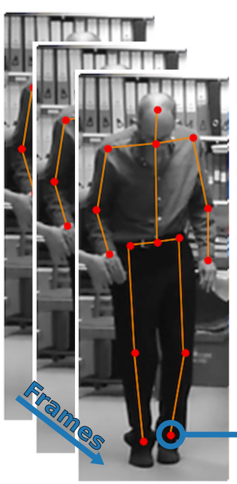
A Computer-Vision Based Method for Quantifying Parkinsonian Gait

Authors: S. Rupprechter, G. Morinan, Y. Peng, J. O'Keeffe   Affiliation: Machine Medicine Technologies   Contact: jonathan@machinemedicine.com

Objective: We proposed and evaluated a novel approach for estimating severity of gait impairment in Parkinson’s disease using a computer vision-based methodology.

Background: Gait is a core motor function and is impaired in numerous neurological diseases, including Parkinson’s disease. In the clinic, gait impairment is commonly rated as part of the Movement Disorder Society Unified PD Rating Scale (MDS-UPDRS [1]) assessment (item 3.10). The system we developed can be used to obtain an objective (second) opinion for a rating to catch potential errors, or to gain an initial rating in the absence of a trained clinician; for example during remote home assessments.

Methods: Videos (n=766) were collected as part of routine MDS-UPDRS gait assessments of Parkinson’s patients, and the deep learning library OpenPose [2] was used to extract body key-point coordinates for each frame. Data were recorded at five clinical sites using commercially available mobile phones or tablets, and had an associated severity rating from a trained clinician (0, 1, 2, or 3; the data did not include severity 4 which would mean the patient is unable to walk). Six features were calculated from time-series signals of the extracted key-points. These features characterised key aspects of the movement including step frequency (estimated using a novel Gamma-Poisson Bayesian model), stride width, arm swing, postural control, and roughness of movement. An ordinal random forest classification model (with one class for each of the possible ratings) was trained and evaluated using 10-fold cross validation.



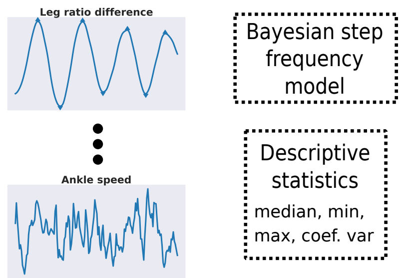


Figure 1. Body key-points were extracted from each frame and signals were created by combining the time-series of various key-points. Features were extracted based on different methods: (a) a Bayesian step frequency model integrating information over time, and (2) summary statistics such as the median amplitude.

Bayesian step frequency estimation

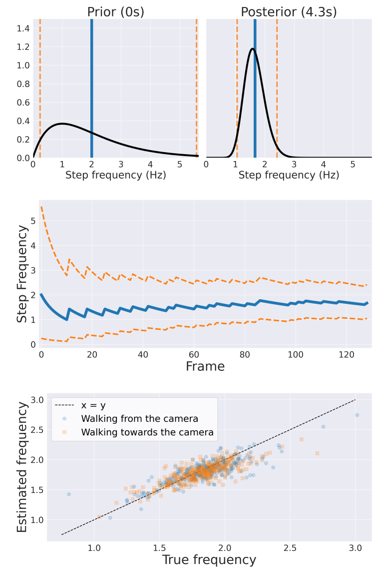


Figure 2. (Top) Examples of the prior distribution (left) and a posterior distribution after 129 frames (approximately 4.3s). (Middle) The evolution of the posterior mean and 95% credible interval for the first 129 updates. (Bottom) Point estimates of the posterior distributions at the last frame of each video were highly correlated with the true labels (Pearson’s r=0.82, p<0.001).

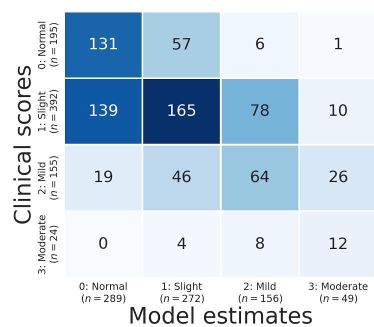


Figure 3. Confusion matrix showing the results from the 10-fold cross-validation. The balanced accuracy was 50% (chance = 25%).

Results: Step frequency point estimates from the Bayesian model were highly correlated with manually labelled step frequencies of 600 video clips showing patients walking towards or away from the camera (Pearson’s r=0.82, p<0.001). Our classifier achieved a balanced accuracy of 50% (chance = 25%). Estimated UPDRS ratings were within one of the clinicians’ ratings in 95% of cases.

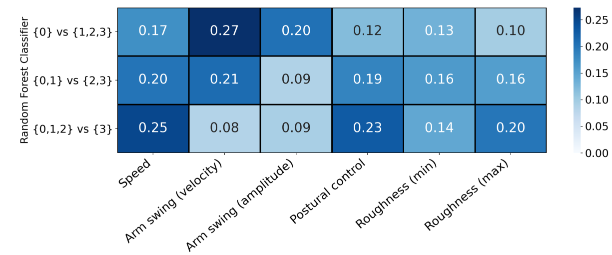


Figure 4. Feature importance of the three random forest classifiers contained within the ordinal classifier. The impurity-based (Gini) importance was calculated as the normalized total reduction of the Gini coefficient by the feature. Arm swing features were important to distinguish normal gait from Parkinsonian gait. Smoothness features were important to distinguish between different levels of Parkinsonian impairment.

	Residuals = 2					Residuals = 1					Residuals = 0				
Original UPDRS	2	1	2	0	2	1	2	2	0	1	2	0	3	1	2
Re-rated UPDRS	0	2	1	1	2	0	2	2	0	1	2	0	3	1	1
Model UPDRS	0	3	0	2	0	0	1	1	1	2	2	0	3	1	2

Figure 5. Fifteen videos were sent to a senior neurologist for re-rating: Five videos for which the model estimation disagreed with the original examiner’s rating by 2, and ten videos for which the residual was 1 or 0 points. Each column shows the three different ratings (original examiner, model, and expert) for a video, with colour shading indicating the level of absolute residual (red=2, yellow=1, green=0). For 4 of the 5 videos with a residual of 2, the expert disagreed with the original rating.

Conclusions: The severity of gait impairment in Parkinson’s disease can be estimated using a single patient video, recorded using a consumer mobile device and within standard clinical settings; i.e. videos were recorded in various hospital hallways and offices rather than gait laboratories. This approach can support clinicians during routine assessments by providing an objective second opinion of the rating, and has the potential to be used for remote home assessments.

[1] Goetz, C. G., et al. (2008). "Movement Disorder Society-sponsored revision of the Unified Parkinson’s Disease Rating Scale (MDS-UPDRS): scale presentation and clinimetric testing results". Movement disorders: official journal of the Movement Disorder Society 23.15: 2129-2170.
[2] Cao, Z., et al. (2019). "OpenPose: realtime multi-person 2D pose estimation using Part Affinity Fields". IEEE transactions on pattern analysis and machine intelligence, 43(1), 172-186.

Click below to watch Dr Sam Rupprechter presenting the findings