Multi-Linear Regressor for Static Posturography Estimation Through an Instrumented Cane

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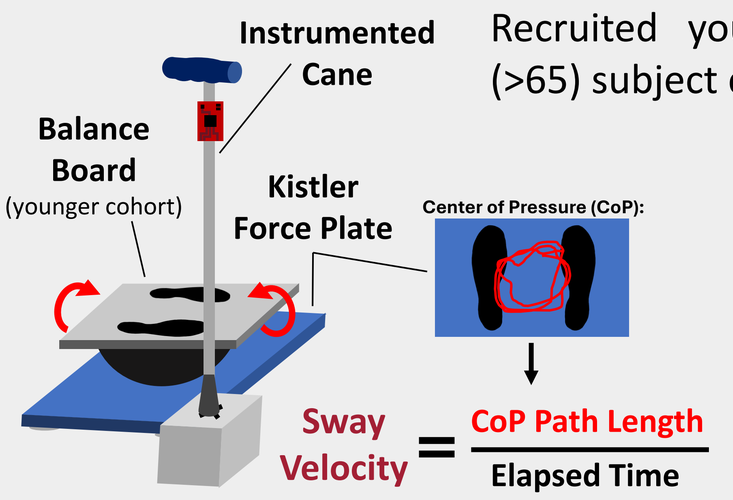
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Motivation

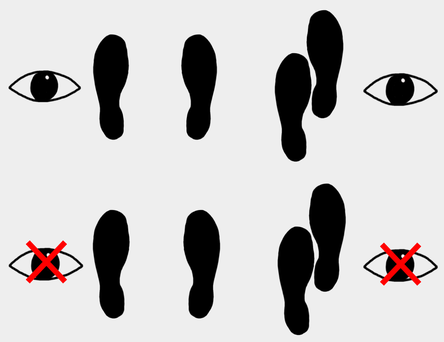
Falls are a serious threat to the independence and health of people over 65. Canes are a common mobility aid and could be used for at-home balance assessment. We used **multi-linear regression with data from an instrumented cane** to predict postural sway velocity and estimate Romberg quotients, **metrics tied to higher risk of fall** in older adults.

Experiment Overview

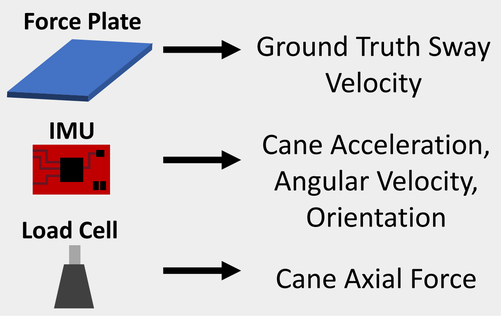


Recruited younger (<50) and older (>65) subject cohorts.

Tested four conditions:



Overview of Data Collected:



Data Collected Per Subject:

Younger Cohort (8 Subjects):

40 Trials → 240 Windows

Older Cohort (8 Subjects):

~25 Trials → 150 Windows

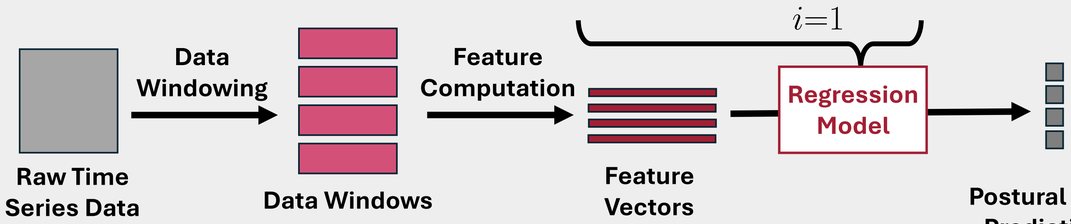
Algorithm Overview

We trained a multi-linear regressor to estimate mean sway velocity for 10-second data windows. Regression was based on a feature vector computed from simple statistical methods.

Model Structure[1]:

$$f(v) = \beta_0 + \sum_{i=1}^{n} \beta_i v_i$$

$\beta \rightarrow$ Trained Weights
$v \rightarrow$ Feature vector



[1] J. Wade et al., "Design and implementation of an instrumented cane for gait recognition,"

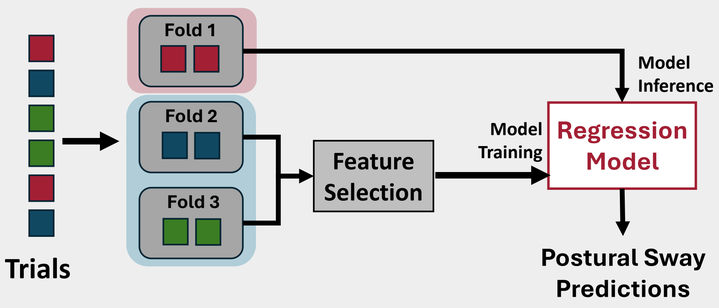
Feature Computation and Selection:

Linear Acceleration (IMU)	Mean	a_x Mean
Angular Velocity (IMU)	Min, Max	a_y Mean
Tilt Angle (IMU)	Range	...
Force (Load Cell)	Standard Deviation	F_{ax} Std. Dev.
...(+vector components)	... (+add. methods)	....
12 Time Series Data Vectors	**9 Statistical Methods**	**1 Feature Vector (108x1)**

Based on training set, selected **12 features** from feature vector for use in predictive model.

Cross Validation:

Trials were divided into **three bins**, for 3-fold cross validation:



Models are evaluated on **entirely unseen data**

Repeated 250 times with random folds for model evaluation

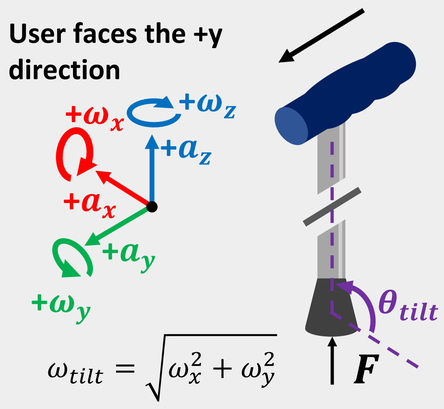
Experiment Results

High-Correlation Features

Identified features with **high correlation to sway velocity**:

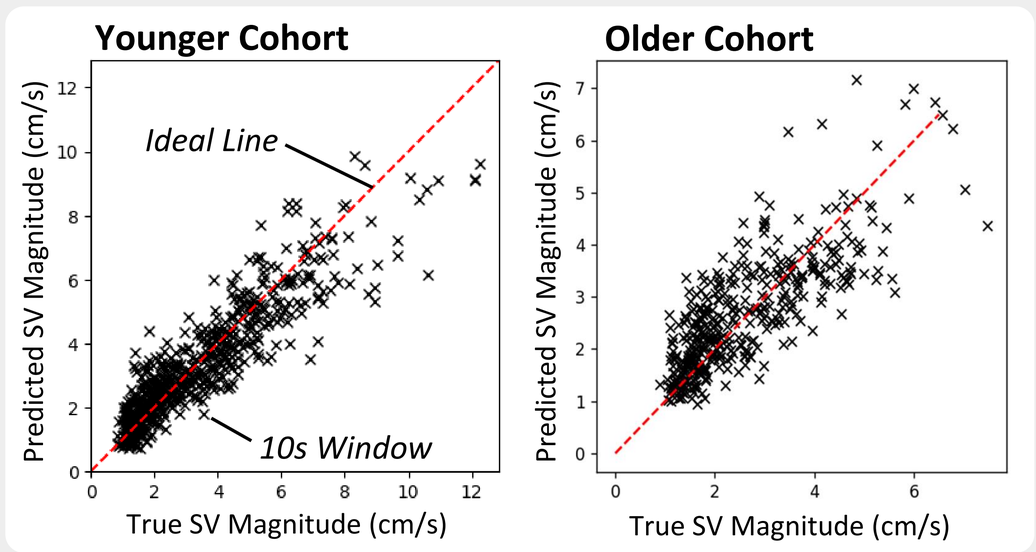
ω_{tilt} Median
$r = 0.87 \pm 0.05$ (younger)
$r = 0.71 \pm 0.12$ (older)

ω_y Mean Absolute Deviation
$r = 0.84 \pm 0.05$ (younger)
$r = 0.66 \pm 0.16$ (older)



Sway Velocity Prediction:

Evaluated model accuracy on **unseen test data**:



SV = Sway Velocity

		Sway Velocity Magnitude	ML Sway Velocity	AP Sway Velocity
Younger Cohort	R^2	0.73 ± 0.04	0.73 ± 0.04	0.57 ± 0.05
	RMSE $\left(\frac{mm}{s}\right)$	8.29 ± 0.51	6.43 ± 0.40	5.60 ± 0.36
Older Cohort	R^2	0.47 ± 0.09	0.45 ± 0.09	0.36 ± 0.12
	RMSE $\left(\frac{mm}{s}\right)$	5.88 ± 0.37	4.71 ± 0.31	3.80 ± 0.24

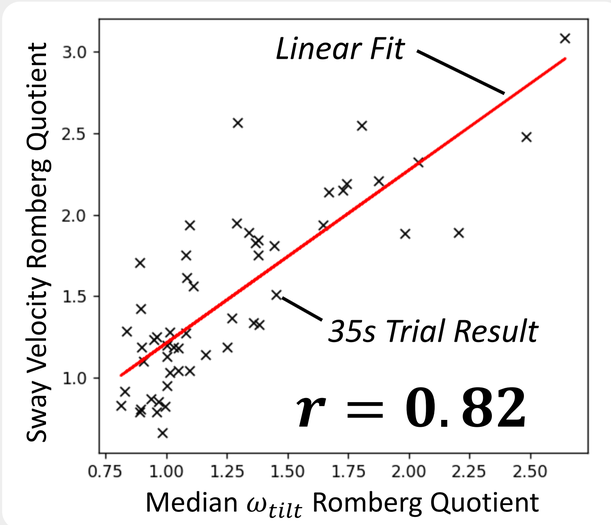
Romberg Quotient Prediction:

Romberg Quotient (RQ):
Measure of reliance on vision. Used to identify proprioceptive decline.

For any balance metric:

$$\text{RQ} = \frac{\text{Eyes-Shut Value}}{\text{Eyes-Open Value}}$$

Median ω_{tilt} RQ correlated most strongly with **sway velocity RQ** (older cohort)



Conclusion

- Found **strong ($R^2 = 0.47; 0.73$) accuracy** for predicting sway velocity with an instrumented walking cane.
- **High correlation ($r = 0.82$) observed** between cane Romberg Quotient and true Romberg Quotient for older cohort.
- **Cane handle motion** was a strong predictor of sway velocity.
- Potential for **continuous balance assessment for older people.**

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