EMBC

Linear Predictive Coding for Acute Stress Prediction from Computer Mouse Movements

Lawrence H. Kim*, Rahul Goel*, Jia Liang*,
Mert Pilanci, Pablo E. Paredes

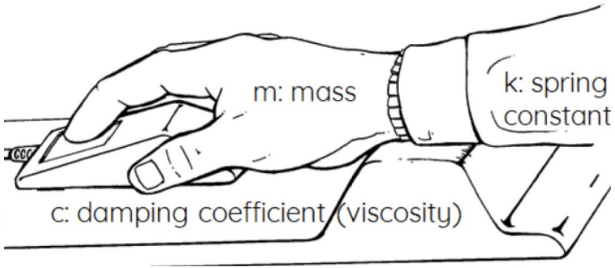
Stanford | ENGINEERING

*These authors contributed equally

Stanford | MEDICINE

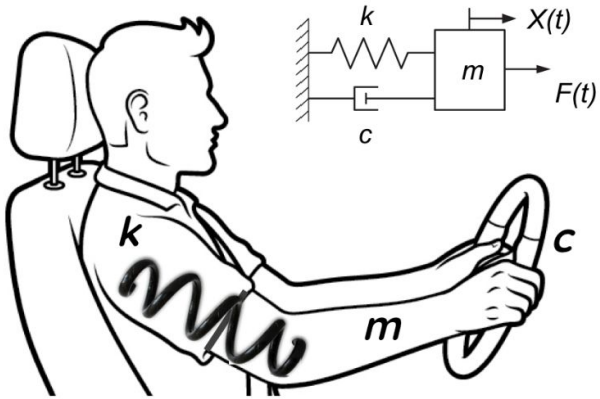

Stress is an instrumental factor for the emotional, cognitive, and physical well-being of people.

Prior work | Stress monitoring using sensorless sensing



Computer Mouse
(Sun 2014)

Trackpad
(Goel 2020)



Car Steering Wheel
(Paredes 2018)

Method | Dataset

- Data collected from *Point-and-Click* task during the MouStress Study was used (Sun 2014)
- Two task parameters were varied:
  - Distance D (64px, 128px, 256px, 512px, 1024px)
  - Width W (8px, 16px, 32px, 64px)
- 49 participants performed 5 repetition of the task with the same configuration under both *stressed* and *calm* conditions

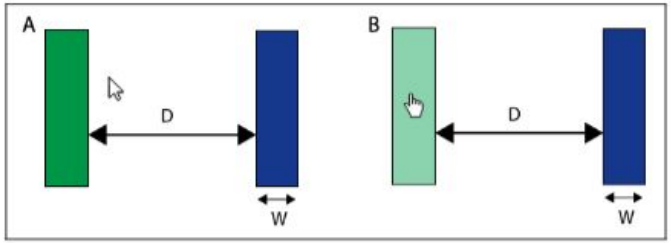
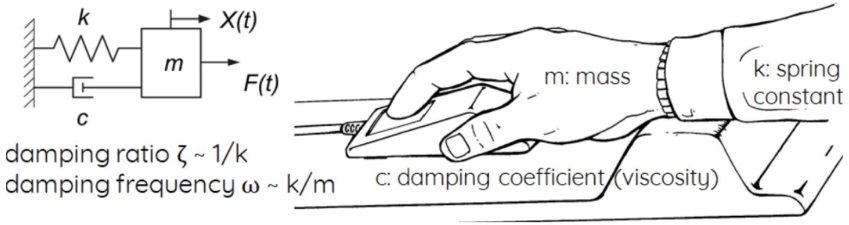
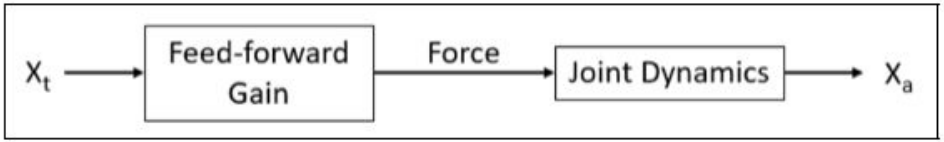


Fig. 3. Point-and-click task from MouStress [6]. a) Participants have to reach the green region and b) click it, which is then dimmed to provide feedback.

MSD model





Open-loop feedforward model for rapid goal-directed arm movement

$$\frac{X_a(s)}{X_t(s)} = \frac{K_f}{Ms^2 + Cs + K}$$

$$\frac{X_a(s)}{X_t(s)} = \frac{K_p \omega^2}{s^2 + 2\omega\zeta s + \omega^2}$$

Parameters (ω, ζ) estimated using prediction-error minimization

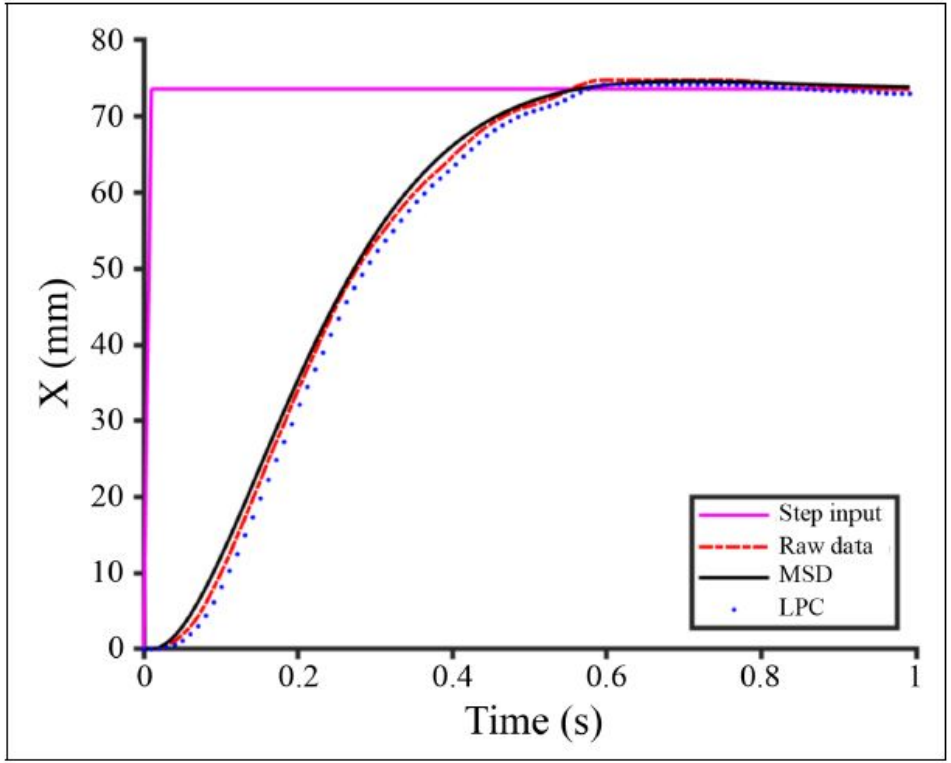
$$\text{GOF} = 100 \times \left(1 - \frac{||X_a - X_s||}{||X_a - mean(X_a)||}\right)$$

Linear Predictive Coding (LPC)

- FIR filter that build predictive model of future samples based only on linear combinations of observed signals from the past (i.e., all pole filter)
- It is an all-pole filter, thus similar in structure to the MSD model in laplace domain
- We used an LPC filter of order 4, and estimated damping freq (ω) as the imaginary part of complex root, and damping ratio (ζ) as the ratio of complex roots' real part and its absolute value
- Here we provide evidence that the two parameters (ω, ζ) from the two approaches (LPC, MSD) are significantly correlated

Method | Example

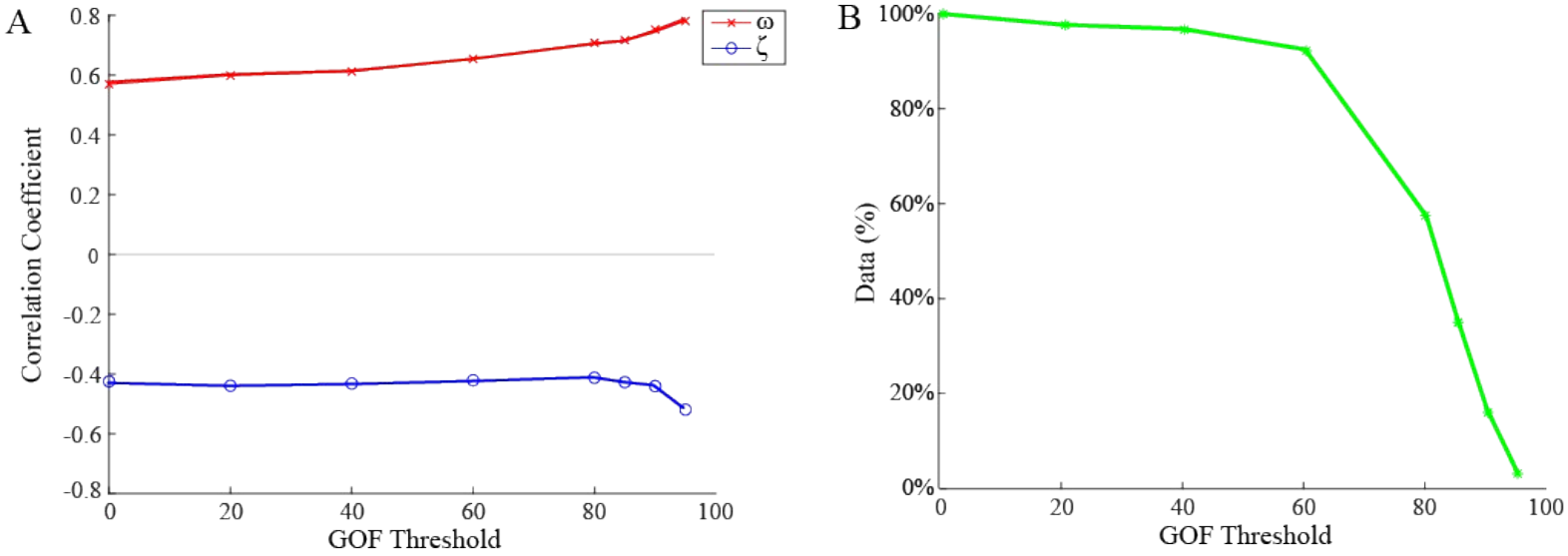
Example of raw data compared with responses from MSD and LPC



Basic Statistics | **Results**

	ω			
Model	calm	stressed	t(48)	p
MSD	12.9 (0.5)	14.4 (0.4)	3.6	$< 0.001^*$
LPC	0.261 (0.002)	0.268 (0.001)	3.8	$< 0.001^*$
	ζ			
Model	calm	stressed	t(48)	p
MSD	1.00 (0.03)	.97 (0.03)	1.1	0.28
LPC	0.5635 (0.0005)	0.5652 (0.0005)	3.2	0.002^*

Correlation | **Results**



Binary Stress Classification | **Method**

- Standard ML Method
  - Support Vector Machine
- Neural network-based ML Methods
  - Long Short-Term Memory (LSTM)
  - Convolutional Neural Network (CNN)
- Built a different classifier per participant per distance of the *Point-and-Click* task

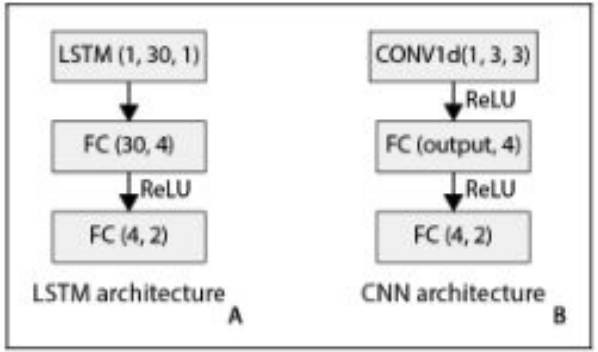


Fig. 4. Architecture of the methods based on A) LSTM and B) CNN. (FC = fully connected layer, ReLU = rectified linear unit)

Binary Acute Stress Classification | Results

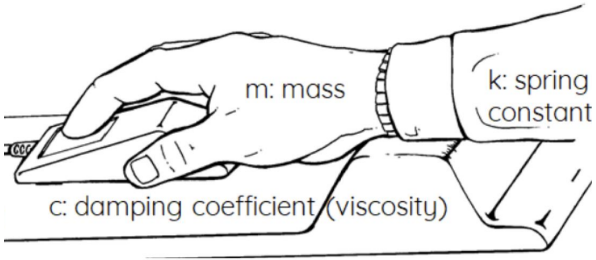
Distance	CNN	LSTM	MSD ω, ζ	LPC ω, ζ	MSD ω	LPC ω	MSD ζ	LPC ζ
64x	51.8% (0.65%)	54.7% (1.1%)	58.8% (1.9%)	53.5% (1.4%)	**60.0%** (1.9%)	54.6% (1.7%)	51.2% (1.0%)	57.1% (1.7%)
128x	53.6% (0.95%)	56.4% (1.5%)	56.4% (2.0%)	55.9% (1.8%)	57.1% (2.0%)	58.8% (1.9%)	52.3% (1.0%)	**58.9%** (2.0%)
256x	55.1% (1.04%)	58.3% (1.7%)	59.1% (2.0%)	57.2% (1.6%)	59.5% (2.0%)	**62.3%** (1.8%)	55.0% (1.3%)	60.4% (1.9%)
512x	60.1% (1.5%)	65.3% (1.8%)	60.0% (2.2%)	58.6% (1.3%)	60.7% (2.1%)	**67.2%** (2.0%)	54.9% (1.6%)	64.4% (2.1%)
1024x	62.2% (1.6%)	67.3% (2.0%)	63.6% (2.3%)	61.4% (1.4%)	65.3% (2.2%)	**72.9%** (1.8%)	56.0% (1.6%)	69.4% (1.9%)
Overall	56.6% (1.01%)	60.4% (1.4%)	59.6% (1.8%)	57.3% (1.3%)	60.5% (1.7%)	**63.2%** (1.4%)	53.9% (0.7%)	62.0% (1.6%)

Conclusion

- Parameters derived from an LPC filter are valid and a good proxy to those from an MSD model of the human arm to predict binary acute stress levels of users based on their computer mouse clicking data

- LPC filter can be easily implemented for real-time processing, vs. an MSD model

- In the future, we plan to
  a. Combine physiological signals (e.g., HR) to further improve the ML performance
  b. Explore using a combination of neural network-based approaches with MSD or LPC
  c. Apply some of these methods to analyze in-the-wild data



Thank You