Computational Modeling of Human Movement: Exploring the Biomechanics, Neural Control, and Cognitive Processes Underlying Movements

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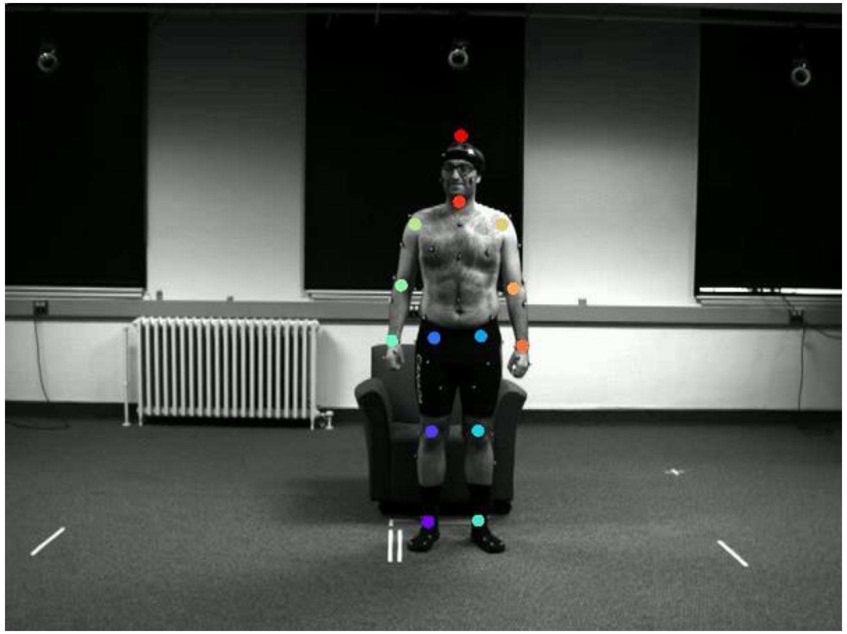
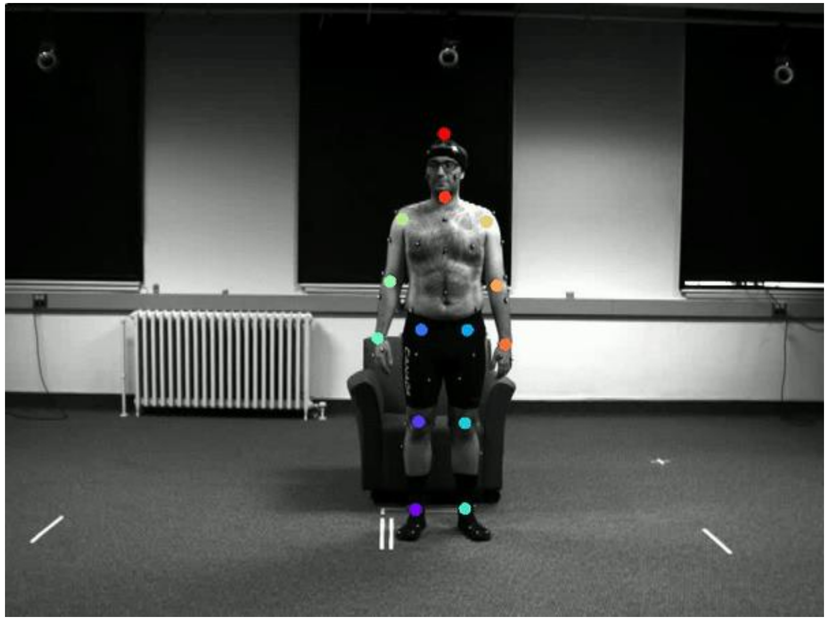
Project 1: Movement classification

Question: Does the model comprehend the movements in a way as humans do?
Can we make inference about NN in the process of training and after that?

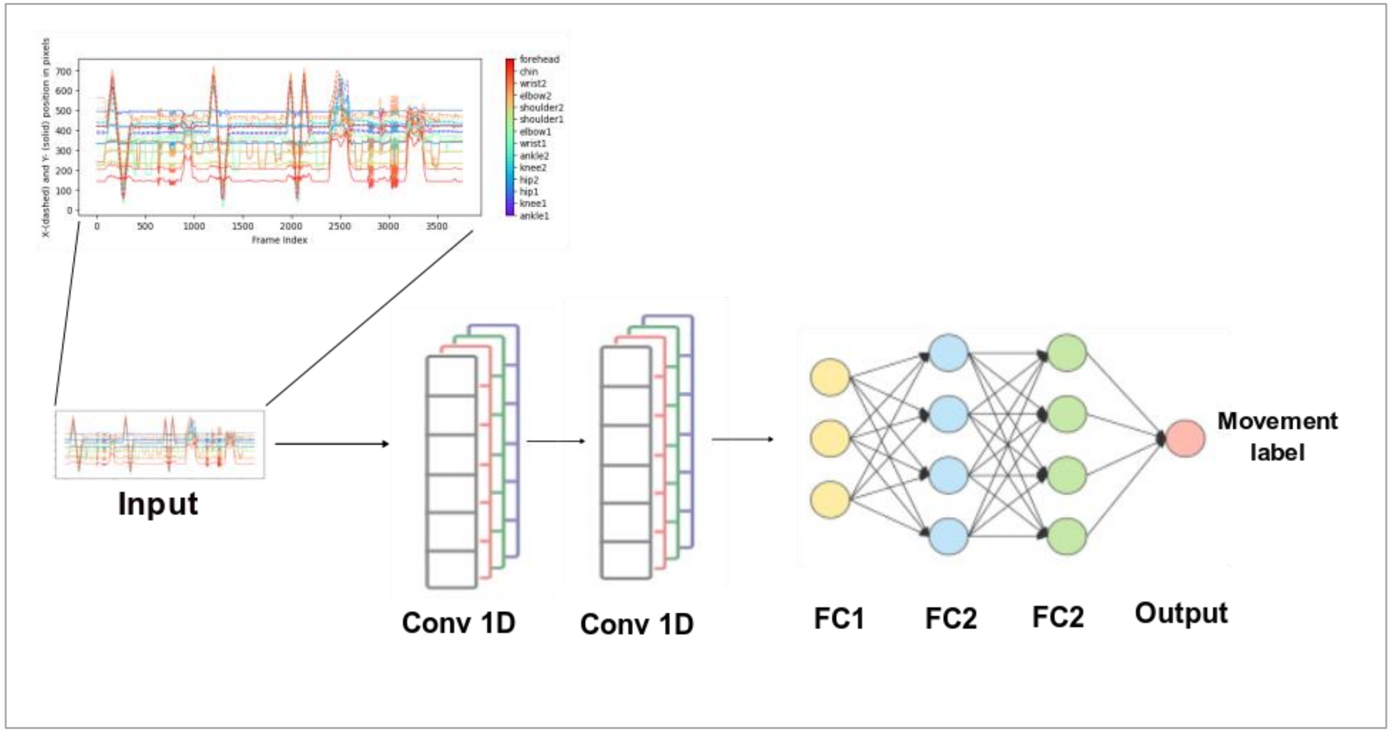
-Deeplabcut(14 joints, 21 movements)

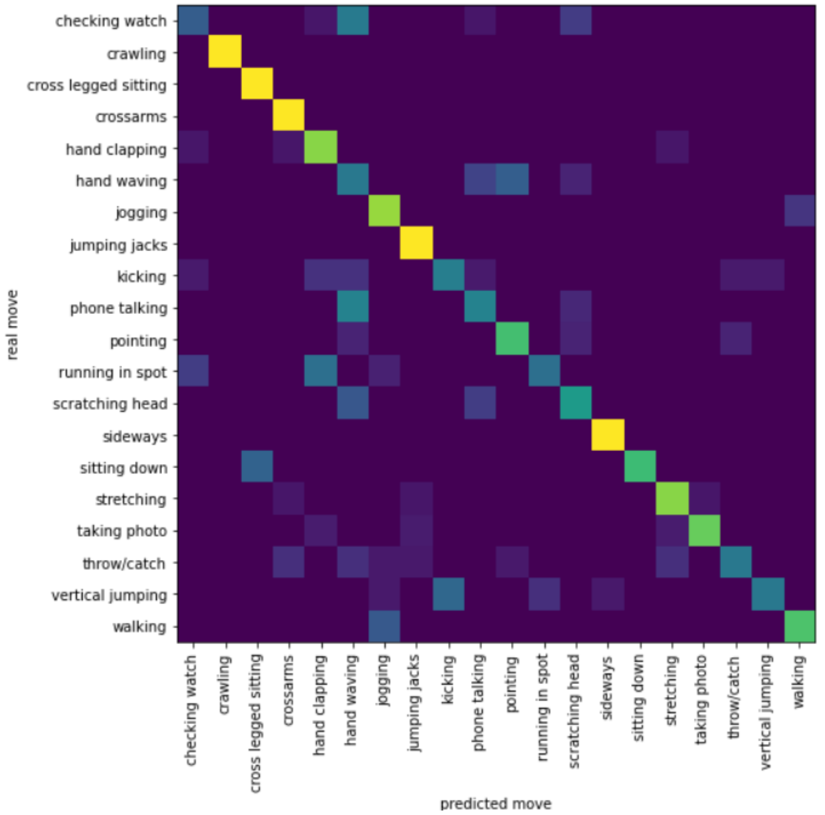




Model

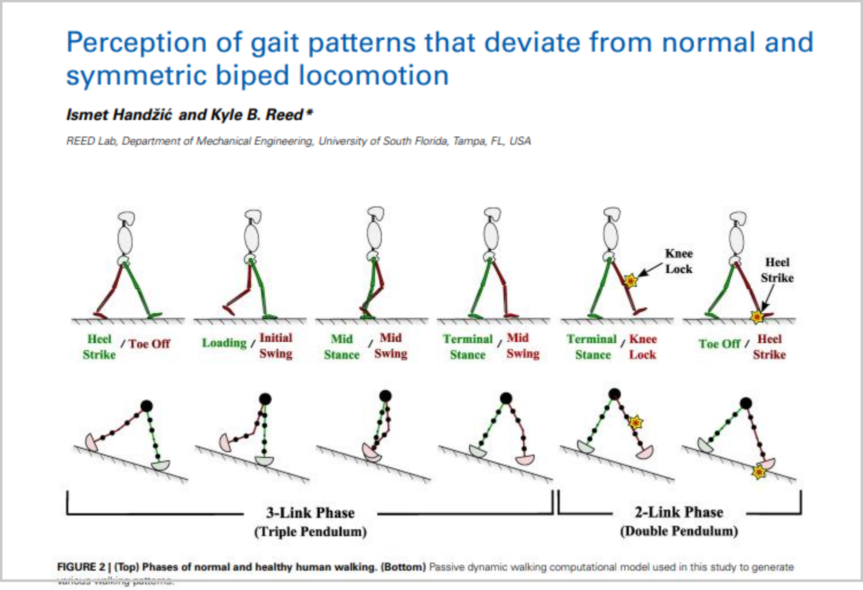
- Architecture
- Performance





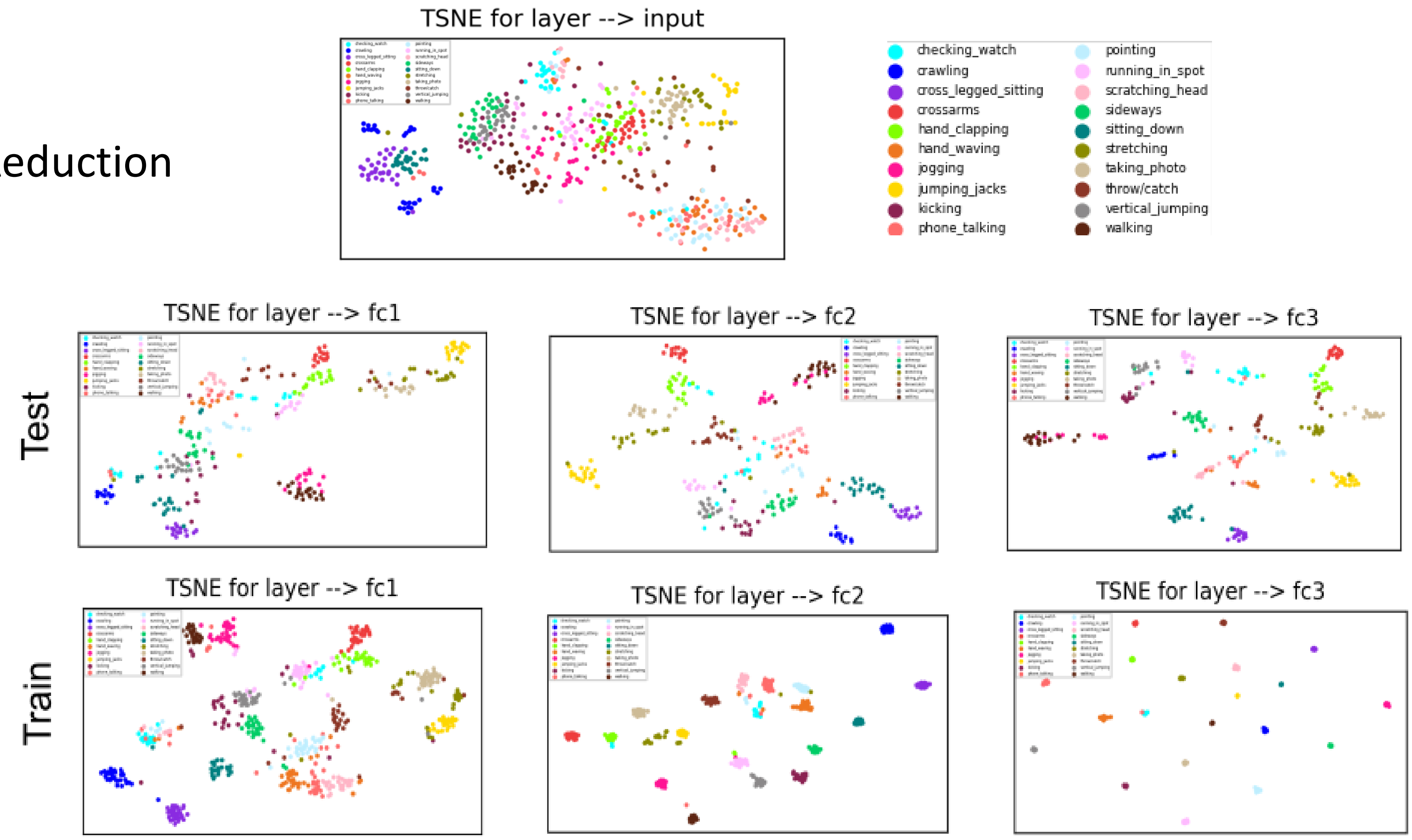
Motivation

- Perception of gait
- Walking patterns that shows degree of abnormality



TSNE

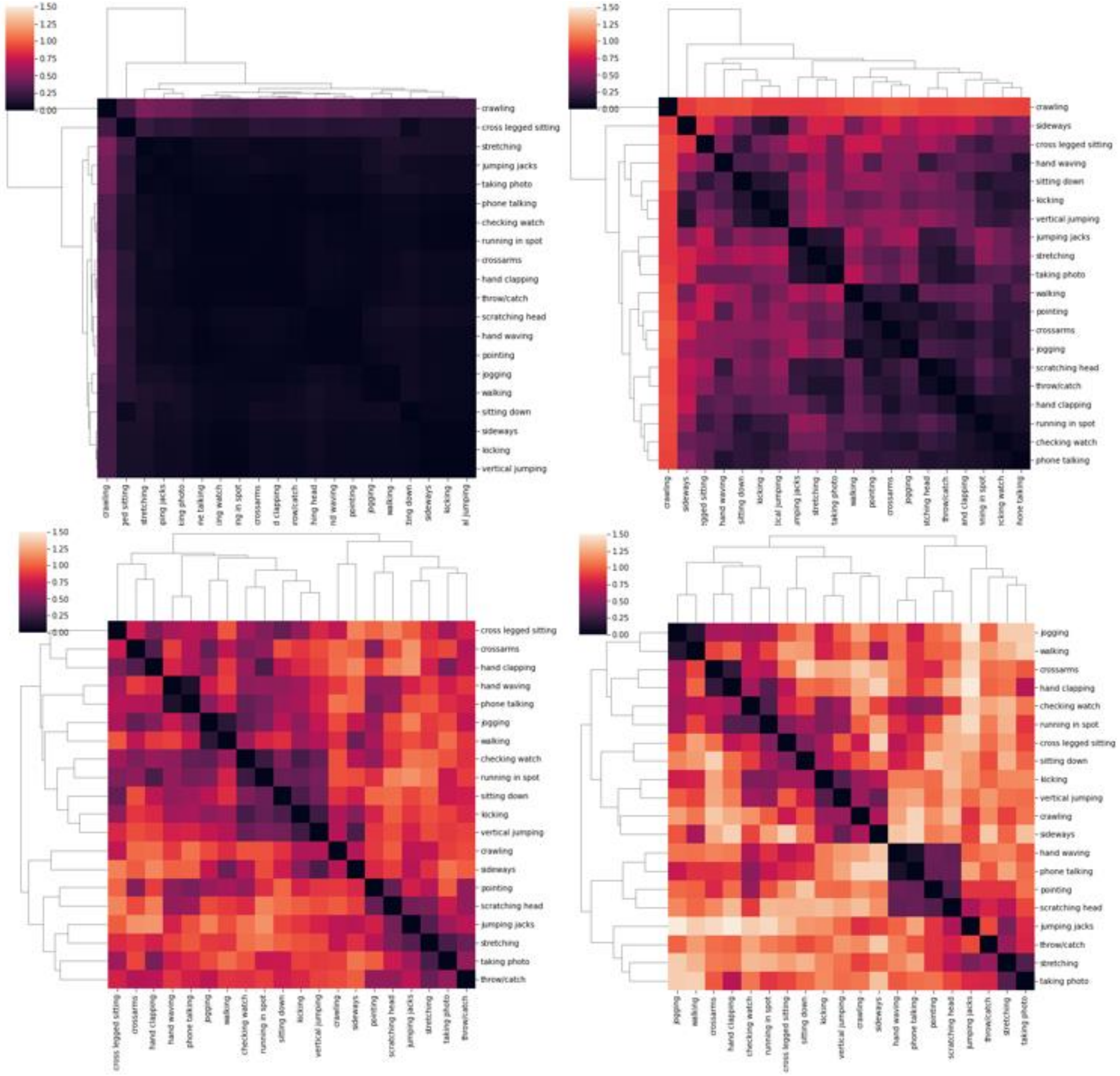
- Dimension Reduction



RDM

- Dissimilarity Analysis

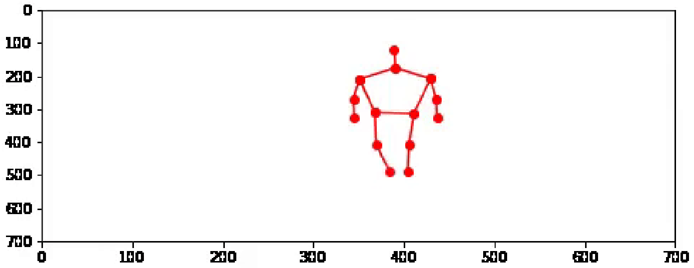
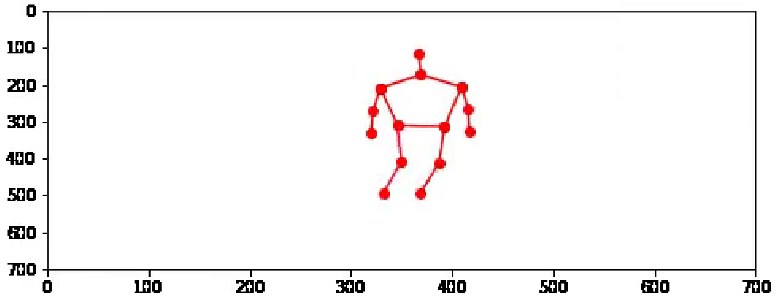
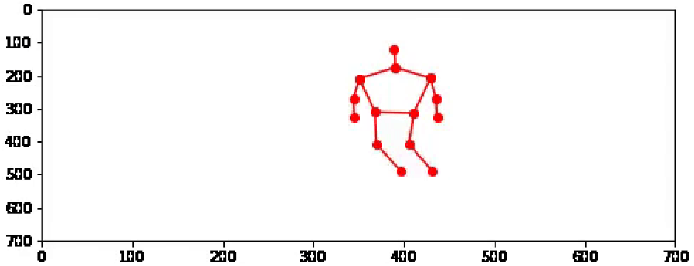
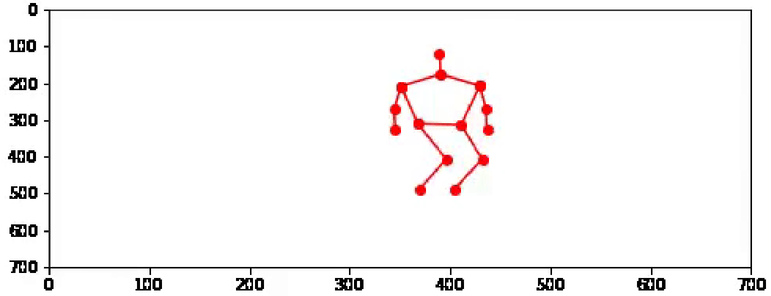
$$d_{i,j} = 1 - r_{ij} = 1 - \frac{1}{\sigma_{b_i}\sigma_{b_j}}(\mathbf{b}_i - \mu_i)^T(\mathbf{b}_j - \mu_j)$$



XAI: Effectiveness by perturbation

- Perturbing one specific joint does not change the performance of the model to distinguish two class of “walking” & “jumping jacks”

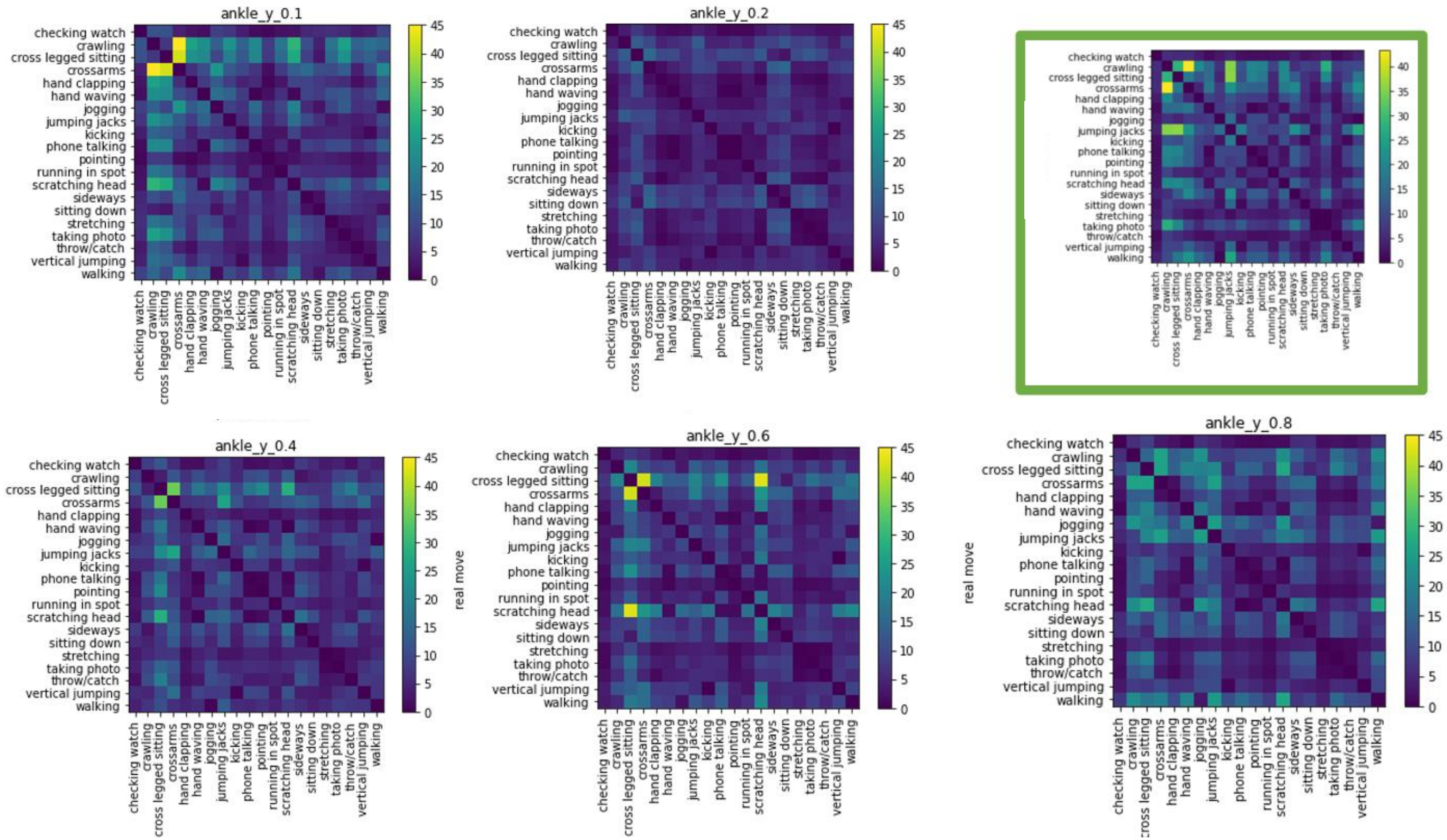
amp \ Freq	0.2	0.5	0.8
20	100	100	100
30	100	100	100
80	100	100	100

XAI: Effectiveness by perturbation

- Calculating d-prime between each two categories.

$$\acute{d} = \frac{\mu_1 - \mu_2}{\sqrt{\frac{1}{2}\left(\delta_1^2 + \delta_2^2\right)}}$$



Purposes to be covered:

- Gain insight regarding what aspects of movements are characteristic of movement disorders
- Neurological disorders assessment and diagnosis: Can we provide a pattern or score for each movement, so it will distinguish normal and abnormal movements
- Explanatory artificial intelligence (XAI): we can achieve specific tools that can help to interpret machine learning pipelines.

Project 2: Background

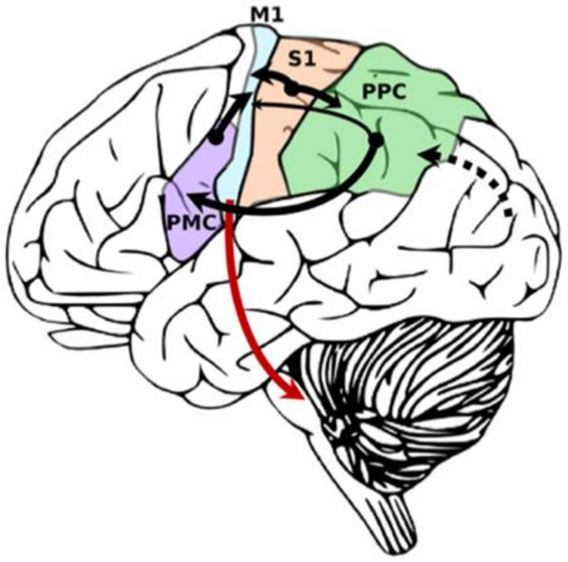


FIGURE 2 | Simplified diagram demonstrating primary sensory inputs to primary motor cortex. Cortico-cortical connections are black. Cortico-fugal projections from M1 are red. Width of arrow denotes strength of connection. Dotted line denotes primary visual input from visual cortex into posterior parietal cortex (PPC) for multimodal integration.

Edwards LL, et al. (2019)

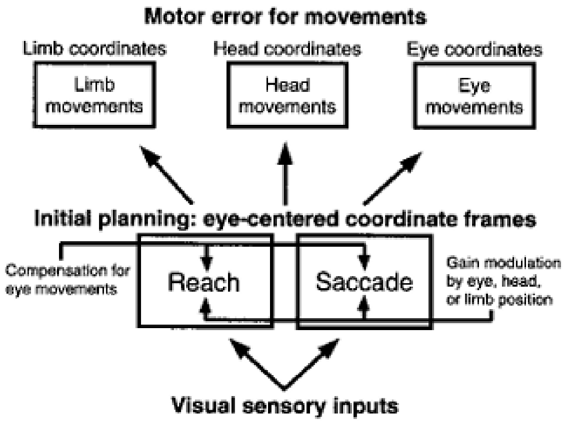


Fig. 4. Summary of pathways for sensory-motor control. Putative flow of information is from bottom to top.

Batista, A. P., Buneo, C. A., Snyder, L. H., & Andersen, R. A. (1999).

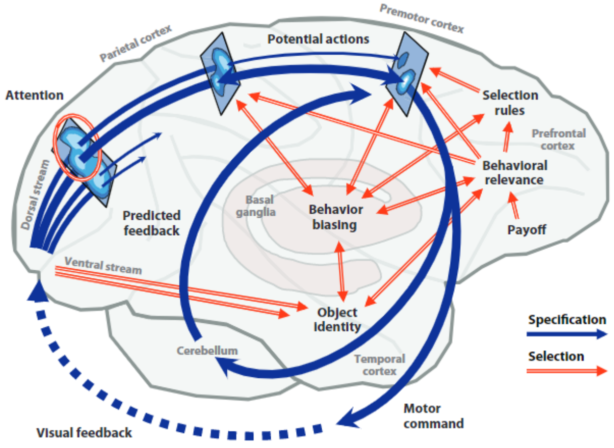


Figure 1

Cisek, P., & Kalaska, J. F. (2010).

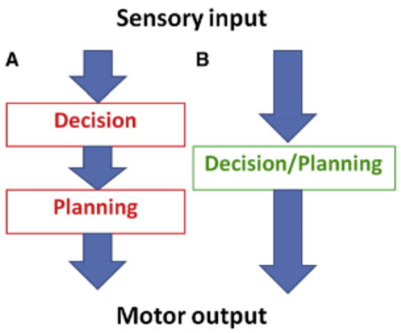
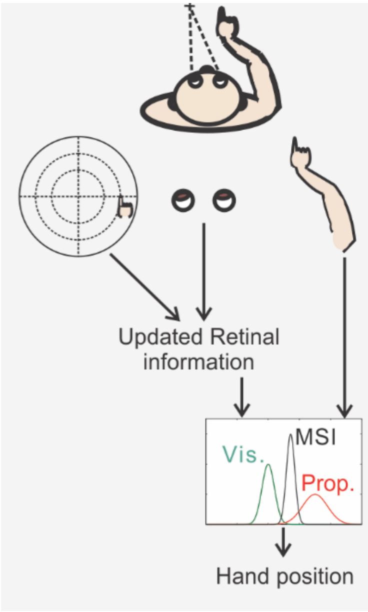


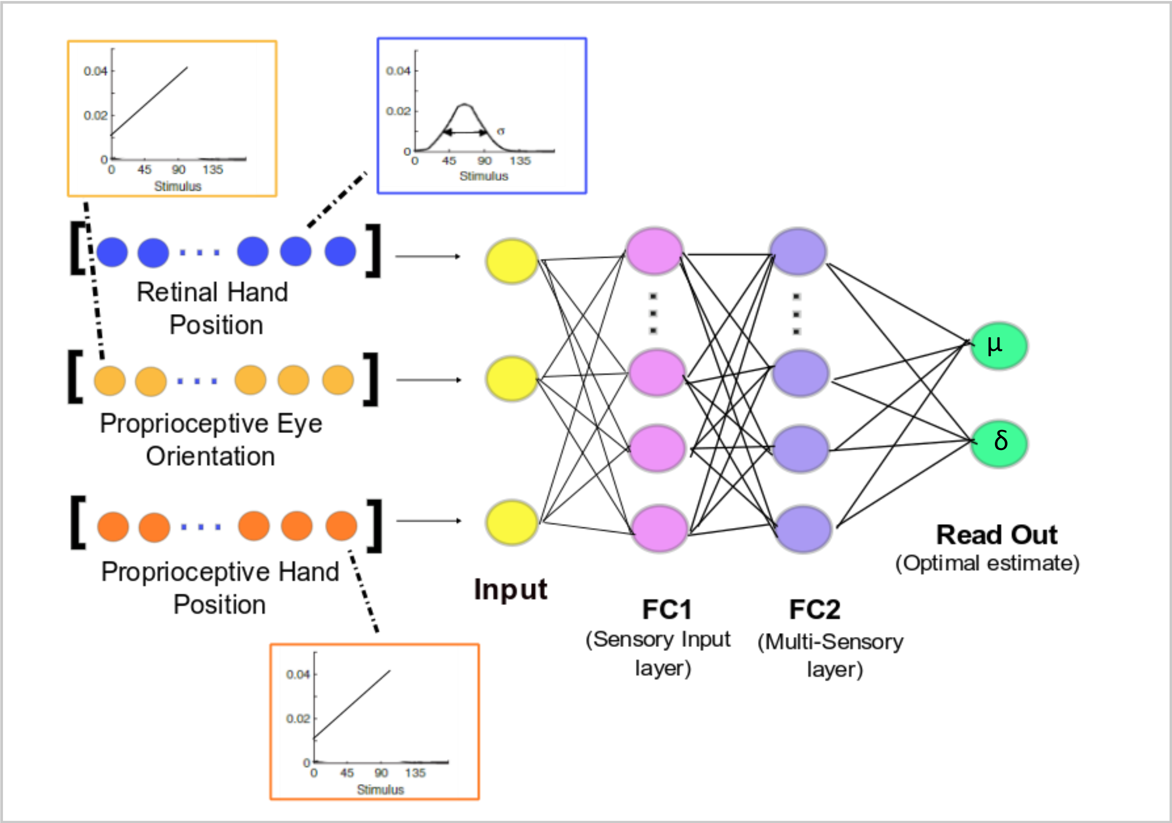
Figure 3. Illustrations of Two Theoretical Frameworks of Decision Making and Action Planning

Andersen, R. A., & Cui, H. (2009).

Project 2: Multisensory Integration

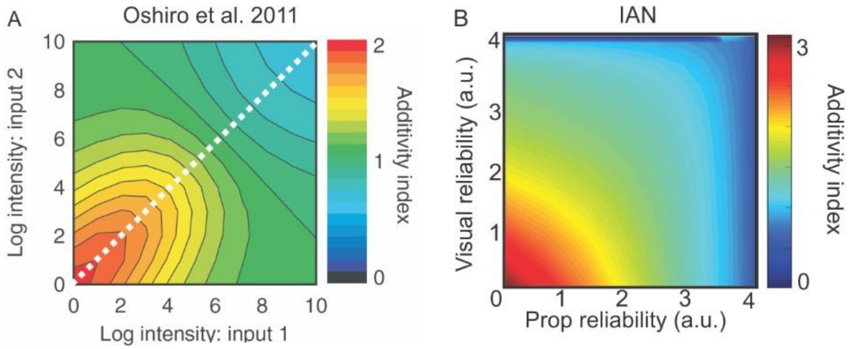
Question: Can ANN perform Multisensory Integration?



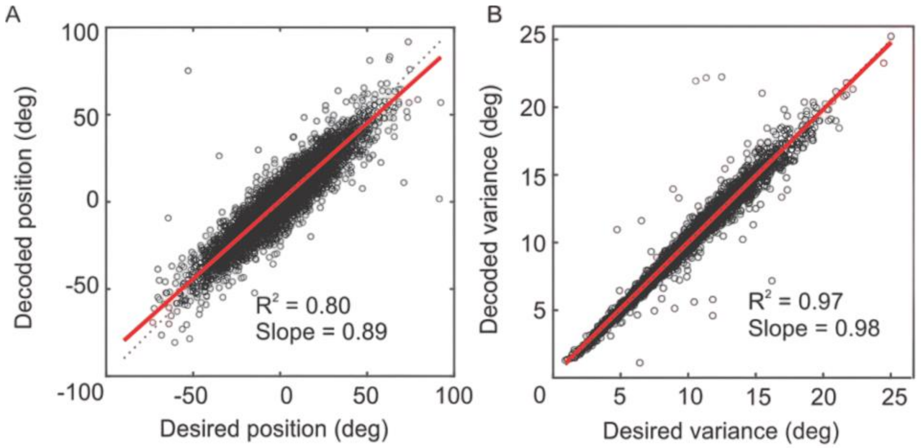


Results

- Performs well with a fraction of the neurons required by explicit normalization method.
- Does not require a neat preconfigured connectivity structure between neurons or explicitly matching population codes for individual neurons.
- Produces a wide range of behaviors similar to recorded activity in the brain.



$$AI = \frac{R_{bimodal}}{(R_{unimodal,1} + R_{unimodal,2})}$$

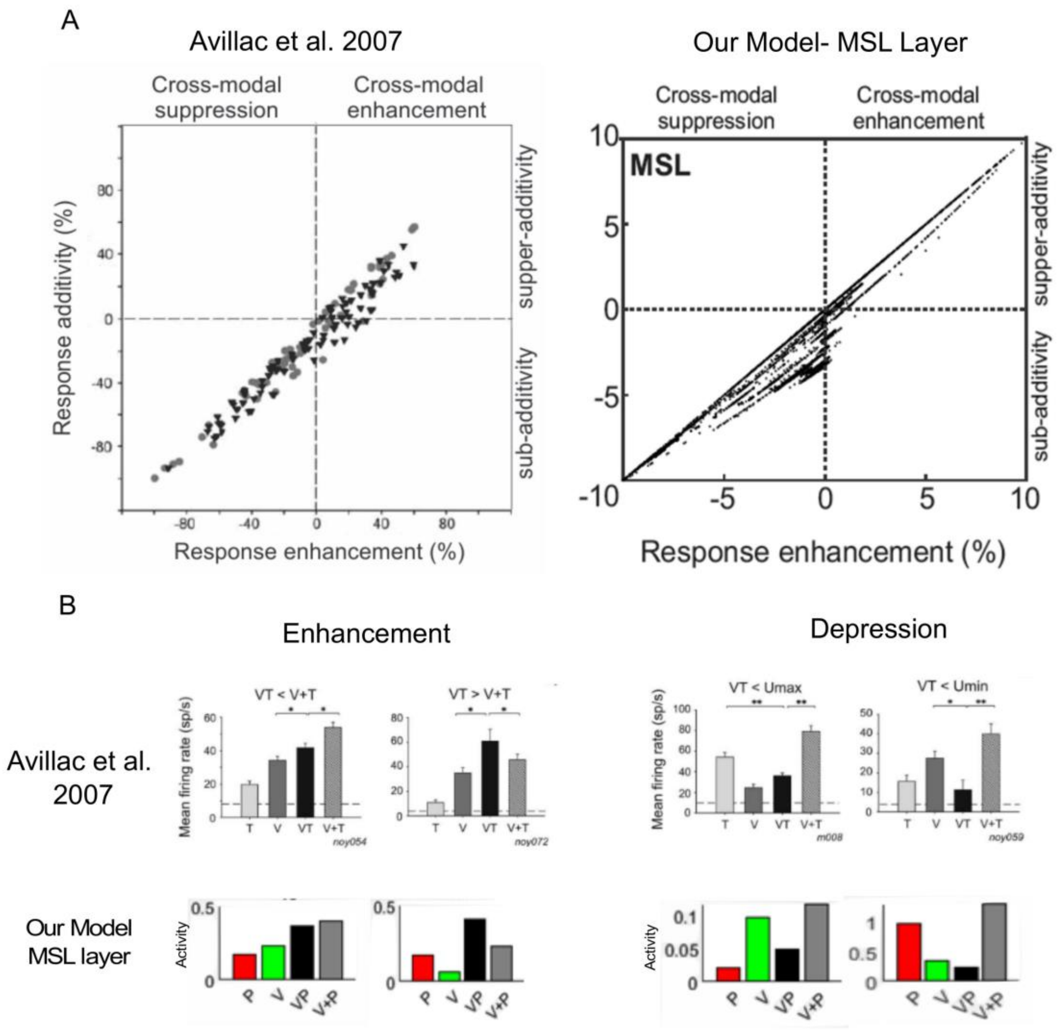


Results

- Inverse Effectiveness
- Multi-sensory suppression
- Super-additivity

$$RE = \frac{R_{bimodal} - max(R_{unimodal,1}, R_{unimodal,2})}{R_{bimodal} + max(R_{unimodal,1}, R_{unimodal,2})}$$

$$RA = \frac{R_{bimodal} - (R_{unimodal,1} + R_{unimodal,2})}{R_{bimodal} + (R_{unimodal,1} + R_{unimodal,2})}$$

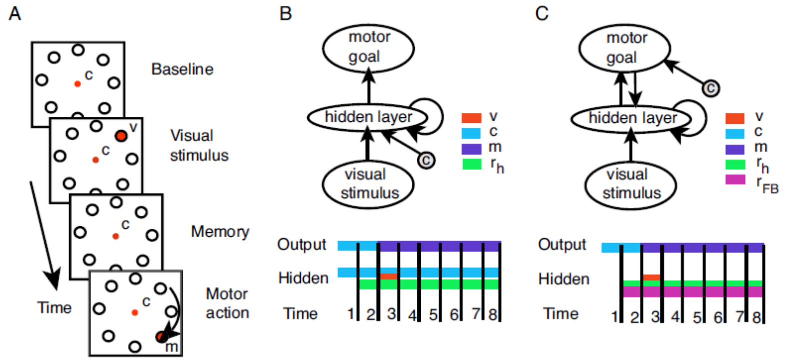


Purposes to be covered:

- Explicit divisive normalization is not necessary for multisensory integration.
- Adding causality
- Doing micro-stimulation and compare the behavior with the neural data
- Implementing this model in real-world application (Robotics)

Project 3: Ideas

- Visuomotor Transformation, the integration of sensory signals with abstract behavioral rules(contexts) and how this results in decisions about motor actions.
- Sensory-motor encoding disassociation, how the brain encodes and processes sensory-motor information for different motor tasks.
- Can we design a model that is able to handle two different motor task using a context/rule signal?
- Does it need different form of transformation while receiving sensory information?



Brozovic´ et al. Contextually Guided Visuomotor Transformations

Project Timelines