Effective, Time-Efficient State Representations for Human-Machine Decision Making

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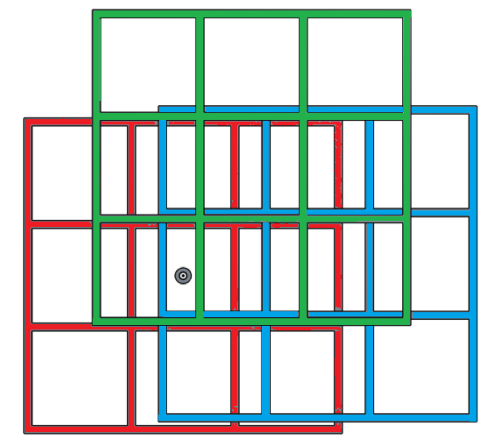
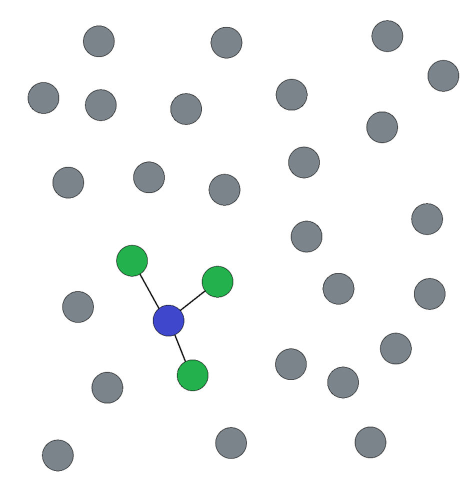
Motivation

As the sensorimotor data available to prosthetic control systems increases in dimensionality, it becomes increasingly important that the data be represented in a useful and computationally efficient way. In this study, we explore the impact that increased sensorimotor information has on current machine learning prosthetic control approaches. Specifically, we examine the effect that high-dimensional sensory data has on the computation time and prediction performance of a temporal-difference learning method embedded within a resource-limited upper-limb prosthesis control system. We also compare a proposed representation method, selective Kanerva coding, against a very popular method, tile coding.

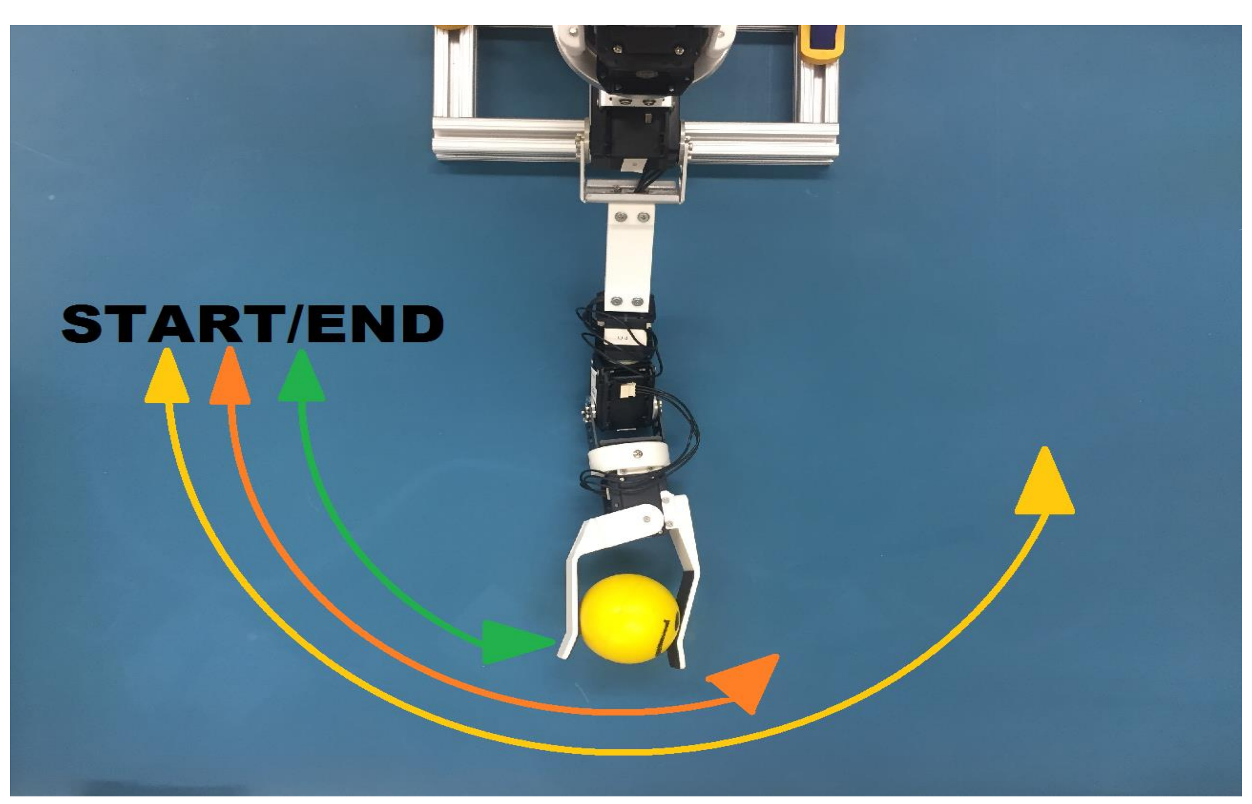


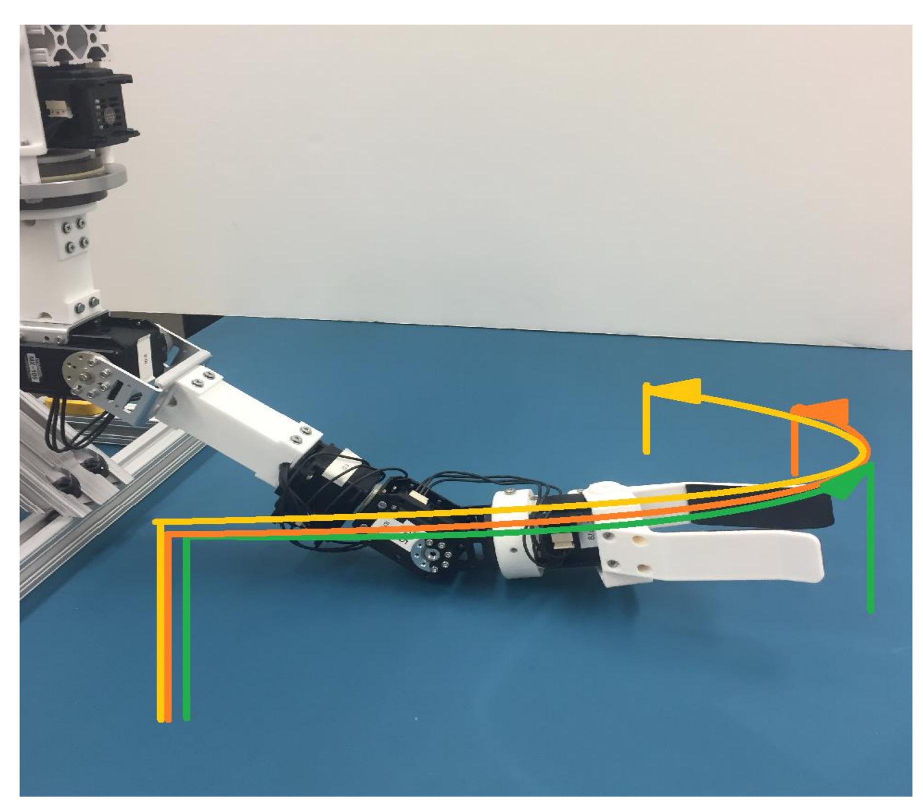
Tile Coding 2D state space with 3 3x3 tilings. 3 active features represent the state (3 tiles have a circle in them).



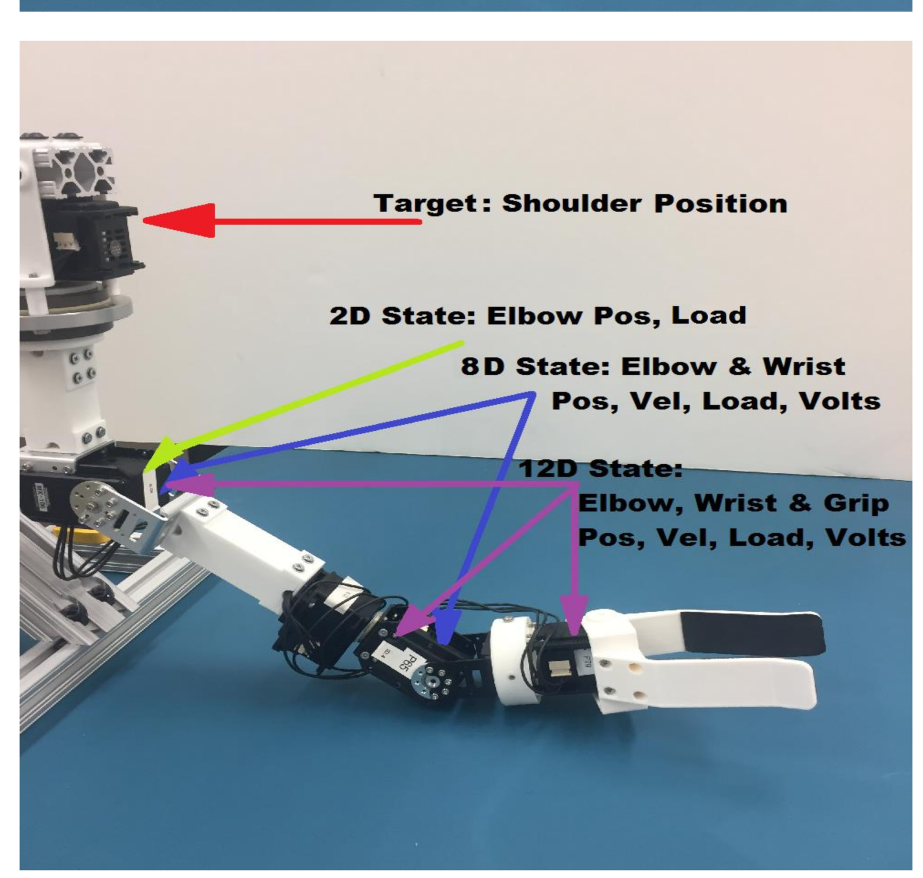
Selective Kanerva Coding 2D state space with 27 prototypes. Using a ratio of 3 active features (green) represent the state (blue).

Data for the Prediction Task

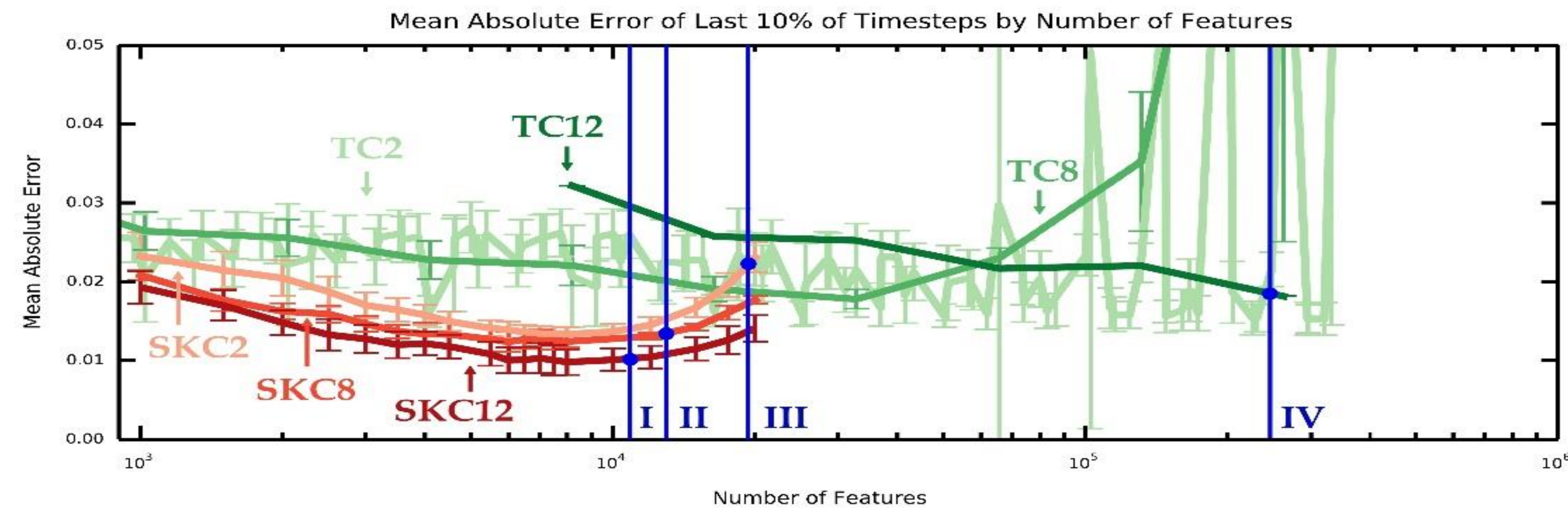


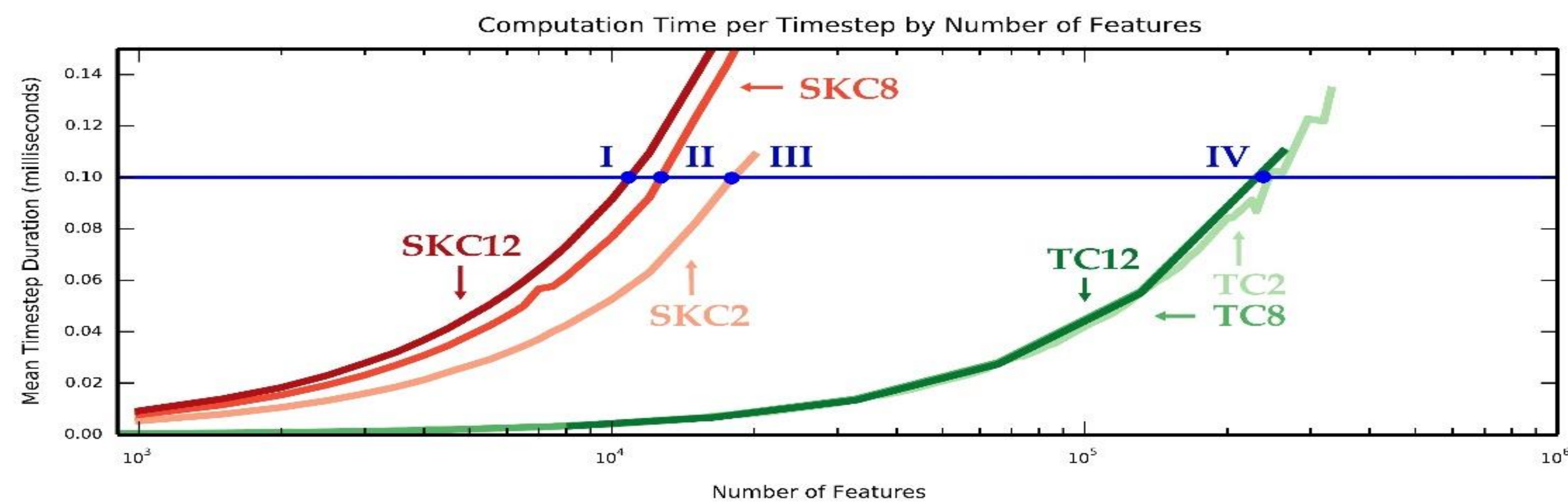


One trial of the generation had an arm grasp one of 3 objects at the same start position, lift its elbow a short distance, rotate its shoulder to the object's designated position, lower its elbow, and release the gripper. Sensor data from all servos of the arm was collected for each of the 90 trials (30/object).
3 different dimensional settings (2, 8, and 12 dimensions) were created for the prediction task. **The target for the prediction task was to answer: What will the shoulder's position (in radians) be in 100 timesteps?**



Comparing Time and Error





- Compared 248 configurations of tile coding and 5 random seeds of selective Kanerva coding
- Additional features increase the computation time per timestep for both representations but more substantially for selective Kanerva coding
- Selective Kanerva coding performs consistently better than tile coding in all 3 dimensional settings for timestep lengths below a reasonable maximum timestep of 100 ms.
- Additionally, the performance of selective Kanerva coding has a noticeable convexity with minimum error at 8000 features across all dimensions.

Conclusions

In addition to showing promising results for selective Kanerva coding, our results confirm potential limitations to tile coding as the number of sensory input dimensions increases. To our knowledge, **this study is the first to explicitly examine representations for real-time machine learning prosthetic devices in general terms**. This work therefore provides an important step towards forming an efficient prosthesis-eye view of the world, wherein prompt and accurate representations of high-dimensional data may be provided to machine learning control systems within artificial limbs and other assistive rehabilitation technologies.

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