Predicting Metabolic Cost During Human-in-the-Loop-Optimization

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Motivation

Metabolic cost is a measurement of the rate of energy required to perform a task. Collecting metabolic cost data is difficult and limiting. We are interested in using human data collected during human-in-the loop optimization of exoskeleton control to predict metabolic cost. The ability to approximate human energy use during walking outside the laboratory environment will allow for more robust experimentation for exoskeletons and prosthetics.

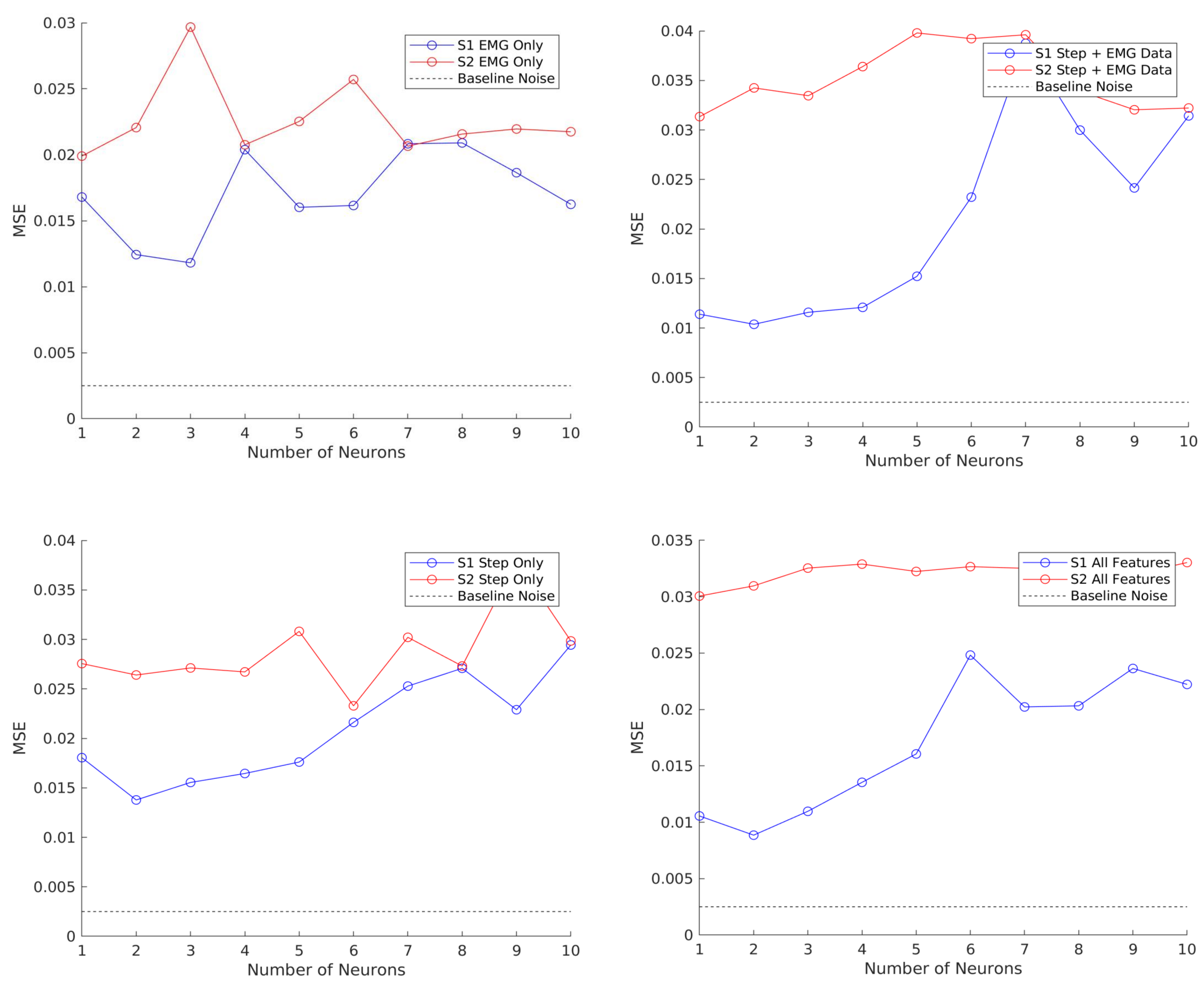
Data

The dataset was taken from an ongoing study in the Stanford Biomechatronics Laboratory, which consists of multiple days of 72 minute human in the loop optimization trials. Two subjects' data were used; this corresponds to approximately 180 sample points per subject.

- **Input features**
  - 4 exoskeleton control parameters
  - 16 EMG sensors total (8 per leg)
  - 9 features from step data
- **Outputs features**
  - Metabolic cost
- **Preprocessing**
  - Metabolic data: normalized
  - EMG data: filtering
  - Step data: extracted from treadmill force sensors

Model

We used a baseline linear regression model to predict metabolic cost. We also used a shallow, one hidden layer neural network to perform curve fitting. To tune the number of neurons in the hidden layer we used k-fold cross-validation while training with Bayesian Regularization. Regularization was also performed during linear regression (LASSO) to preven overfitting.



Results

	Constant Prediction MSE	All Features Lin. Reg	All Features NN	Step & EMG Lin. Reg.	Step & EMG NN	Step Only Lin. Reg	Step Only NN	EMG Only Lin. Reg.	EMG Only NN
Subject 1	0.0657	0.0089	0.0089	0.0089	0.0104	0.0200	0.0138	0.0158	0.0118
Subject 2	0.0465	0.0176	0.0301	0.0168	0.0313	0.0217	0.0233	0.0203	0.0199

Table 1. MSE of all subsets of models and learning algorithms used

Discussion

- EMG data is relatively more significant than step data as predictors for metabolic cost
- The variations in predictions between the two subjects indicates that trying to create a network to generalize these predictions for multiple individuals would likely yield poor predictions
- Control parameters as inputs has relatively low significance
- There may be better models neural network for this problem

Future Work

- Collect a larger data set with features from more individuals
- Include more human-specific features (such as height, weight, etc.) for better generalization
- Current dataset is relatively small with a large number of predictors; feature dimensionality could be reduced with feature selection or principal components analysis

References

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