Cracking the Neural Code for Sensory Perception and Locomotion

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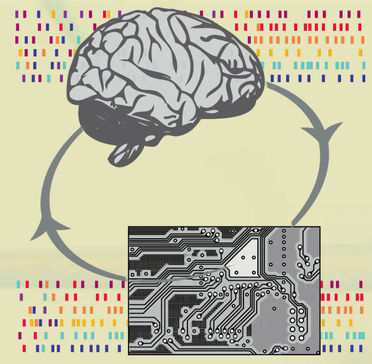
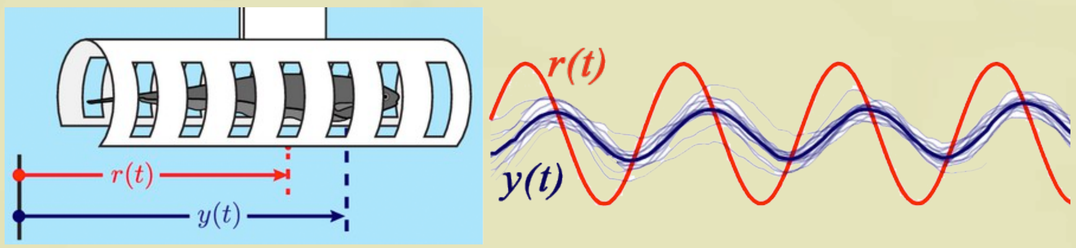
Introduction

- Nervous System can be thought as a highly complex neural network that has not been reversed engineered completely. Nowadays, there is increasing interest in cracking the neural code and fully understand the human brain.
- Aim of this project is to build a novel machine learning black box with the input being neural activity and the output being external variable.
- Since the primate nervous system is extremely complicated, we used the neural data recorded from Black Ghost Knifefish which has a simpler nervous system. The knifefish tend to hide within the limit of a refuge so that it will follow the movements of the refuge to stay inside it (Eatai Roth, et al., 2011). For example, if you move the refuge sinusoidally, the Knifefish is going to move according to it.





- As a result, the input neural data is black ghost knifefish's neural spike recordings of three neurons and the output is the velocity of the fish.

Specifications and Design Requirements

- Expected result is satisfactory predictions of fish velocity by using neural signal. Since our problem is a regression problem, we used Mean Squared Error (MSE), which is called loss function, for model comparison. So, the less error is the ultimate goal. However, it does not give an objective comparison among existing methods so that we focused on predictions beside MSE.
- Sample rate of the neural signal is 25k Hz.
- We aimed to implement a novel approach in contrast to binning techniques that are used widely in neural decoding because binning technique downsamples the neural signal.

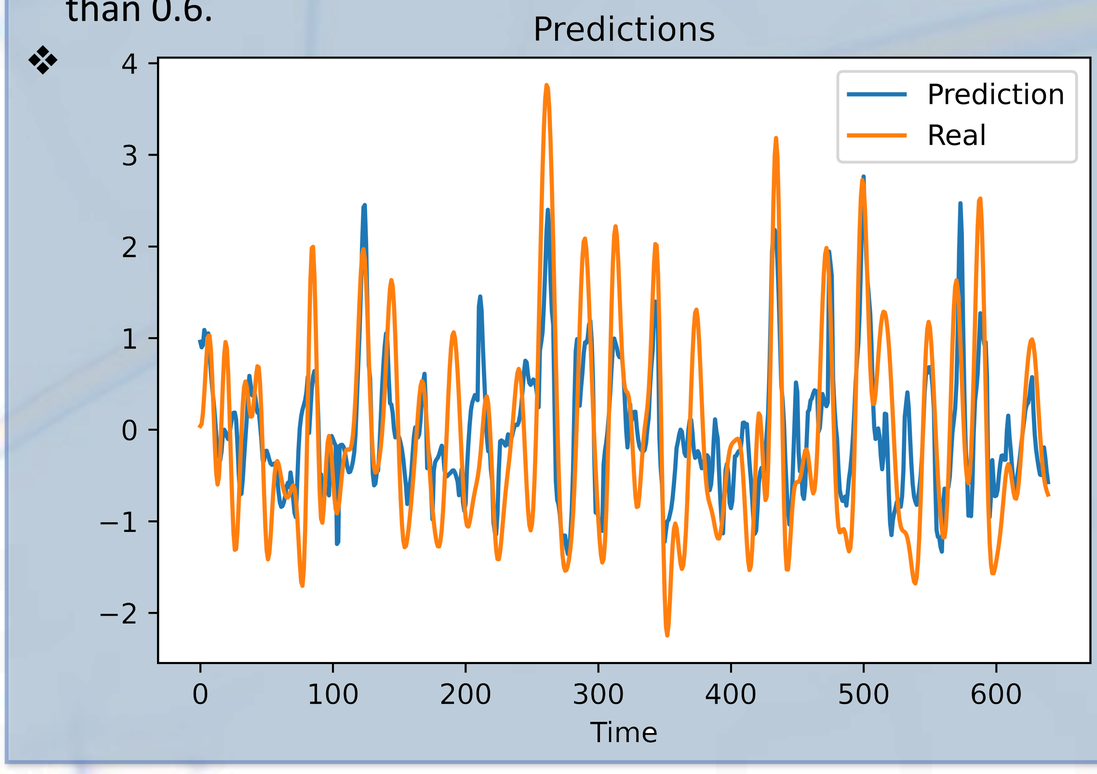
Solution Methodology

- First, we must decide which feature is the most correlated with the neural data. We have done it by looking feature importances using Decision Trees. Eventually, we decided to use V_{fish}.
- After an extensive research about neural decoder techniques, we found that Neural Network (NN), which has LSTM (Long Short-Term Memory) layers in it, is the best method among numerous approaches (Joshua I. et al.,2020).
- LSTM is a Recurrent NN unit. It has memory to remember previous inputs and predicts output considering not only the current input, but also a finite amount of past time. Hence, it is one of the best methods for predicting time-series dataset.

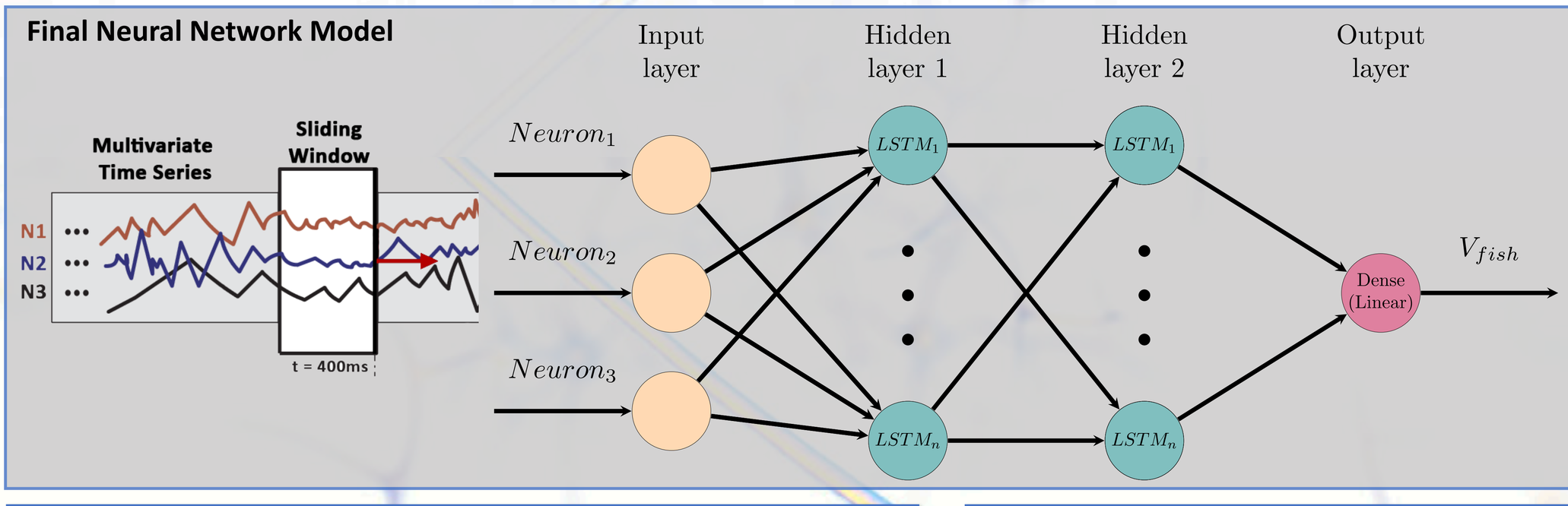
Application Areas

- Neural Decoder project can be thought as the first step of human-machine interface and neural chips. Hence, it can be used to overcome nervous system disorders (eg., Parkinson's disease).

Results and Discussion

- We evaluated 100+ neural network models. In each evaluation, we tried to find optimal parameters for our problem. Our final network model can predict the V_{fish} from neural signal with the MSE less than 0.6.
- 

Final Neural Network Model



Design Hyperparameters	Optimized Values
Hidden Units	16
Batch Size	64
Look Back	10
# of Epochs	20000
Optimizer	Adam
Software	Python

References

- Joshua I. et al. (2020) Machine Learning for Neural Decoding. eneuro.0506-19.2020.
- Eatai Roth, et al. (2011) Stimulus predictability mediates a switch in locomotor smooth pursuit performance for Eigenmannia virescens. Journal of Experimental Biology 2011 214: 1170-1180;
- Ismail Uyanik, et al. (2020) Variability in locomotor dynamics reveals the critical role of feedback in task control. eLife 2020;9:e51219

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