NX-414-Report

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I. Introduction

Modelling the visual cortex neuronal activity is an important research area in the process of understanding brain functions and developing new treatments for visual disorders. To perform such a modelling two approaches can be used: the data driven approach and the task driven one. While the first one uses a convolutional neural network to predict the neural activity of each neuron of interest, the second one uses a neural network trained on a specific task (such as predicting the class of images) to extract the hidden neurons from some layers in order to predict the activity of each neuron of interest. Using the dataset from Majaj and colleagues (2015) paper [1], our aim is to predict the neuronal activity of the 168 neurons present in the dataset using both approaches.

II. Methods

For the data driven approach, we have predicted the neural activity of the 168 neurons using both Ridge and Linear Regression on pixels extracted from images, on all components of the network and only on the first 1000 principal components (PCs) to prevent overfitting. A shallow neural network with 2 layers was also used. For the task driven approach, we used the ResNet50 pretrained model from pytorch library and then extracted the 1000 first PCs of the hidden neurons from layers conv1, layer1 to layer4 and avgpool to predict the neural activity of the 168 neurons. We also performed finetuning on the pretrained ResNet50 in order to optimize weights and then performed ridge regression.

III. Results

Data driven approach: Using pixels to predict the neural activity of the 168 neurons, the explained variance and R^2 score for each neuron is included in the range -1.75 and -0.25 with mean -0.965 for Linear Regression and between -0.05 and 0.4 with mean 0.0919 for Ridge Regression with alpha equals to 460 000. Similar results were observed using Ridge Regression with alpha equals to 490 000 while keeping only the first 1000 PCs of the model (mean equals to 0.0906) (Figure 1). However, the 2 layers shallow neural network was only able to explain on average -0.183 of the variance even if the distribution of explain variance goes from -0.6 to 0.3. Then, for the data driven approach, Ridge Regression with alpha equals 460 000 makes the more accurate predictions.

Task driven approach: Performing Ridge Regression using ResNet50 pretrained model on the first 1000 PCs of each layer is able to explain on average between 0.098 (conv1) and 0.403 (layer3) of the variance of the human brain neural activity (Figure 2). Similar results are obtained after finetuning the same pretrained model, since conv1 and layer3 explained

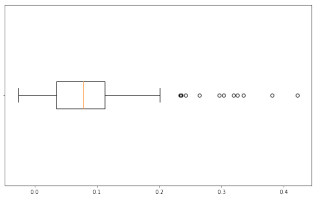

Fig. 1. Boxplot of the explained variance for the different IT neurons taking the 1000 PCs of the Ridge Regression model (alpha = 490 000

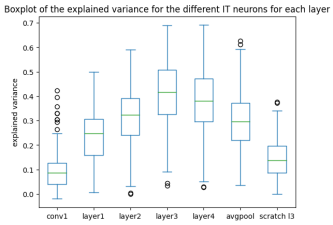

Fig. 2. Boxplot of the explained variance for the different IT neurons for each layers using a task driven approach using the 1000 PCs a pretrained ResNet50 model

respectively 0.0976 and 0.0.408 of the variance. Comparing these predictions with a scratch ResNet model, we can see that differences in explained variances are respectively 0.260 and 0.266 with the pretrained ResNet and with the finetuned Resnet. Then, even if finetuned RestNet50 and pretrained ResNet50 give very similar results, the finetuned model is able to predict more accurately the human visual cortex neuronal activity.

Figure 1 shows that the mean explained variance prediction of the 168 neurons accross layers has the shape of an inverted 'U', meaning that predictions using middle layers are more accurate. Indeed, in a classification task, while middle layers of our neural network will extract high level features, the first layers will extract low-level features (shape, edges...) which may not capture the complex pattern of our images and then artificial neurons of the corresponding layer are less representative of the neural activity of the human visual cortex. Similarly, the last layers will reduce the dimensionality of the features previsouly extracted which in turn will reduce the amount of information kept and then reduce the explained variance.

IV. Conclusion

The human visual cortex neural activity is more accurately predicted using a task driven approach, the finetuned ResNet50 model shows the better results.

REFERENCES

[1] N. J. Majaj, H. Hong, E. A. Solomon, and J. J. DiCarlo, "Simple learned weighted sums of inferior temporal neuronal firing rates accurately predict human core object recognition performance," *Journal of Neuroscience*, vol. 35, no. 39, pp. 13 402–13 418, 2015.