

Big Data and AI Strategies

Neural Network Explained Part IV: Data Pre-Processing

In the [previous note](#), we outlined a prototypical neural net trading model that takes stock level variables as inputs and forecasts stock returns. One may be tempted to immediately apply the model to existing data. However the nature of neural nets requires the user to invest efforts into pre-processing the data. We describe some of the common practices below. While not all of them are requirements for neural nets, they generally are likely to improve the performance of the model.

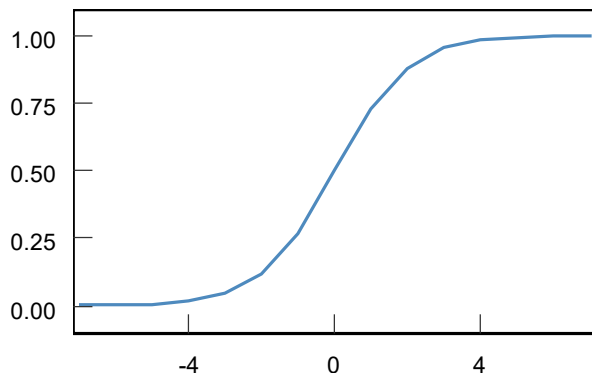
Normalization

For neural nets, it is almost always necessary to normalize the inputs, e.g. using Z-scores instead of raw values. To understand the importance of normalization, consider the sigmoid function shown in Figure 1. It's easy to see that information will be lost if the absolute value of x gets too large, i.e. $|x| > 4$. Let's say the input is the raw values of P/E ratio. The sigmoid function will output the same values on companies with P/E ratios of 5, 10, or 100. This issue is known as vanishing gradient but fortunately is easy to overcome. Simply converting the P/E ratios into cross-sectional Z-scores serves as an effective solution.

As an aside, why is sigmoid still commonly used as activation function, knowing the aforementioned issue? This is because its functional form in effect shrinks extreme observations and is often desirable for the stability of neural nets. The model would probably perform better, if we shrink a company with a P/E Z-score of 10 towards the mean, instead of taking the observation at face value.

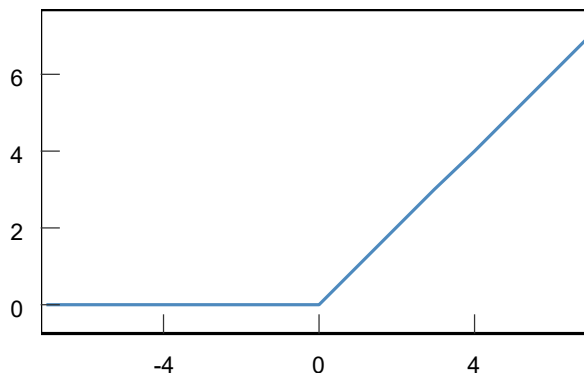
Another possibility is to use an activation function like ReLU (Figure 2). It preserves all the information for $x > 0$, and as such greatly reduces the issue of vanishing gradient. Indeed, it appears that for deep neural nets, where the input variables have to go through multiple layers of activation functions, ReLU tends to show better performance than sigmoid. Nonetheless, it is still not advisable to have extreme values as inputs. Values that are too small (negative) continue to suffer from vanishing gradient, and values that are too big (positive) miss out on the nonlinearity treatment. Therefore normalization is still a good idea.

Figure 1: Sigmoid



Source: J.P. Morgan

Figure 2: Rectified Linear Unit (ReLU)



Source: J.P. Morgan

An important pitfall to avoid in normalization is forward looking bias. Cross-sectional Z-scores use contemporaneous information and are less prone to the issue. Care must be taken when computing time series Z-scores so as to avoid information leakage. We should also keep in mind what point in time information (mean, standard deviation, etc.) is available in the test/validation sets vs. the training sets.

Orthogonalization

Previously we said that more data is better for neural nets. In reality, this is only true for orthogonal data. Having more predictors (x variables) increases the number of parameters to estimate. Therefore the information introduced by every

additional predictor must outweigh the risk of overfitting. This is especially relevant for equity long/short models, where, according to one recent survey, over 400 factors now inhabit the 'factor zoo' (Harvey and Liu, 2019)¹. Many of these factors are closely related. For instance, price/book, price/sales, and price/earnings are all measures of Value. Principle component analysis (PCA) offers an effective way of dimensionality reduction. Say we have a cross section of Russell 3000 members and their 400 factor loadings, in a 3000 x 400 matrix. PCA is applied to this matrix, which essentially produces various linear combinations (components) of the columns. We choose to retain the top 50 components, which may already capture 90% of the information in this matrix, and are now left with a much more manageable 3000 x 50 matrix with orthogonal columns.

PCA seems to have a reputation for lack of interpretability. This is not always the case. Hypothetically, if in one of the components, the weights are $\{1/4, 1/4, 1/2\}$ on $\{\text{price/book, price/sales, and price/earnings}\}$, and 0 on all other factors, then it can be identified as the Value component. Of course, in practice, the weights are a lot less clear cut, but in this author's experience, the top components oftentimes carry intuitive economic interpretations upon careful inspection.

PCA also benefits from normalization due to its scale sensitive nature. Therefore we should pre-process the data matrix into Z scores before applying PCA.

Outliers and Missing Data

Outliers are taken care of by some activation functions by design. As discussed above, sigmoid shrinks extreme values and maintains the stability of the neural nets. There are a number of other similar functions, and they share the common characteristics of finite range. What if we choose something with infinite range, such as ReLU? In that case outliers must be handled at source. That is, during normalization, we can winsorize the data and apply upper and lower bound to the values.

Missing values in the data matrix (after normalization) can be replaced with 0. This implies that the stock has a factor loading in-line with the market or sector average. One can consider predicting the missing data with existing data. In other words, if there is only one factor missing for a particular stock, we can predict it using the information from the other 399 factors. There are pros and cons to each approach. However we must recognize that predicting the missing data point does not create new information out of thin air, because the predicted value is simply derived from the known data. The main purpose of our exercise is to avoid throwing out the all the good data because of one missing data point.

Point in Time Data

Some information does not come with explicit time stamp but may be exposed to subtle yet highly problematic risk of forward looking bias. An example is index membership. Using the current members of the S&P 500 for historical back test will introduce an upward bias in stock returns, because by definition, stocks that were not in the index before and later got added must have performed better than the ex-members that they replaced. Another example is industry classification. The S&P 500 Telecommunication GICS sector contained only three members in early 2018, but the sector definition has been expanded since late 2018 to contain 26 members including mega cap names such as Alphabet and Disney. Sector neutrality from today's perspective is very different from early 2018.

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¹ Harvey, Campbell R. and Liu, Yan, 2019, A Census of the Factor Zoo, available at SSRN: <https://ssrn.com/abstract=3341728>

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