Apply Artificial Neural Network to Solving Manpower Scheduling Problem

References

Facebook. 2017. Pytorch document. Website. Https://pytorch.org/docs/stable/index.html.

A
Visualization of different neural network

The following part describes the architecture of different networks we compare. When the mapping is established, the neural network structures and computing graphs can be expressed as:

The structure of FDNN:

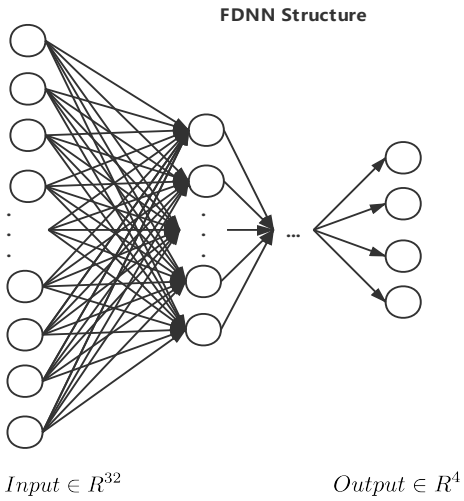

Figure 1: Feedforward Deep Neural

The computing graph of FDNN:

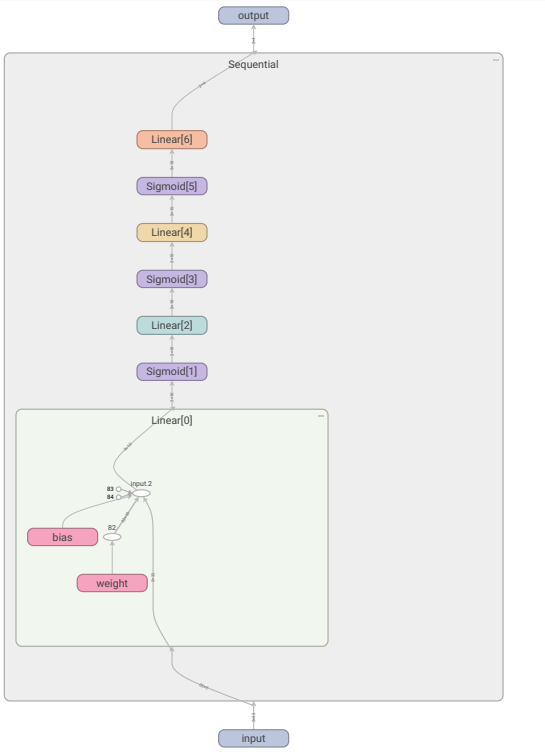

Figure 2: Computing graph of FDNN

The structure of RNN:

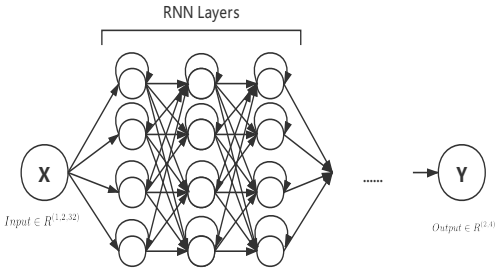

Figure 3: Recurrent Neural Network

The computing graph of RNN:

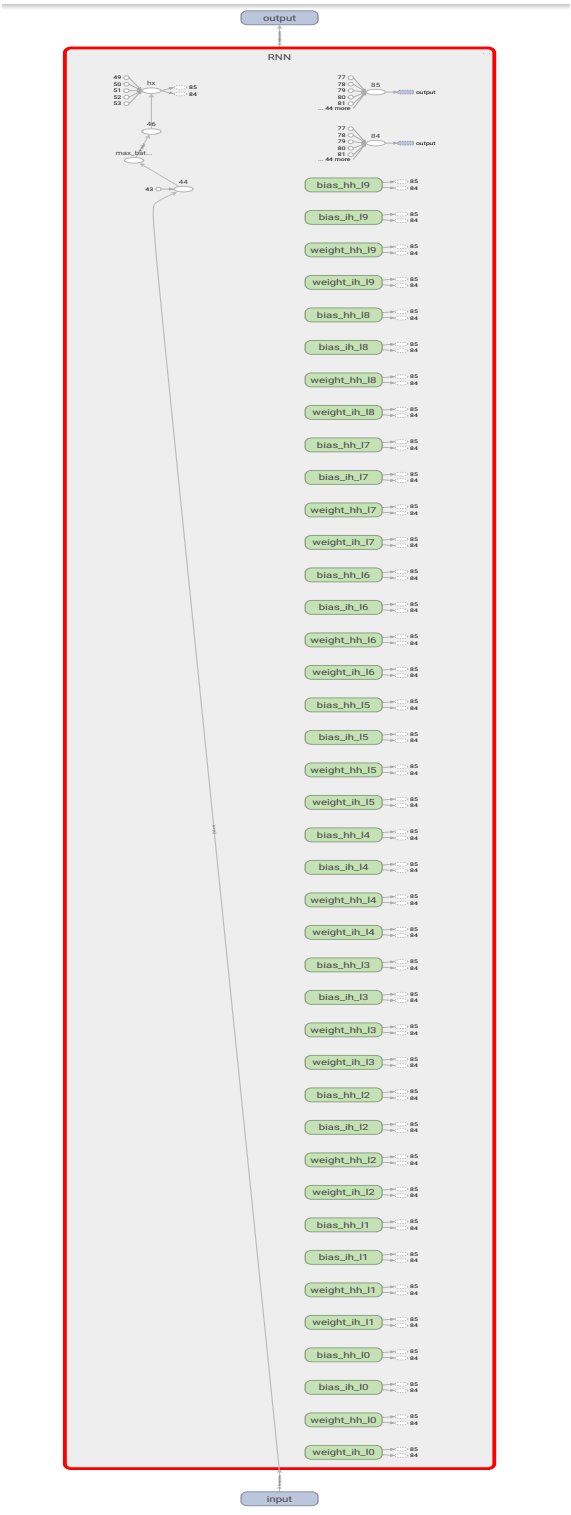

Figure 4: Computing graph of RNN

The structure of LSTM:

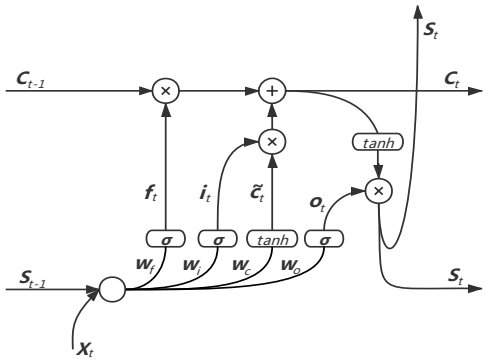

Figure 5: Long Short Term Memory Network

The computing graph of LSTM:

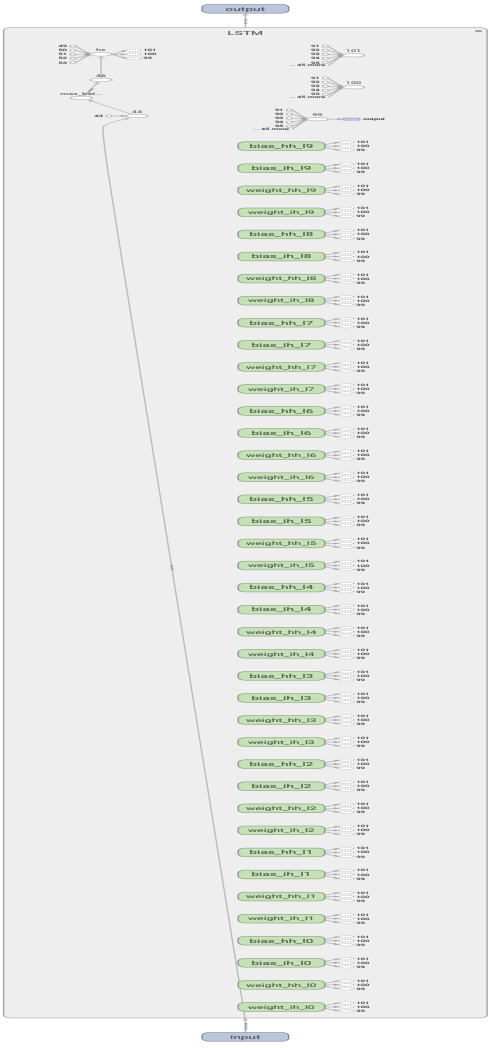

Figure 6: Computing graph of LSTM

The structure of GRU:

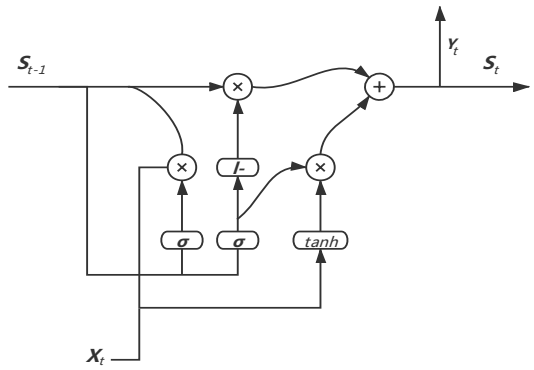

Figure 7: Gated Recurrent Unit

The computing graph of GRU:

Figure 8: Computing graph of GRU

The structure of CNN:

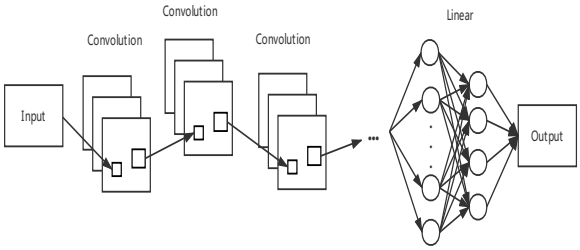

Figure 9: Convolution Neural Network

The computing graph of CNN:

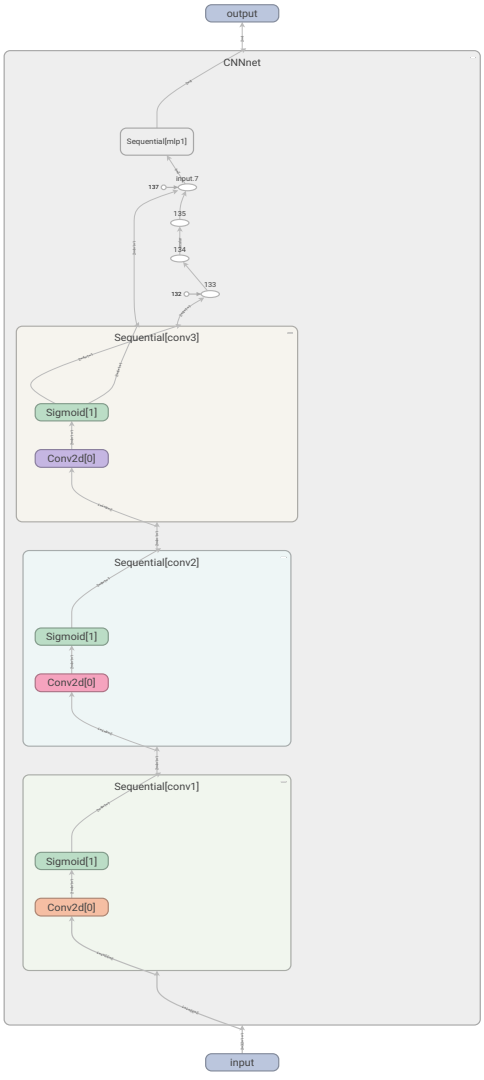

Figure 10: Computing graph of CNN

B
Equations for training the neural network

These equations are math formulas used for different neural networks (Facebook 2017).

B.1 FDNN

Apply affine transformation for input dataset:

$$y = xW^T + b \tag{1}$$

x represents the input dataset, and W represents a matrix consists of weights.

B.2 RNN

RNN performs the following transformations on each element in the neural network in sequence:

$$h_t = \tanh\left(W_{ih}x_t + b_{ih} + W_{hh}h_{(t-1)} + b_{hh}\right) \tag{2}$$

h_t means hidden state at time t, x_t means input dataset at time t, and h_{t-1} means hidden state at time $t-1$.

B.3 LSTM

For a LSTM neural network, every layer in this model will be transformed and calculated in these processes:

$$\begin{aligned}
i_t &= \sigma\left(W_{ii}x_t + b_{ii} + W_{hi}h_{t-1} + b_{hi}\right) \\
f_t &= \sigma\left(W_{if}x_t + b_{if} + W_{hf}h_{t-1} + b_{hf}\right) \\
g_t &= \tanh\left(W_{ig}x_t + b_{ig} + W_{hg}h_{t-1} + b_{hg}\right) \\
o_t &= \sigma\left(W_{io}x_t + b_{io} + W_{ho}h_{t-1} + b_{ho}\right) \\
c_t &= f_t \odot c_{t-1} + i_t \odot g_t \\
h_t &= o_t \odot \tanh\left(c_t\right)
\end{aligned} \tag{3}$$

H_t is the hidden state at time t, c_t is the cell state at time t, x_t is the input dataset at time t, h_{t-1} is the hidden state at time $t-1$. i_t is the input gate of time t, f_t is the forget gate at time t, g_t is the cell gate at time t, and o_t is the output gate of time t.

B.4 GRU

For a GRU neural network, the data of each layer will be calculated in the following order:

$$\begin{aligned}
r_t &= \sigma\left(W_{ir}x_t + b_{ir} + W_{hr}h_{(t-1)} + b_{hr}\right) \\
z_t &= \sigma\left(W_{iz}x_t + b_{iz} + W_{hz}h_{(t-1)} + b_{hz}\right) \\
n_t &= \tanh\left(W_{in}x_t + b_{in} + r_t * \left(W_{hn}h_{(t-1)} + b_{hn}\right)\right) \\
h_t &= (1 - z_t) * n_t + z_t * h_{(t-1)}
\end{aligned} \tag{4}$$

h_t means hidden state at time t, x_t means input dataset at time t and h_{t-1} means hidden state at time $t-1$. r_t means reset gate, z_t means update gate and n_t means new gate.

B.5 CNN

A one-dimensional convolutional neural network is used to process input data. The transformation and calculation method can be expressed as:

$$\text{out}\left(N_i, C_{\text{out}_j}\right) = \text{bias}\left(C_{\text{out}_j}\right) + \sum_{k=0}^{C_{in}-1} \text{weight}\left(C_{\text{out}_j}, k\right) \star \text{input}\left(N_i, k\right) \tag{5}$$

The operator $\star$ represents the cross-correlation operator. Its relation with convolution is $f(t) \star g(t) = \overline{f(-t)} * g(t)$. N_i means batch size, C means the number of channels, and L means the length of signal sequence.

C
Result for scheduling problem

For the problem mentioned in the paper, the forecast result of 30 days can be represented by the graph shown below.

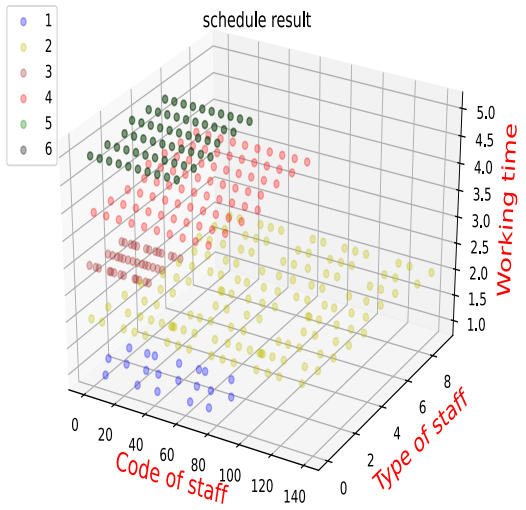

Figure 11: Scheduling result for arrangement

For the more complex problems, the forecast result of 30 days can be represented by the graph shown below.

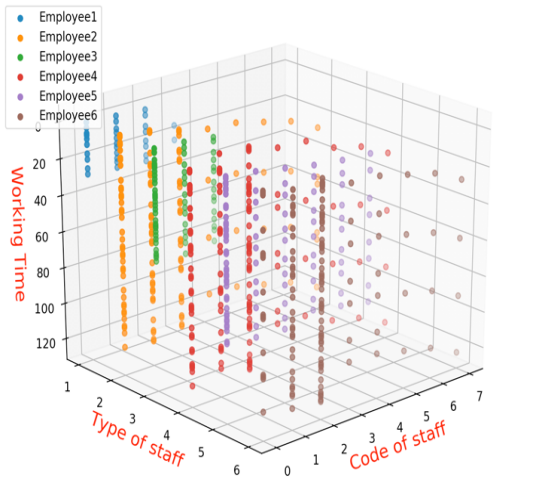

Figure 12: Scheduling result for arrangement