Basics of deep learning and neural networks

Autumn 2020

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##                           ##
##  Deep Learning in Python  ##
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§1 Introduction to Deep Learning in Python
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§1.1 Basics of deep learning and neural networks
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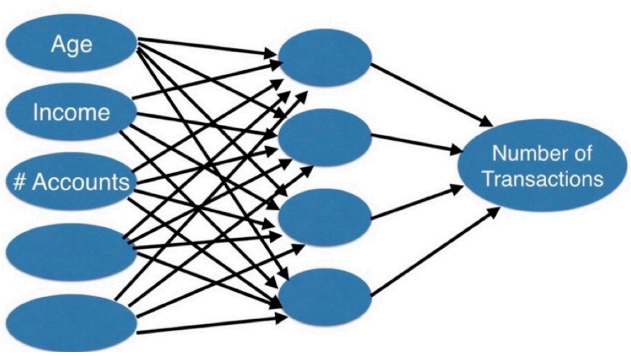
1 Introduction to deep learning

1. What is the value of interactions for neural networks?

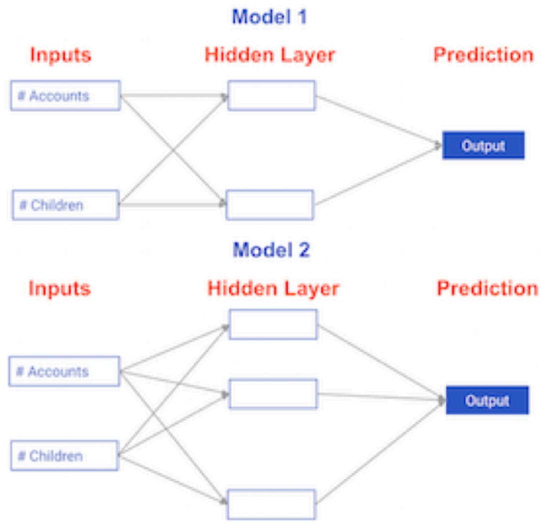
Deep learning uses especially powerful neural networks with almost anything such as *text*, *images*, *videos*, *audio*, or *source code* because neural networks really well account for interactions.

2. How do interactions work in neural networks?



3. Practice question for comparing neural network models to classical regression models:

- Which of the models in the diagrams has greater ability to account for interactions?



☐ Model 1.

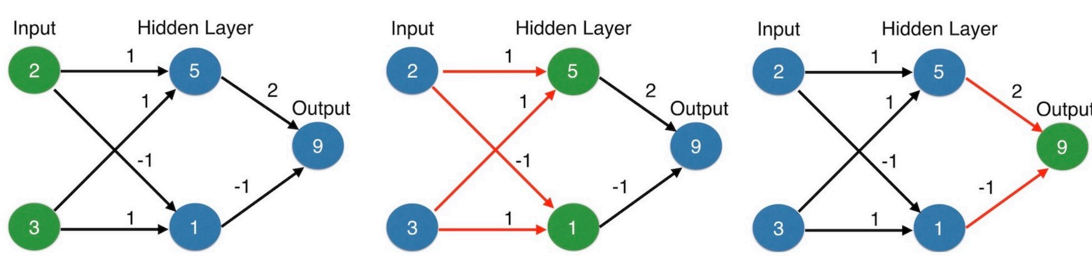
☒ Model 2.

☐ They are both the same.

2 Forward propagation

1. How does the forward propagation function?

- Multiply - add process.
- Dot product.
- Forward propagation is for one data point at a time.
- The output is the prediction for that data point.



2. Code of the forward propagation:

[1]:
```
import numpy as np

input_data = np.array([2, 3])
weights = {
```

```
    'node_0': np.array([1, 1]),
    'node_1': np.array([-1, 1]),
    'output': np.array([2, -1])
}
node_0_value = (input_data * weights['node_0']).sum()
node_1_value = (input_data * weights['node_1']).sum()

hidden_layer_values = np.array([node_0_value, node_1_value])
print(hidden_layer_values)
```

```
[5 1]
```

[2]:
```
output = (hidden_layer_values * weights['output']).sum()
print(output)
```

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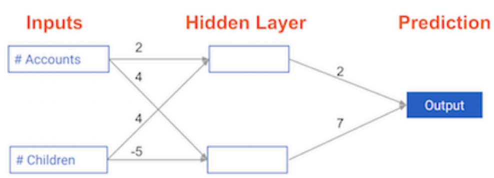
9
```

3. Practice exercises for the forward propagation:

▶ Diagram of the forward propagation:



▶ Data pre-loading:

[3]:
```
import numpy as np

input_data = np.array([3, 5])
weights = {
    'node_0': np.array([2, 4]),
    'node_1': np.array([4, -5]),
    'output': np.array([2, 7])
}
```

▶ The forward propagation algorithm practice:

[4]:
```
# Calculate node 0 value: node_0_value
node_0_value = (input_data * weights['node_0']).sum()

# Calculate node 1 value: node_1_value
node_1_value = (input_data * weights['node_1']).sum()

# Put node values into array: hidden_layer_outputs
hidden_layer_outputs = np.array([node_0_value, node_1_value])
```

```
# Calculate output: output
output = (hidden_layer_outputs * weights['output']).sum()

# Print output
print(output)
```

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-39
```
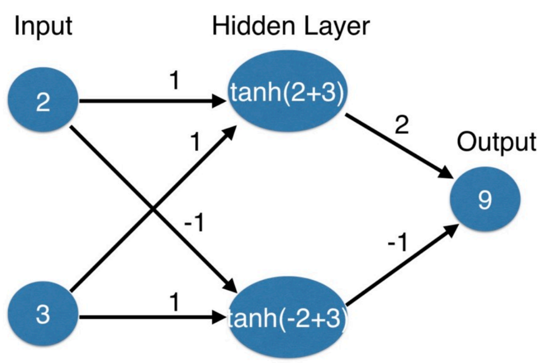
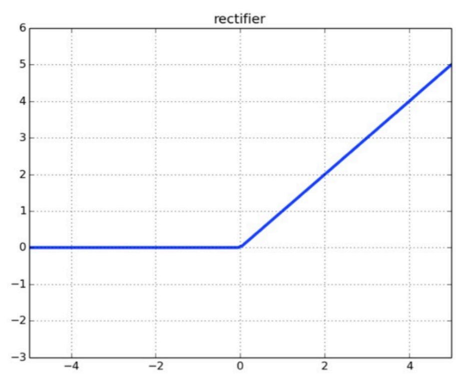

3 Activation functions

1. How do activation functions work?

It is applied to node inputs to produce node output.



2. What is the rectified linear activation (ReLU)?



$$RELU(x) = \begin{cases} 0 & if \quad x < 0 \\ x & if \quad x \geq 0 \end{cases}$$

3. Code of activation functions:

[5]:
```python
import numpy as np

input_data = np.array([-1, 2])
weights = {
    'node_0': np.array([3, 3]),
    'node_1': np.array([1, 5]),
    'output': np.array([2, -1])
}
node_0_input = (input_data * weights['node_0']).sum()
node_0_output = np.tanh(node_0_input)
node_1_input = (input_data * weights['node_1']).sum()
node_1_output = np.tanh(node_1_input)
hidden_layer_outputs = np.array([node_0_output, node_1_output])
output = (hidden_layer_outputs * weights['output']).sum()

print(output)
```

```
0.9901095378334199
```

4. Practice exercises for activation functions:

▶ Data pre-loading:

[6]:
```python
import numpy as np

input_data = np.array([3, 5])

weights = {
    'node_0': np.array([2, 4]),
    'node_1': np.array([4, -5]),
    'output': np.array([2, 7])
}
```

▶ The rectified linear activation function practice:

[7]:
```python
def relu(input):
    '''Define your relu activation function here'''
    # Calculate the value for the output of the relu function: output
    output = max(0, input)

    # Return the value just calculated
    return (output)


# Calculate node 0 value: node_0_output
node_0_input = (input_data * weights['node_0']).sum()
node_0_output = relu(node_0_input)

# Calculate node 1 value: node_1_output
```

```
node_1_input = (input_data * weights['node_1']).sum()
node_1_output = relu(node_1_input)

# Put node values into array: hidden_layer_outputs
hidden_layer_outputs = np.array([node_0_output, node_1_output])

# Calculate model output (do not apply relu)
model_output = (hidden_layer_outputs * weights['output']).sum()

# Print model output
print(model_output)
```

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▶ **Data re-pre-loading:**

[8]:
```
input_data = [
    np.array([3, 5]),
    np.array([1, -1]),
    np.array([0, 0]),
    np.array([8, 4])
]
```

▶ **Network to many observations/rows of data applying practice:**

[9]:
```
# Define predict_with_network()
def predict_with_network(input_data_row, weights):

    # Calculate node 0 value
    node_0_input = (input_data_row * weights['node_0']).sum()
    node_0_output = relu(node_0_input)

    # Calculate node 1 value
    node_1_input = (input_data_row * weights['node_1']).sum()
    node_1_output = relu(node_1_input)

    # Put node values into array: hidden_layer_outputs
    hidden_layer_outputs = np.array([node_0_output, node_1_output])

    # Calculate model output
    input_to_final_layer = (hidden_layer_outputs * weights['output']).sum()
    model_output = relu(input_to_final_layer)

    # Return model output
    return (model_output)


# Create empty list to store prediction results
```

```python
results = []
for input_data_row in input_data:
    # Append prediction to results
    results.append(predict_with_network(input_data_row, weights))

# Print results
print(results)
```

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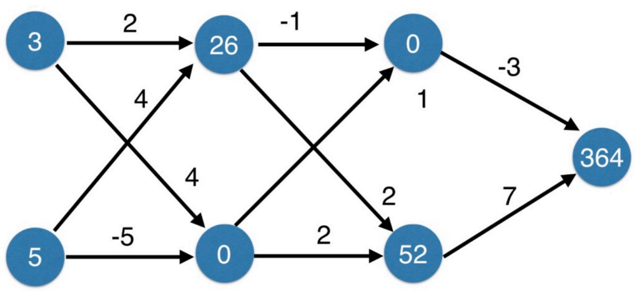
[52, 63, 0, 148]
```

4 Deeper networks

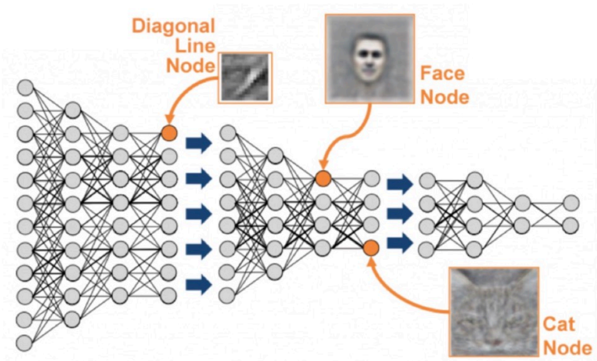
1. How do multiple hidden layers function?



Calculate with ReLU Activation Function

2. Why is deep learning also sometimes called representation learning?

- Deep networks internally build representations of patterns in the data; in this way, partially replace the need for feature engineering.
- Subsequent layers build increasingly sophisticated representations of raw data.



3. How does the deep learning process?

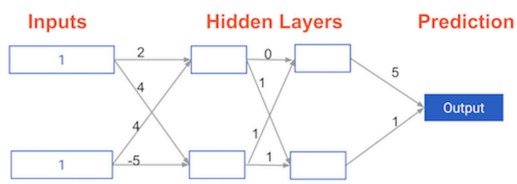
- The modeler doesn't need to specify the interactions.

- When training the model, the neural network gets weights that find the relevant patterns to make better predictions.

4. **Practice question for the forward propagation in a deeper network:**

- Ther is a model with two hidden layers. The values for an input data point are shown inside the input nodes. The weights are shown on the edges/lines. What prediction would this model make on this data point?

    Assume the activation function at each node is the *identity function*. That is, each node's output will be the same as its input. So the value of the bottom node in the first hidden layer is -1, and not 0, as it would be if the ReLU activation function was used.



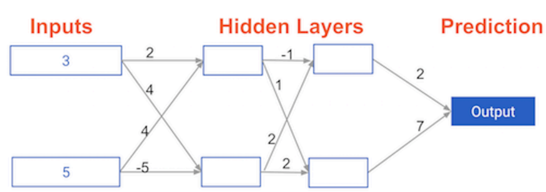
☒ 0.

☐ 7.

☐ 9.

5. **Practice exercises for deeper networks:**

▶ **Diagram of the forward propagation:**



▶ **Data pre-loading:**

[10]:
```
import numpy as np

input_data = np.array([3, 5])

weights = {
    'node_0_0': np.array([2, 4]),
    'node_0_1': np.array([4, -5]),
    'node_1_0': np.array([-1, 2]),
    'node_1_1': np.array([1, 2]),
    'output': np.array([2, 7])
}
```

```python
def relu(input):
    output = max(0, input)
    return (output)
```

▶ **Multi-layer neural networks practice:**

[11]:
```python
def predict_with_network(input_data):
    # Calculate node 0 in the first hidden layer
    node_0_0_input = (input_data * weights['node_0_0']).sum()
    node_0_0_output = relu(node_0_0_input)

    # Calculate node 1 in the first hidden layer
    node_0_1_input = (input_data * weights['node_0_1']).sum()
    node_0_1_output = relu(node_0_1_input)

    # Put node values into array: hidden_0_outputs
    hidden_0_outputs = np.array([node_0_0_output, node_0_1_output])

    # Calculate node 0 in the second hidden layer
    node_1_0_input = (hidden_0_outputs * weights['node_1_0']).sum()
    node_1_0_output = relu(node_1_0_input)

    # Calculate node 1 in the second hidden layer
    node_1_1_input = (hidden_0_outputs * weights['node_1_1']).sum()
    node_1_1_output = relu(node_1_1_input)

    # Put node values into array: hidden_1_outputs
    hidden_1_outputs = np.array([node_1_0_output, node_1_1_output])

    # Calculate model output: model_output
    model_output = (hidden_1_outputs * weights['output']).sum()

    # Return model_output
    return (model_output)


output = predict_with_network(input_data)
print(output)
```

```
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```

6. Practice question for learned representations:

- How are the weights that determine the features/interactions in Neural Networks created?

  ☐ A user chooses them when creating the model.

  ☒ The model training process sets them to optimize predictive accuracy.

☐ The weights are random numbers.

7. Practice question for levels of representation:

- Which layers of a model capture more complex or "higher level" interactions?

  ☐ The first layers capture the most complex interactions.

  ☒ The last layers capture the most complex interactions.

  ☐ All layers capture interactions of similar complexity.