Toward A Quantum Neural Network

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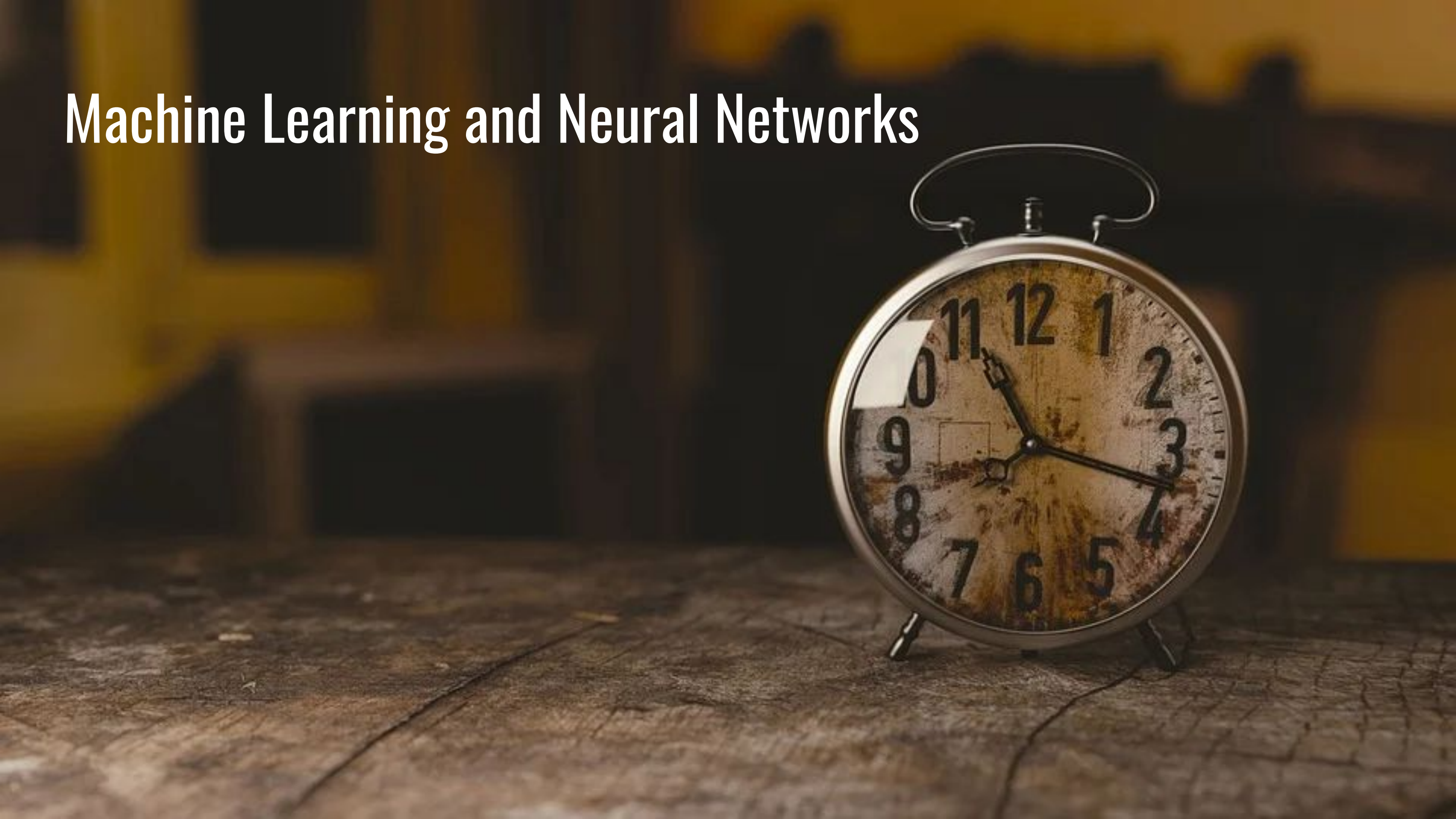
Machine Learning and Neural Networks



Machine Learning and Neural Networks

- In the 1950s Alan Turing argued that modern digital computing technology holds the promise for artificial intelligence

- Following Turing’s inspiration, the first algorithms that could demonstrate machine learning appeared in the latter half of the 20th century

Machine Learning and Neural Networks

Our Project

This project's goal is to take the next step in classical machine learning and implement a quantum neural network. In this report, we:

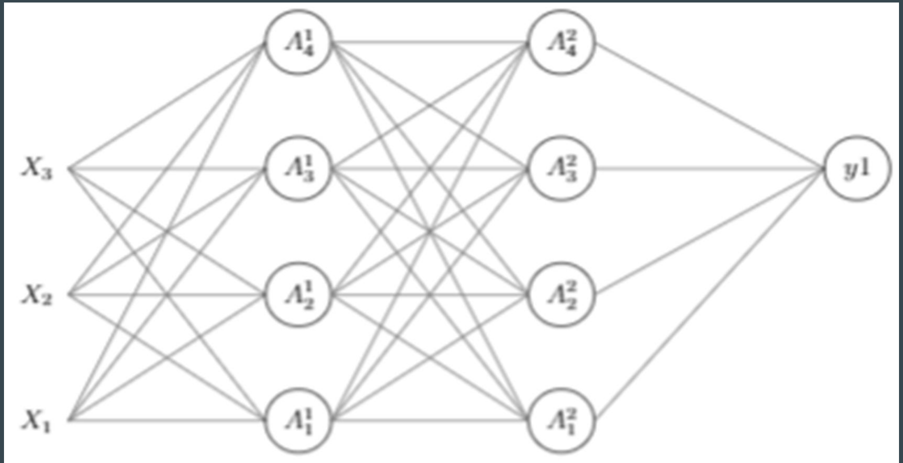
- Implement a practical example of a classical NN model
- Explore the time complexity of this NN model

And

- Discuss key differences between classical and quantum algorithms
- Explore ways to reduce time resources needed for a classical NN by employing quantum methods

Our Neural Network (Structure)

We implemented a classical NN code to diagnose pneumonia in a patient's x-ray image. The NN structure contains 3 layers: an input, hidden, and output layer. The figure on the right illustrates the architecture of this NN. The NN contains 3 input features: X_1, X_2,X_3.

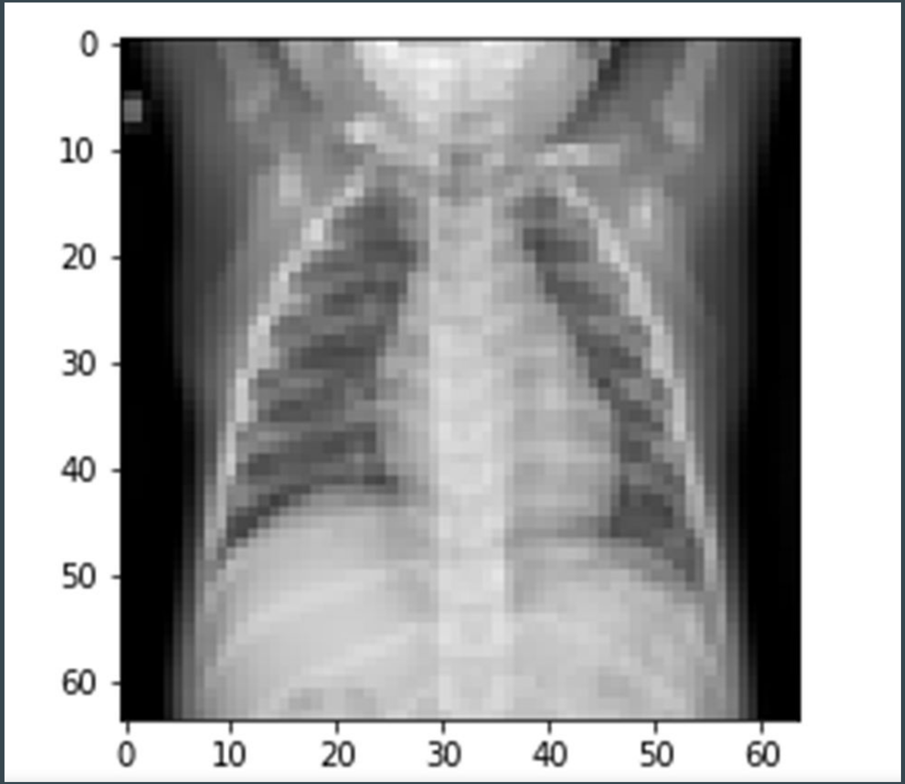


- In our implementation, each NN processes 12,288 input features (X_1,...., $X_{12,288}$)

Our Neural Network (Implementation)

Each NN used a ReLu function in the output node to predict whether a patient's x-rays presented symptoms of pneumonia:

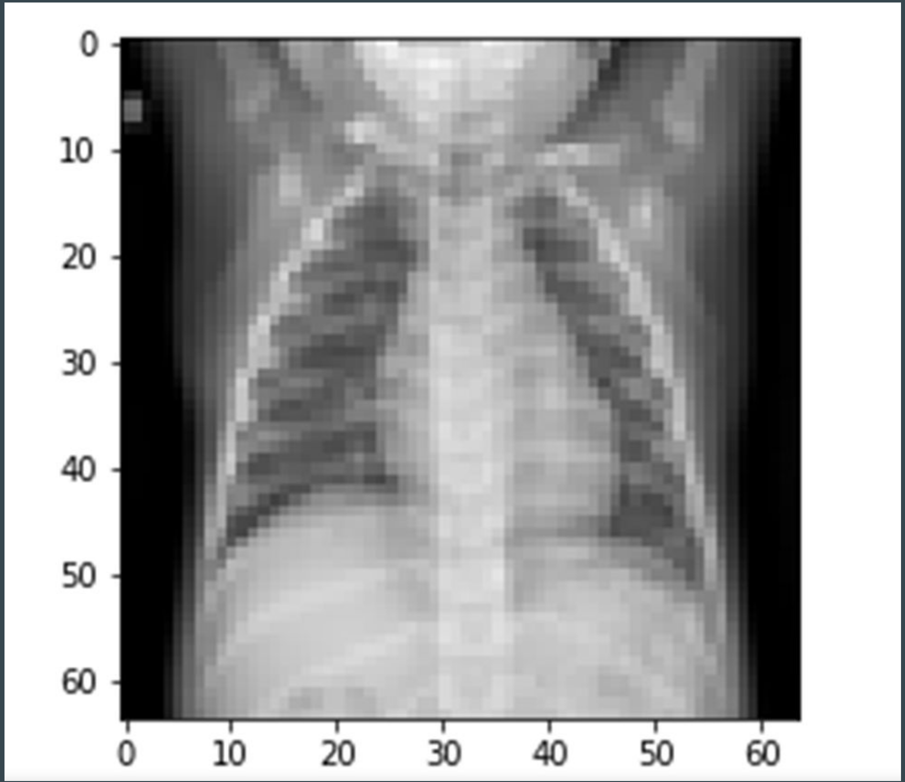
- These images contained a total of 12,288 input features (64x64 pixel resolution and 3 RGB values per pixel)



Our Neural Network (Purpose)

These NNs helped us:

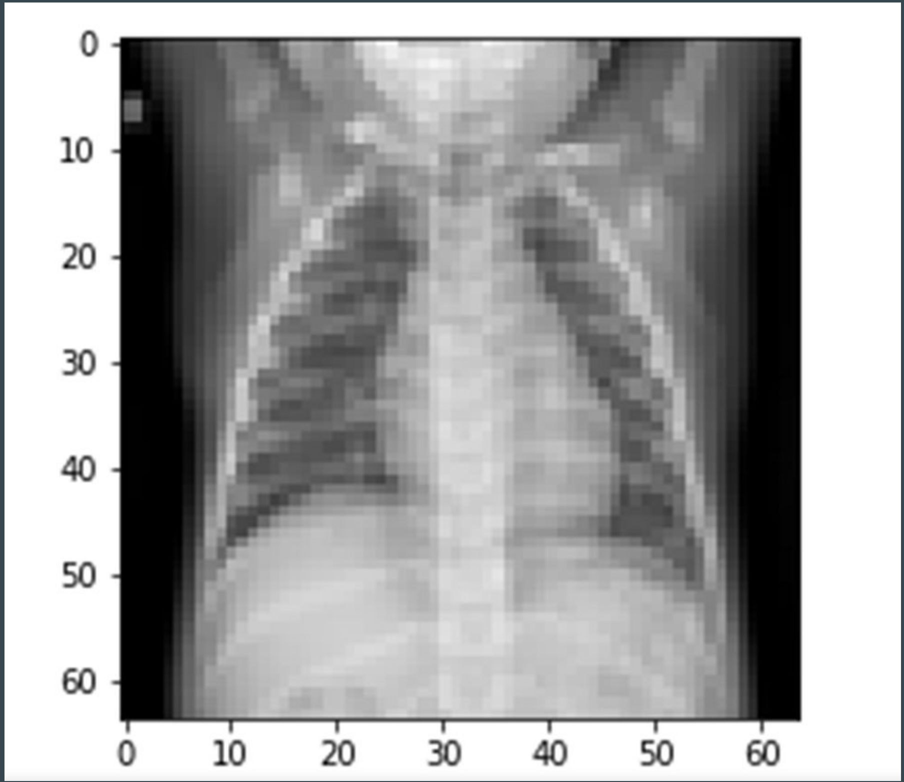
1. Understand how to train a classical neural network using Gradient Descent.
2. Evaluate the time it takes to train a NN using the method of Gradient Descent.



Our Neural Network (Results)

We trained 4 NN architectures with the following results:

- The most effective model was 79.3% accurate (using batch gradient descent)
- The average accuracy was 74%
- Each NN trained approximately 3800 images in 1 hour



Our Neural Network (Shortcomings)

We have demonstrated

- Classical NNs can require prodigious time resources to make a prediction

This is where Quantum Comes in...

- Encouraged by the success of the Shor and Grover algorithms, quantum algorithms hold promise for application in NNs
- What does this imply for NNs?

Algorithm	Time Complexity
Gradient Descent	O(k)
Updating Gradients	O(j)
Updating Parameters	O(h)

$$O(k)(O(j) + O(h)) = O(k)(O(j + h)) = O(k)O(2j) = O(k2j)$$

Pictured Above: Time Complexity of the back-propagation process

Toward a Quantum Neural Network

- In comparison to classical computers, quantum computers are known for dramatic enhancements in optimization problems
- We propose to take advantage of quantum mechanics' "massive parallelization" and interference properties to shorten the time it takes for a NN to "learn"
- This proposed algorithm would ideally:
  - Serve as a replacement to Gradient Descent, a classical algorithm
  - Compute the same X-ray images in a shorter time frame
  - Underscore the advantages of quantum-based methods
- Further research is needed to implement these ideas

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