Check-In Code:

vision

Intro to CV: PyTorch and MLP

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today's agenda

1. **Overview**
   Computer Vision & MNIST
2. **General (Supervised) Machine Learning Problems**
   How do we formulate and approach a machine learning problem?
3. **Introduction to PyTorch**
   Tensors, Gradients, Autograd, Linear Algebra
4. **Multilayer Perceptron**
   Applying what we've learned

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Overview

Introduction to Computer Vision and MNIST

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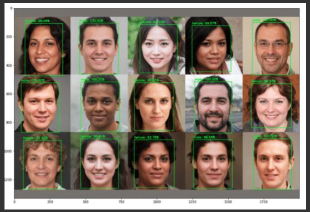
What is Computer Vision?

Definition:

- Computer Vision is a field of AI that enables computers and systems to derive meaningful information from digital images, vidoes, and other visual inputs - and take actions or make recommendations based on that information.

Applications:

- Autonomous Vehicles
- Facial Recognition
- Medical Imaging
- Virtual Reality
- Security
- Robotics



Today, we're talking about the tools (PyTorch) needed for CV and building towards Neural Networks (the foundations of CV)

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General ML Problems

Formulating a (supervised) ML problem

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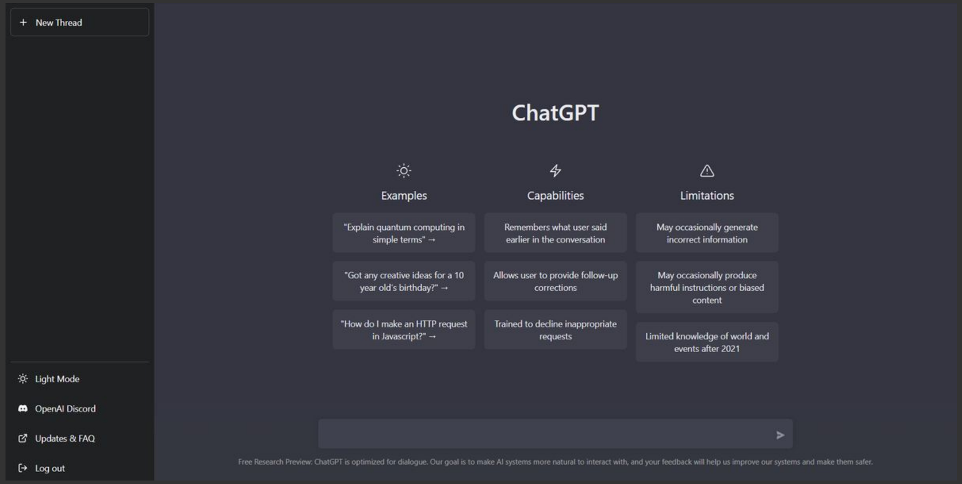
General Machine Learning Problems

- In general, ML can be applied to many different situations, and their formulations are broad and varied
- From decision-making (such as in playing chess) to holding conversations (chatbots)



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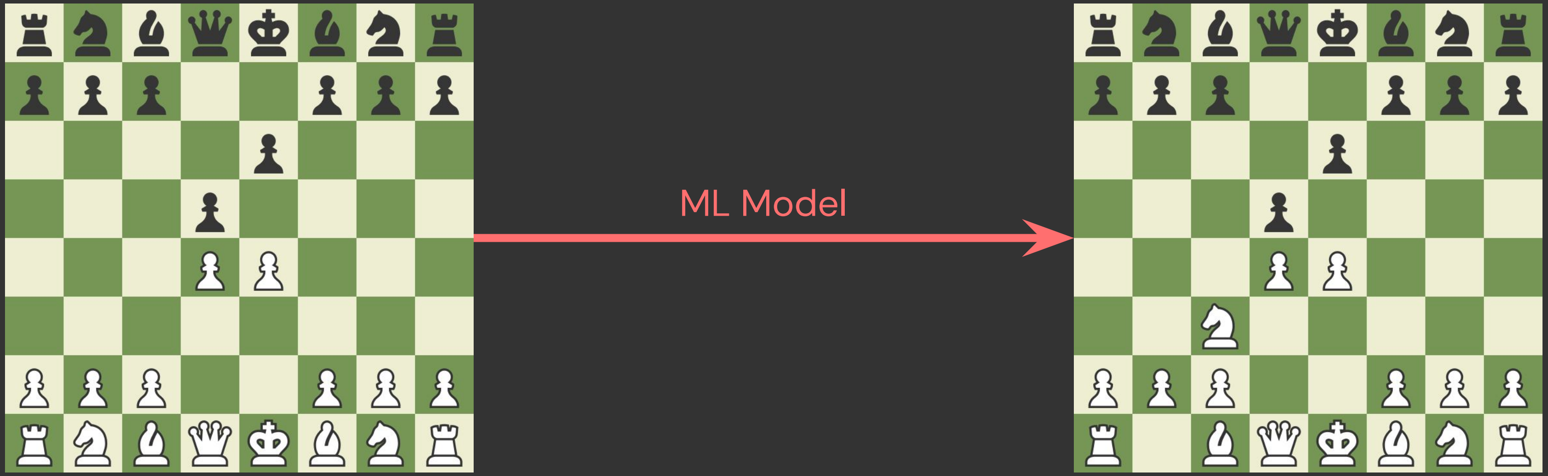
At the core it’s about designing a function mapping input to a desired output.



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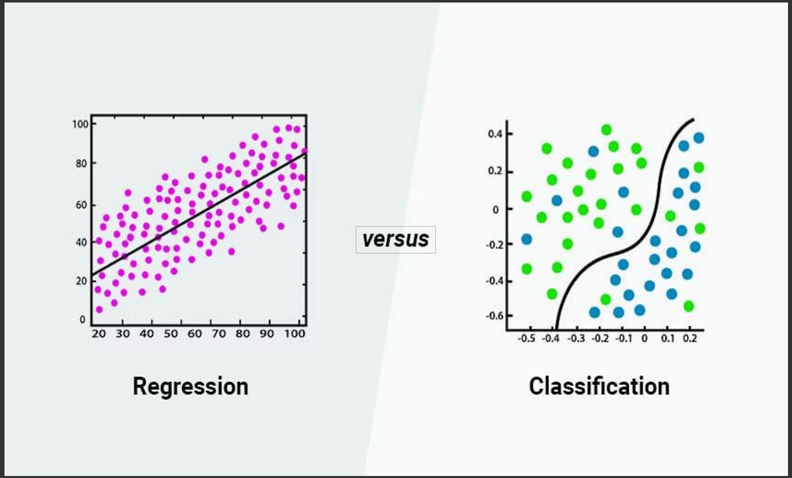
Basic Formulations: Regression vs Classification

Machine Learning

- Using data to train a model to make predictions
- Mathematically, this core process of predictive modeling is called function approximation
    - Approximating a mapping function (f) from input variables (x) to output variables (y)
    - The mapping function predicts the category/labels for a given observation.
    - The biggest difference between regression and classification is regression outputs a continuous variable while classification outputs a discrete variable



Regression

- Ex. Predicting the price a house will set for
- Predicts a continuous quantity

Classification

- Ex. Email being classified as ‘spam’ or ‘not spam’
- Predicts a discrete class label

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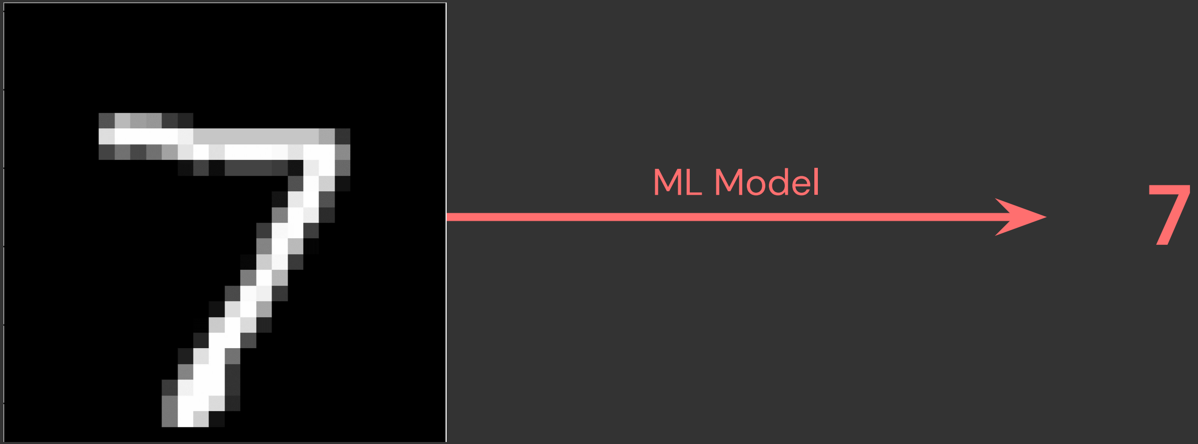
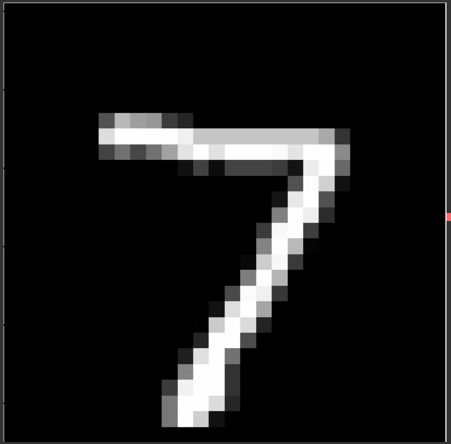

ML Model
7



28x28

ML Model

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10 possible labels

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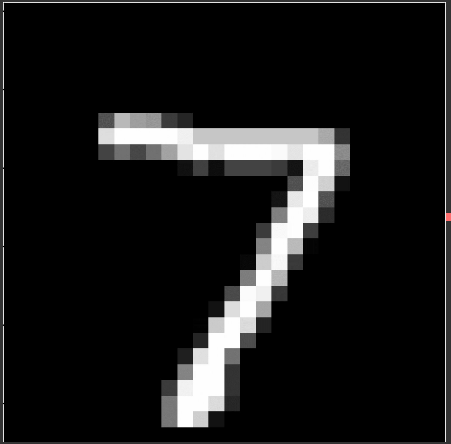

784 x 1

ML Model

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10 possible labels

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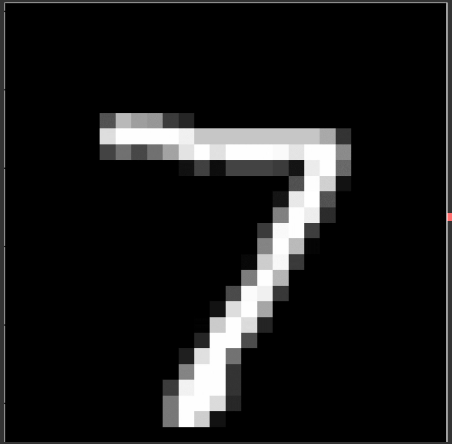

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Intro to Pytorch

Tensors, Gradients, Autograd, Linear Algebra

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Introduction to PyTorch – Tensors

Tensors

- A data structure (equivalent to a multidimensional array i.e. matrix) to store numeric values.
  - Default data structure for neural networks
- Tensor attributes
  - torch.dtype - species type of data in tensors
  - torch.device - specifies where tensor computations are performed, either CPU or GPU
  - torch.layout - species how tensors are stored in memory
- Tensor Operations
  - There's 100s of operations including arithmetic, linear algebra, matrix manipulation, etc.
  - Similar to NumPy
- CPU v. GPU
  - Default, tensors are ran on the CPU. You can switch to GPU for faster processing (but it's more taxing on the memory for larger tensors)

```
data = [[1, 2],[3, 4]]
x_data = torch.tensor(data)
```

```
np_array = np.array(data)
x_np = torch.from_numpy(np_array)
```

```
tensor = torch.rand(3,4)

print(f"Shape of tensor: {tensor.shape}")
print(f"Datatype of tensor: {tensor.dtype}")
print(f"Device tensor is stored on: {tensor.device}")
```

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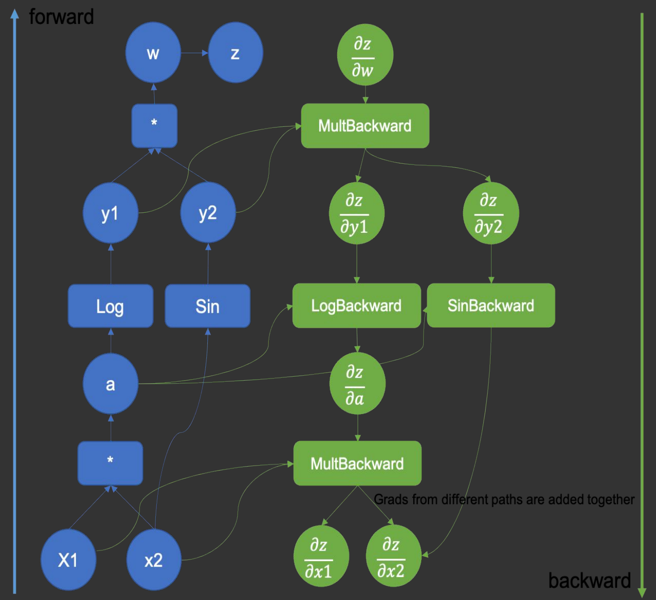
Introduction to PyTorch – Gradients and Autograd

Neural Network Training

- Composed of 5 essential steps: defining architecture, forward propagation, calculating loss, **backward propagation**, and updating weights using learning rate
- Gradients and Autograd are essential to backward propagation



Gradients

- Used to find the derivatives of the function
- Used to update the weight using a learning rate to reduce the loss and train the neural network.

Autograd

- torch.autograd
  - a differentiation engine (calculates derivatives, specifically vector-Jacobian product) that allows for the computation in backpropagation
  - Simple terms, it computes partial derivatives while applying the chain rule

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Neural Networks

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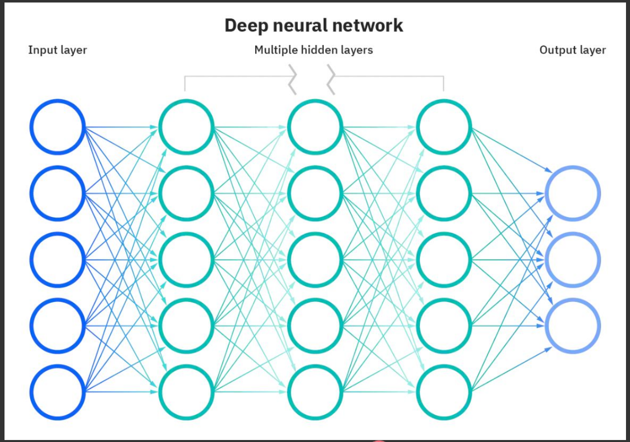
Neural Networks: Definition

Definition

- Mimics the brain through a set of algorithms
- A neural network is comprised of 4 main components: inputs, weights, a bias, and output
- Expressive nonlinear function approximators
  - Given an arbitrary number of "neurons", neural networks can approximate any function
  - Introduce nonlinearities through activation functions

$$\sum_{i=1}^{m} w_i x_i + bias = w_1 x_1 + w_2 x_2 + w_3 x_3 + bias$$

- Deep Learning: a subset of ML techniques based on multiple layers of neural networks



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How can we get computers to identify objects in images?

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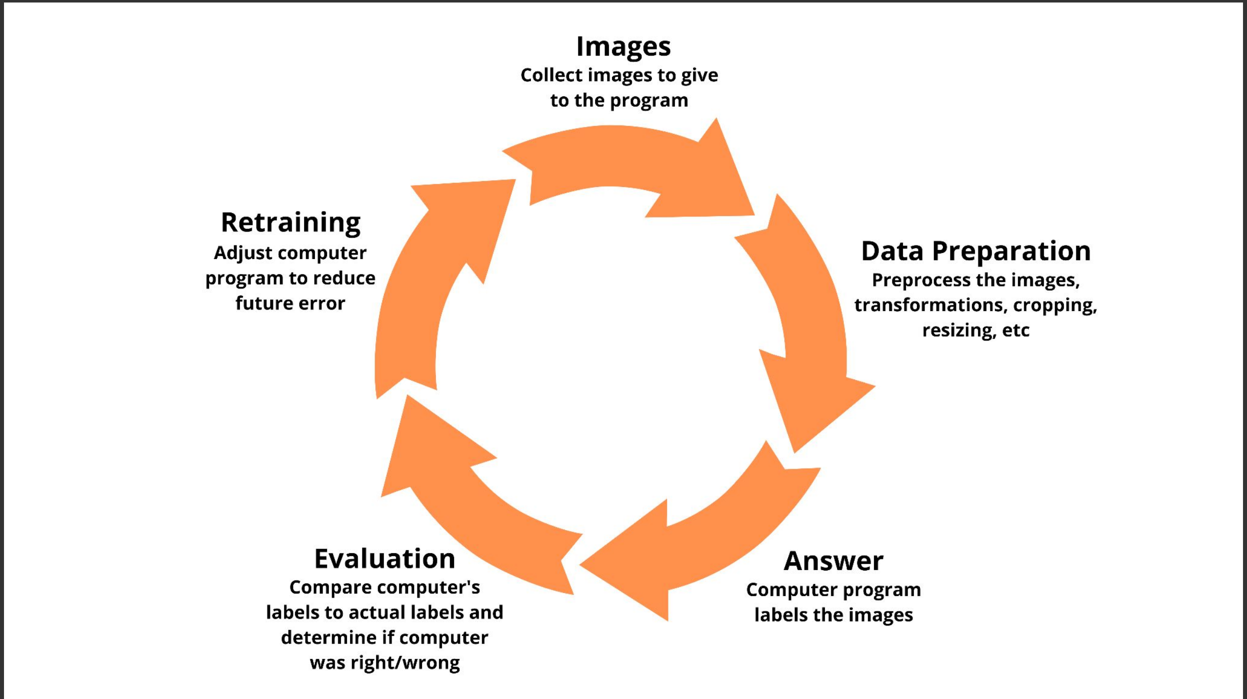
The Idea



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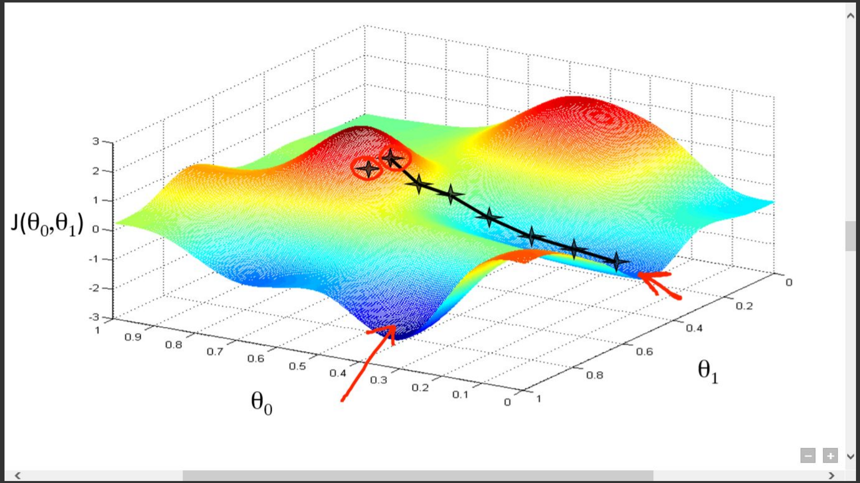
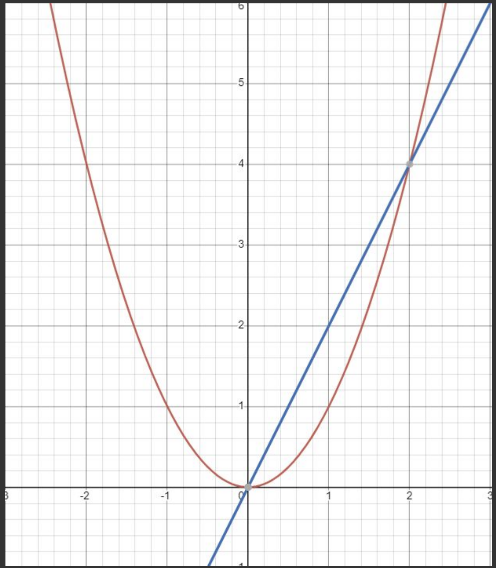
Gradient Descent

- Model how wrong our neural network is as a differentiable function
- Gradient - multidimensional idea of derivative
    - Direction of furthest increase: negative gradient is direction of furthest decrease
- We map out the loss as a function of our neural network weights, and adjust weights to decrease error, or “loss”





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Loss Functions

- We need a method of evaluating how correct/wrong a given answer is
- We apply a softmax function to predict probabilities
- A method of evaluating how well specific algorithms models the given data
    - Large loss function = predictions deviate too far from the results
    - Using optimization functions, loss functions learns to reduce the error in prediction

Categorical Cross Entropy

- Measures the difference between 2 probability distributions
    - In our case, we have 2: the current neural network distribution and the correct one
- Also differentiable

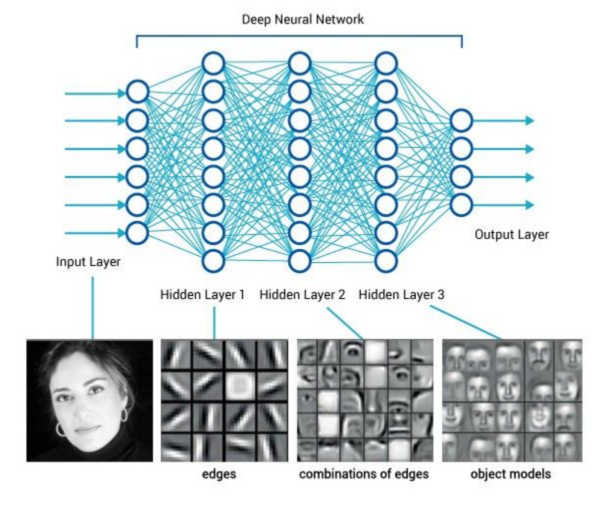
Neural Networks: Computer Vision

Why Neural Networks (Deep Learning) and not classic ML?

- Classic ML is more dependent on human intervention to manually determine a hierarchy of features (we need to label the dataset)
- Requires structured data
- Deep Learning w/neural networks don't! You can input in an unstructured dataset and have it give you the set of features that distinguish each object (very useful for more complex cases)

Why Neural Networks for Computer Vision

- Traditionally, researchers had to train the computer to look for specific features in various images (top down approach).
- With a neural network approach, the deep learning algorithms trains itself to analyze the features in the image (bottom up approach)
- Thus, instead of having to tell the computer "what **should** be there," neural networks allow the computer to identify "what's there."



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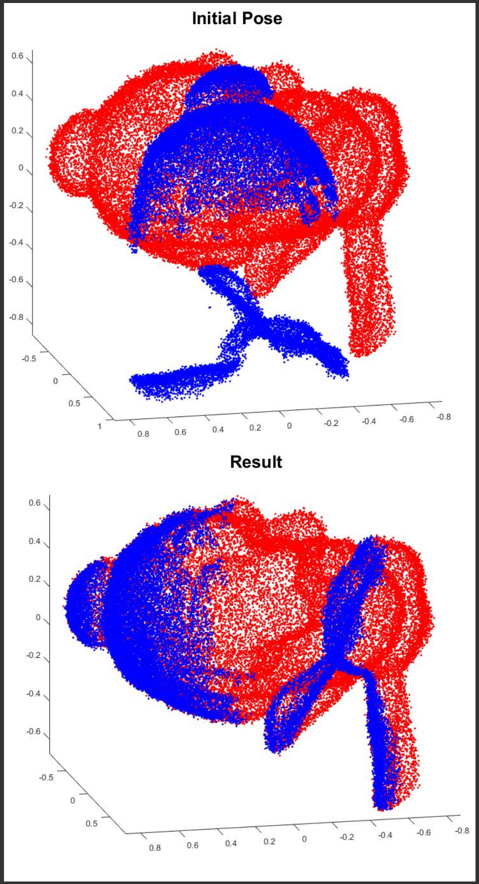
Neural networks are not everything.

Neural Networks – Intuitions

- Neural networks are very popular for recognition tasks in computer vision/all the rage right now
- But they're still lacking in other areas - many 3D computer vision tasks require a mix of classical and deep ML
- Neural networks can be used as black boxes but they don't substitute for intent in approaching a problem

When are neural networks good?

- Essentially a nearest neighbors in the feature space
- Good for dimension reduction
- When euclidean distance represents semantic similarity



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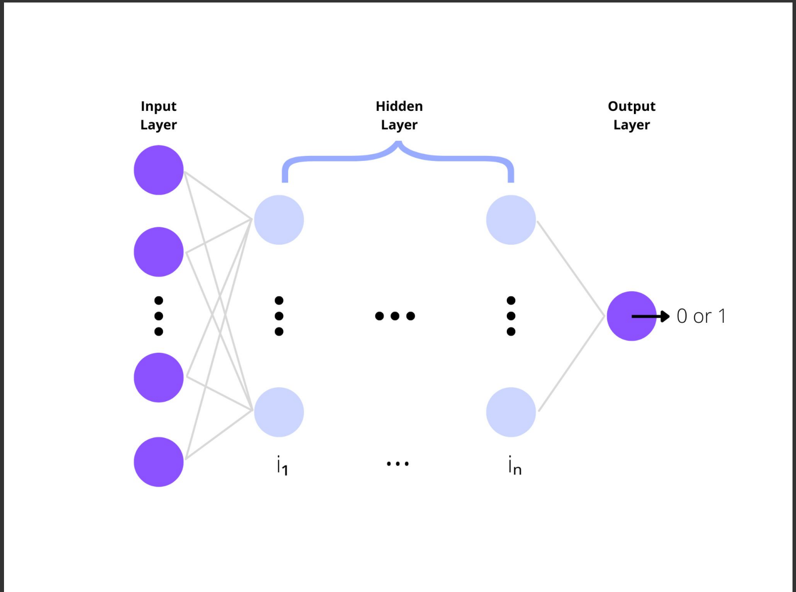
Multilayer Perceptron

Definition

- A fully connected class of feedforward neural networks
- Neural networks with at least three layers
- These three layers are input layer, hidden layer, and output layer

Let's learn how to make one!



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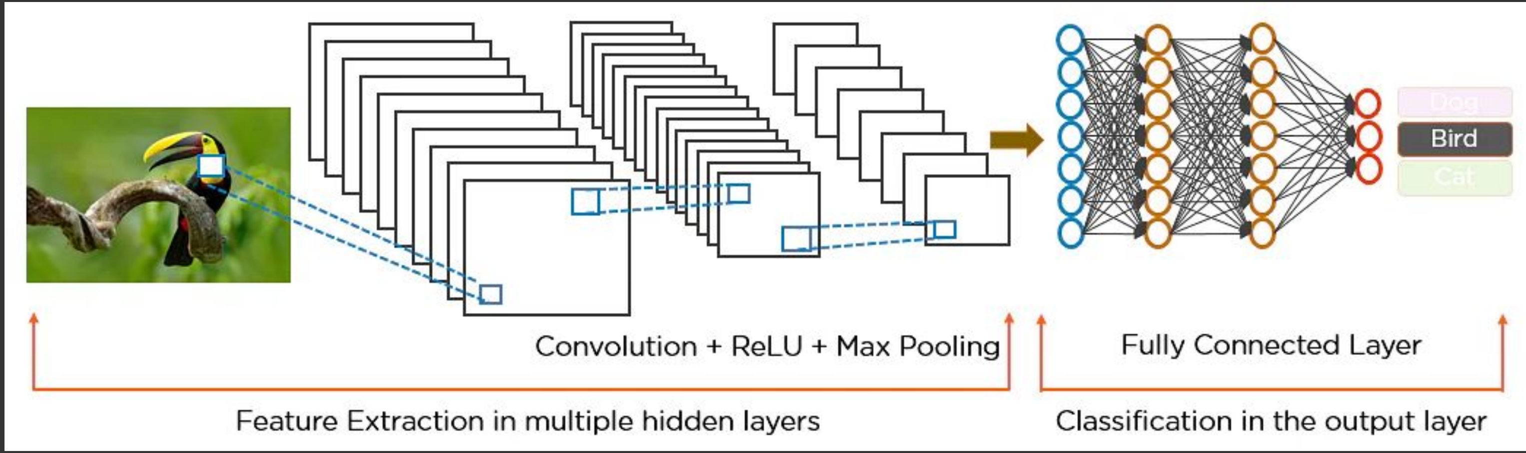
Neural Networks and CNN: Brief Overview

Neural Network Architectures in Computer Vision

- Convolutional Neural Networks (foundation for modern CV).
- Gets an image, designates it some weightage based on different objects of the image, and then distinguishes from each other
- **More on this in Workshop 2!**



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Intro to AI: Reinforcement Learning

Check-in code: reinforce