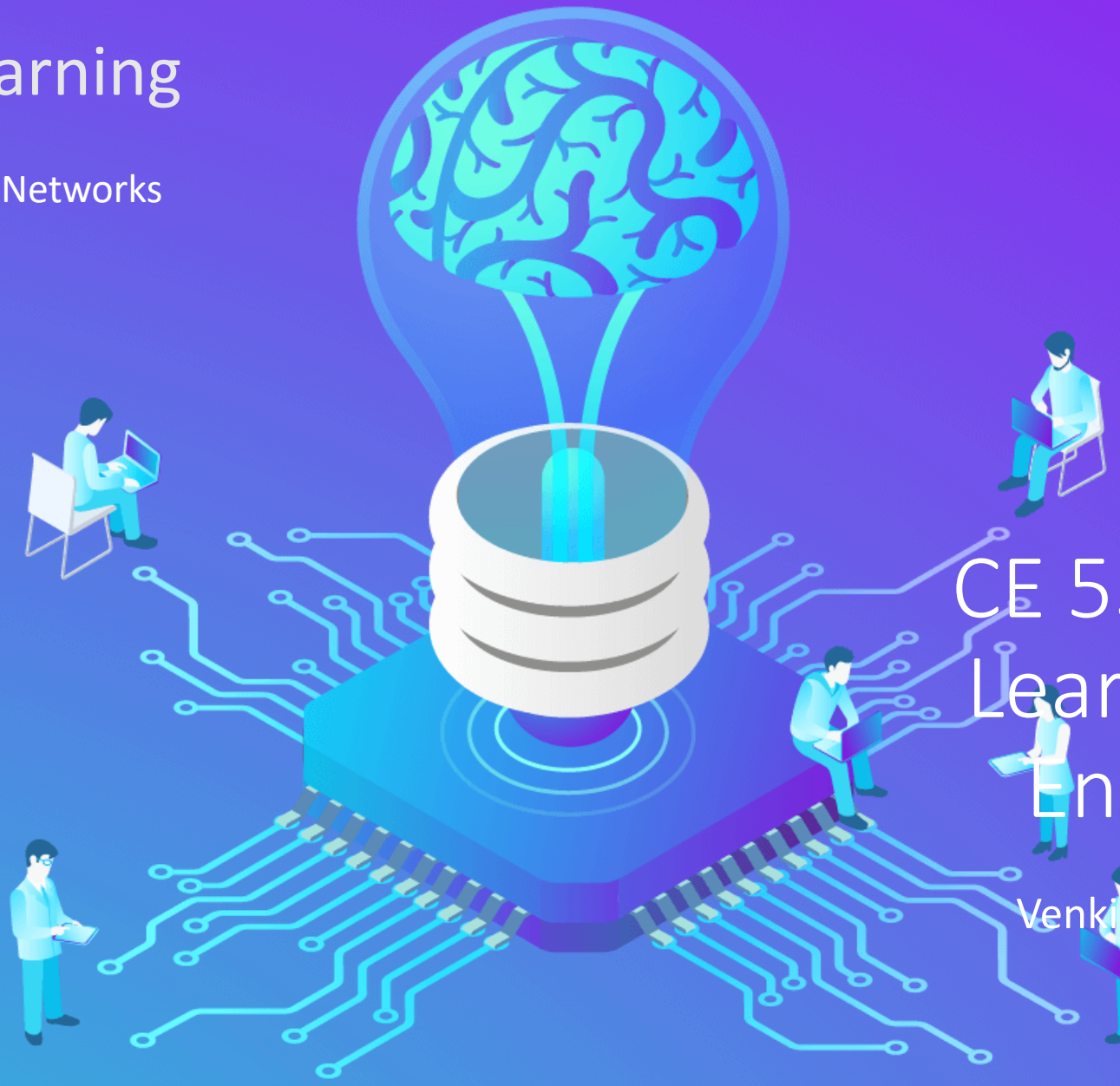
Machine Learning

Convolution Neural Networks



CE 5331 Machine Learning for Civil Engineers

Venki Uddameri, Ph.D. , P.E.

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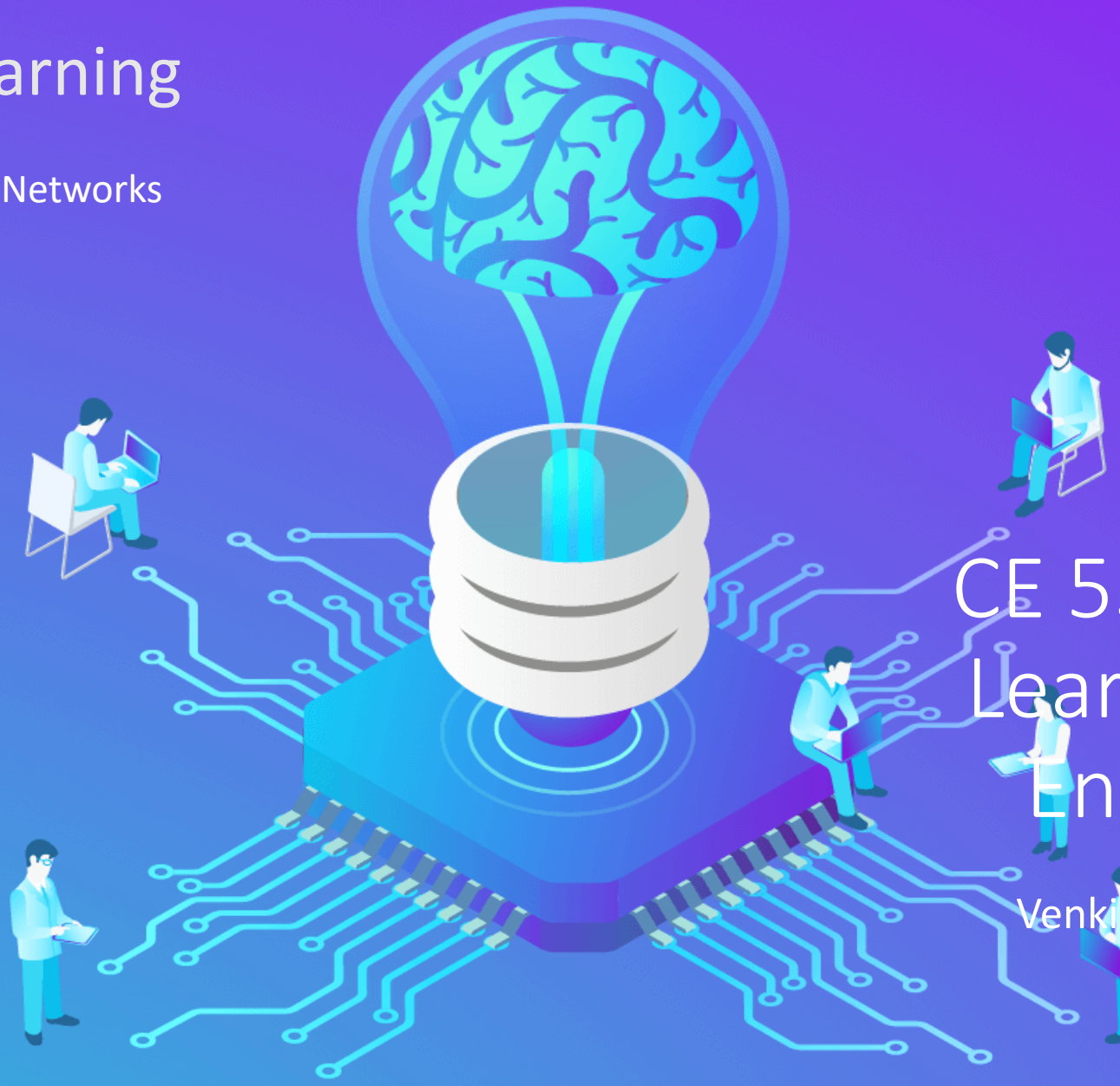

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Recap

- What is Machine Learning
- How is it useful for Civil Engineers
- Overview of Machine Learning Methods
- Linear Regression
  - Bivariate
  - Regression interpretation
  - Multivariate
- Logistic Regression
  - Maximum likelihood estimation
  - Regularization (introduction)
- Naïve Bayesian Classifier
  - What is it
  - What makes it naïve
  - Bayes theorem
  - Prior, likelihood and posterior
- K-Nearest Neighbor
  - How does the algorithm work
  - Why is it a lazy learner
  - How to do regression and classification
- Introduction to Decision Trees
  - Fundamentals
  - Information Gain, Entropy and Gini Index
  - ID3 algorithm
  - Classification and Regression Trees (CART)
  - Multi-Adaptive Regression Splines (MARS)

- Ensemble learners
  - Introduction
- Their benefits and drawbacks
- Simple (voting) ensemble learners
- Bagging and Pasting
- Generic bagging classifiers
- Random Forest classifiers
- Bagging Classifier
- Unsupervised Learnng
  - KNN

Perceptrons
Multilayer Perceptrons
Deep Neural Networks
Time-series modeling
LSTM amd GRU
Image Processing Basics

Python – Introduction
Python – Functions
Python - Pandas
Python – np, scipy, statsmodels
Python – Scikit learn – linear, metrics
Python – Matplotlib, seaborn
Python – Mixed_Naive_Bayes
Python – scikit learn neighbors module
Python – scikit learn ensemble voting
Python – scikit learn bagging classifier
Python – scikit learn RandomForestClassifer

R – Classification and Regression Trees using rpart
R – Drawing trees using rpart.plot
R - Multiadaptive Regression Splines (MARS) using Earth Algorithm

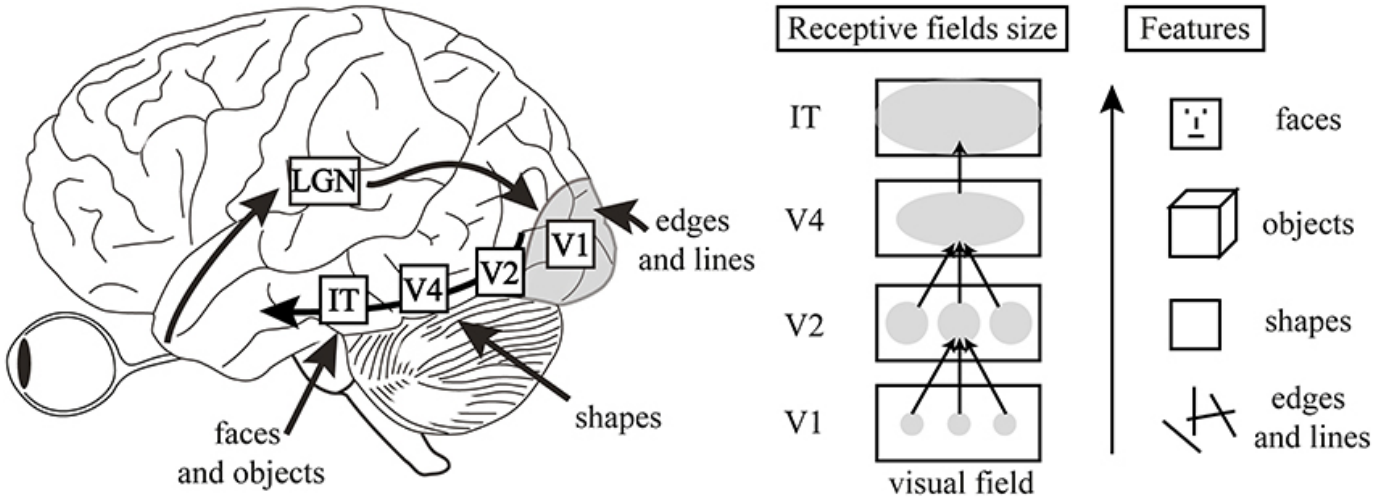
Convolution Neural Networks

What are CNNs

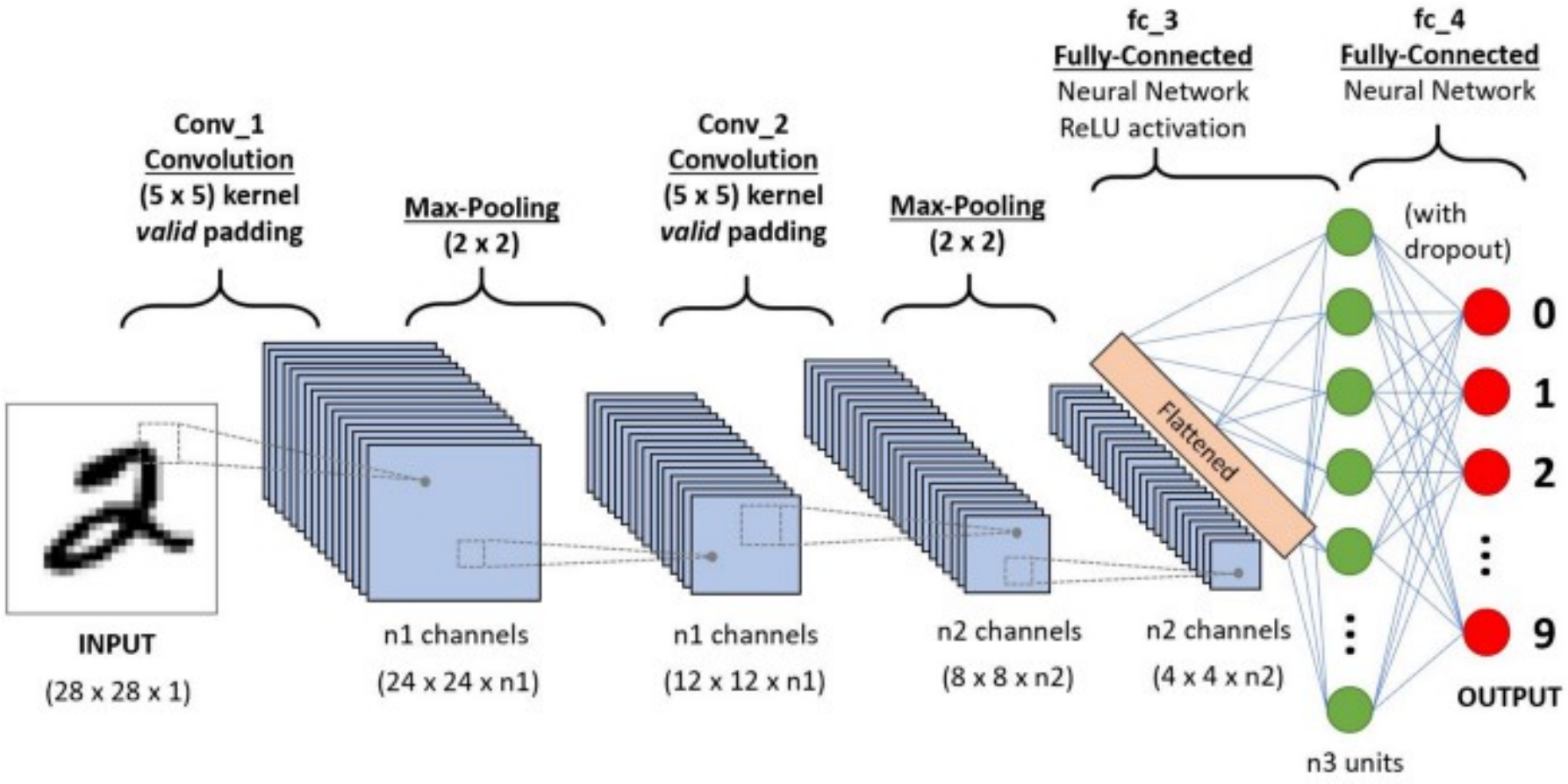
- Convolution Neural Networks are deep learners that are used for image processing tasks
  - Image classification
- They are built by modeling the visual cortex of the brain
- They assign importance to various parts of an image and learn to identify and distinguish one part from another
  - Importance is assigned using weights and biases
- They offer greater flexability and lower preprocessing for image classification

Visual Cortex

- Responsible for recognizing visual stimuli by the human brain
- Each neural in the visual cortex is responsible to only learn a small feature of the overall picture
  - This small portion is referred to as perceptive field
  - Some only are able to distinguish hortizontal lines and others only vertical
- A series of overlapping neurons are then used to complete the entire image



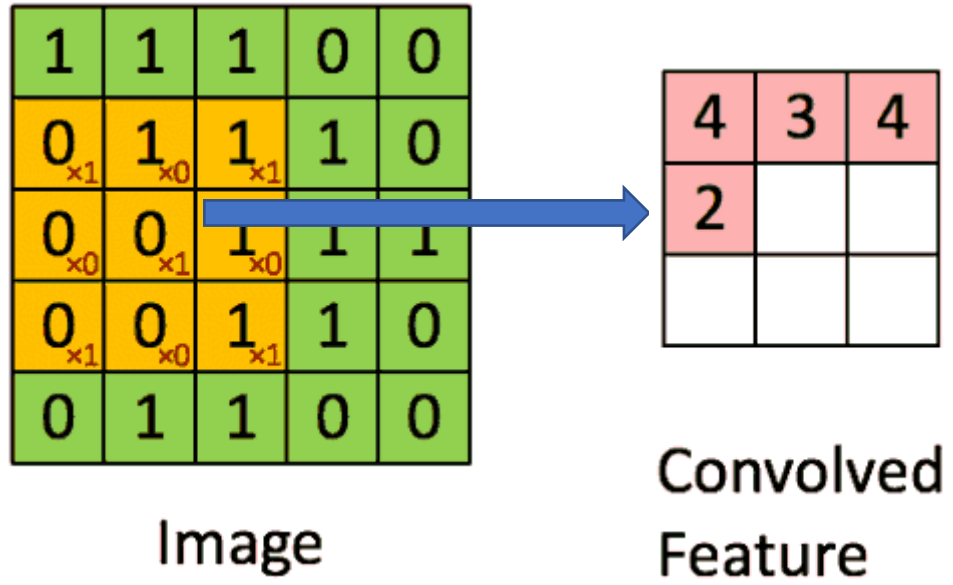
CNN Architecture

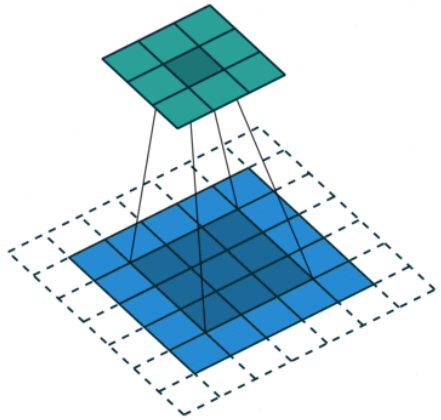


Convolution, Pooling layers are followed by a fully connected ANN

Convolution Layer (Kernel)

- Uses a convolution operation with a filter the image
- The filter moves sequentially across the image in discrete steps
  - Stride is the step size





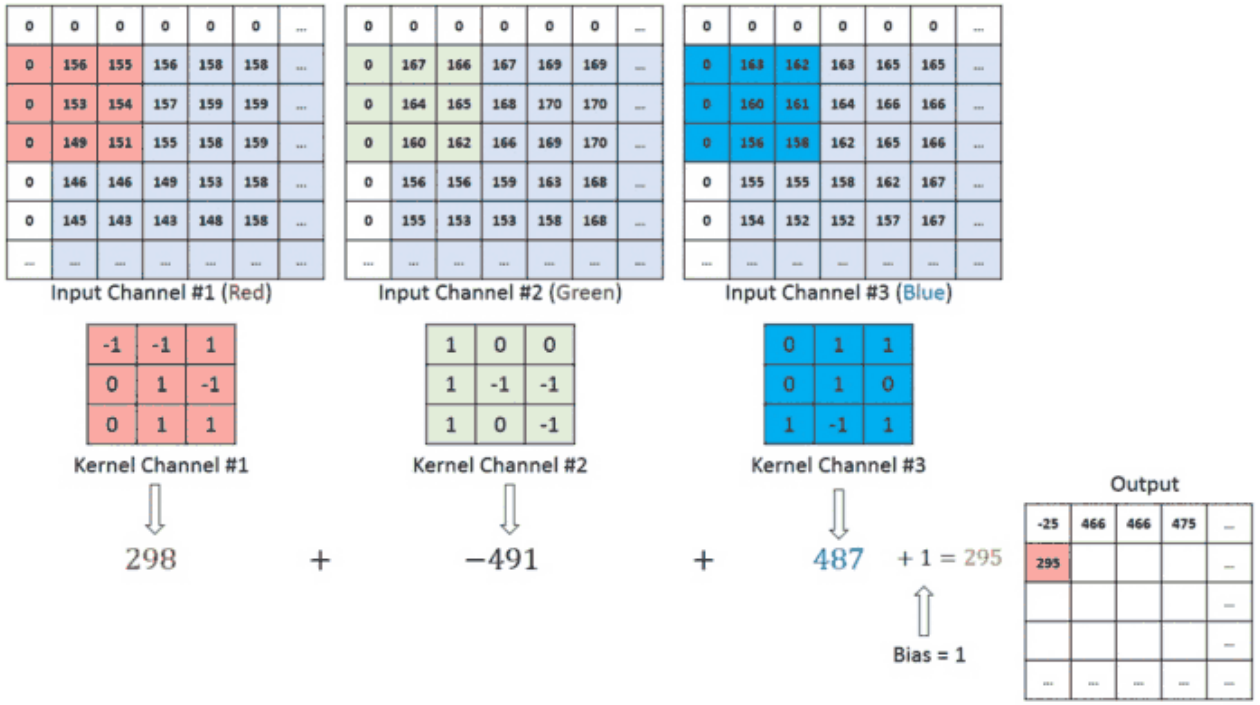
$$K = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 1 \end{bmatrix}$$

Filter

Stride = 1

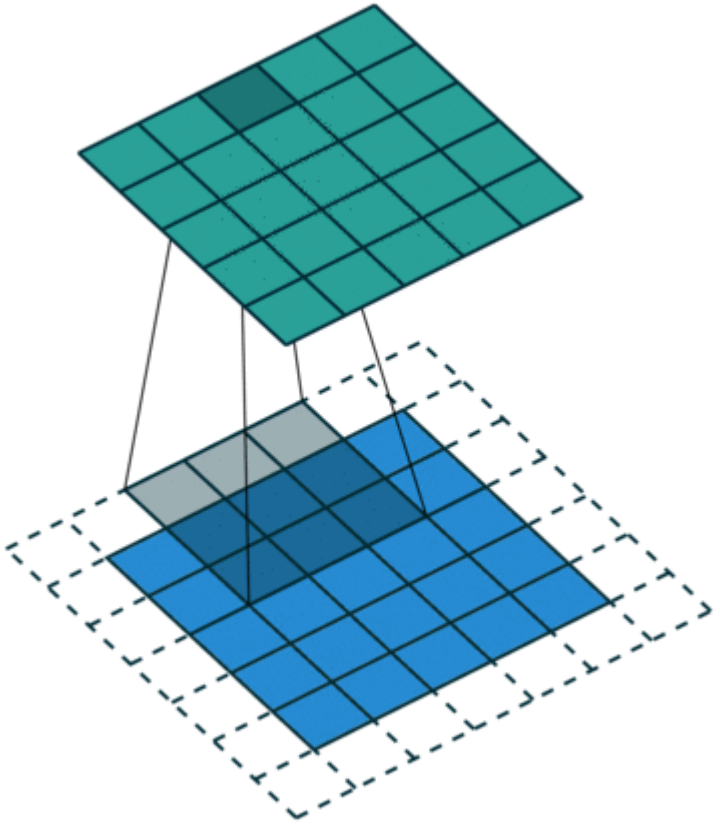
Convolution Layer

- When an image has multiple bands convolution is applied over each band and the results aggregated into a single band



Convolution Layer - Padding

- Same Padding - Convolution is carried out by padding the image
  - Extend the image by adding pixels along the boundary
  - Results in a convoluted image that the same dimensions as the original image
- Valid Padding - Convolution is carried out by not padding the original image
  - No addition of pixels
  - Results in a convoluted image that has the same size as the filter dimension



Padded cells always have zero values

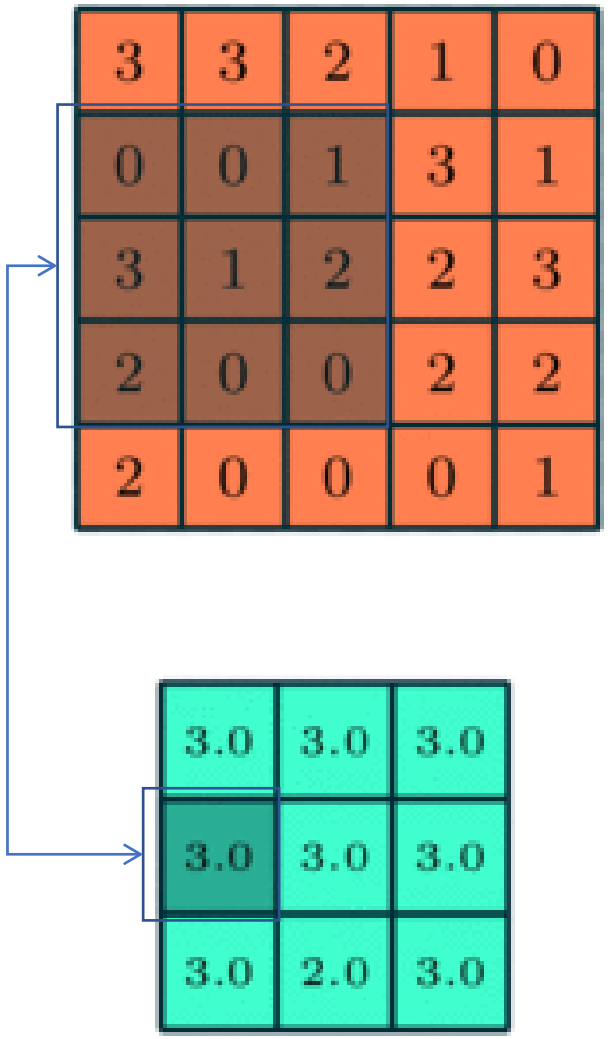
Are there valid objects along the edge that need to be preserved?

Convolution Layers - Purpose

- There can be more than one Convolution layer within the model
- The purpose of the convolution layers is to extract some portion of information about the image
- Lower level convolution layers typically extract lower level features
  - Edges, color, gradient
- Higher level convolution layers extract high dimensional features
  - Shapes, boundaries within an image

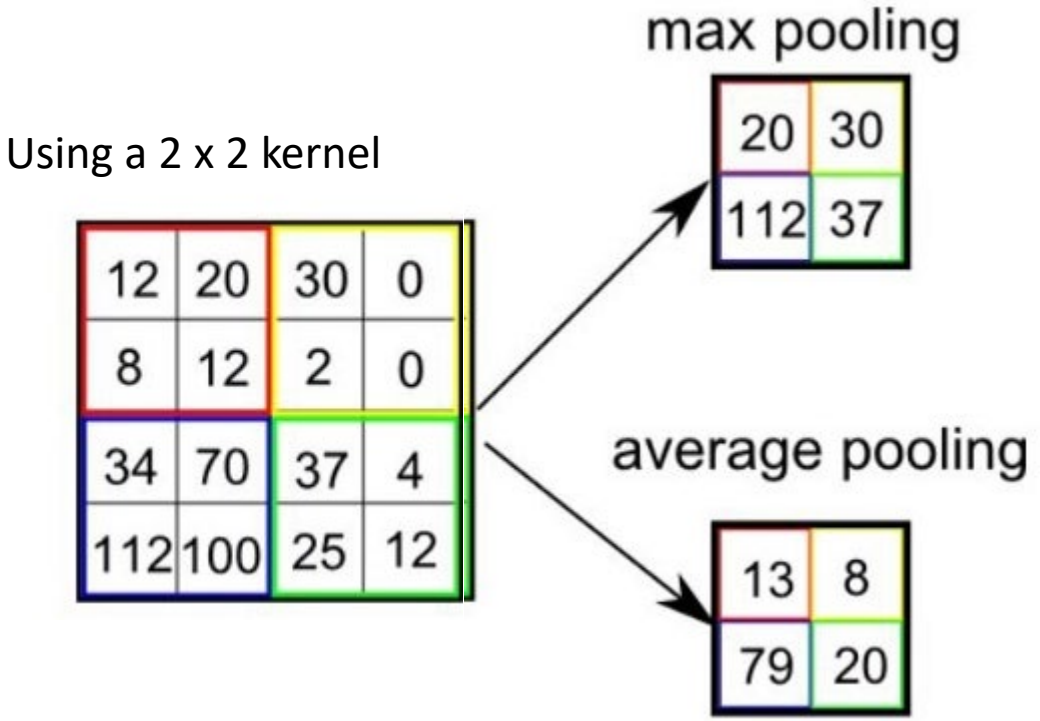
Pooling Layer - Purpose

- Reduces the spatial size of the image
  - Reduce the amount of computations
  - Extract dominant features while maintaining rotational and positional invariant
    - Very similar to the functionality of Principal Component Analysis
- Pooling helps remove (or at least reduce) noise from the dataset
  - Enhance the information (signal)



Pooling Types

- There are two pooling types
  - Average Pooling
  - Max Pooling
- Average Pooling takes the average value over the dimension of the kernel
- Maximum Pooling takes the maximum value over the dimension of the kernel

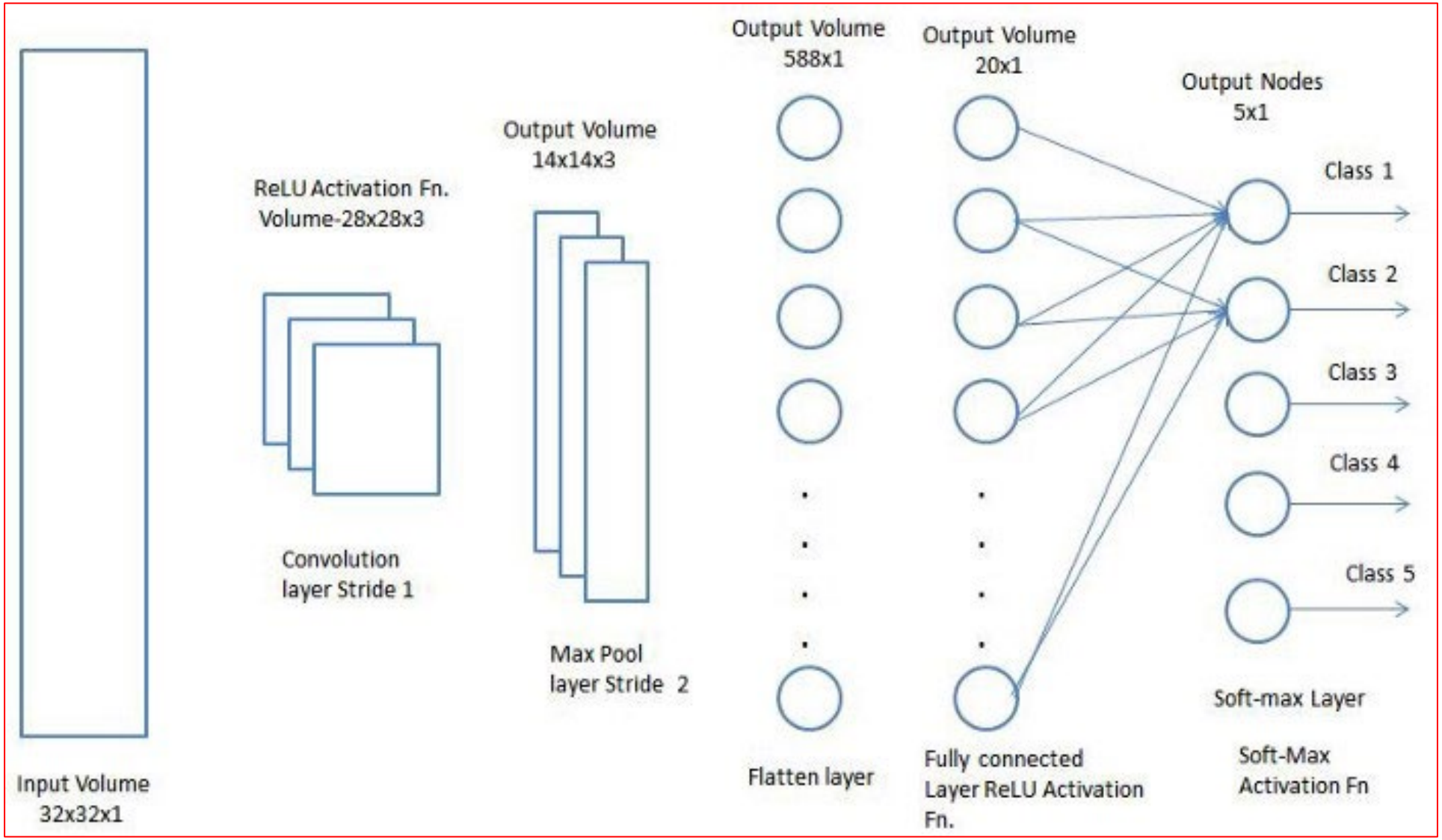


Max pooling removed lower values more so than average pooling and hence more noise reduction

Fully Connected Layer

- The final portion of the CNN is a fully connected Feedforward Neural Network
  - MLP
- This layer learns nonlinear relationships in the transformed space
  - Space transformed by earlier convolution and pooled layers
- The image has to be flattened to 1D array before being sent out to the fully connected layer
- Use an activation function to perform classification?
  - Logistic or Softmax

2D data has to be flattened before sending it to a fully connected layer


Input Volume
32x32x1
ReLU Activation Fn.
Volume-28x28x3
Convolution
layer Stride 1
Output Volume
14x14x3
Max Pool
layer Stride 2
Output Volume
588x1
Flatten layer
Output Volume
20x1
Fully connected
Layer ReLU Activation
Fn.
Output Nodes
5x1
Class 1
Class 2
Class 3
Class 4
Class 5
Soft-max Layer
Soft-Max
Activation Fn

You should know

- What are convolution neural networks
- What can it be used for and why?
- What is a kernel and a stride?
- What is a convolution layer
  - What is it’s purpose?
  - How does it work?
- What is a pooling layer
  - What is it’s purpose?
- What is the purpose of the Fully Connected Layer?