HAND-WRITING DETECTION USING NEURAL NETWORKS

CPT_S 437 PROJECT

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PROBLEM STATEMENT

"HANDWRITING DETECTION REMAINS A CHALLENGING TASK DUE TO VARIATIONS IN WRITING STYLES, SIZES, AND ORIENTATIONS. THIS PROJECT EVALUATES 3 NEURAL NETWORKS TO IDENTIFY THE MOST EFFECTIVE."

DATASET

SOURCE: MNIST (MODIFIED NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY) DATASET

DESCRIPTION: HANDWRITTEN DIGIT IMAGES

DIMENSIONS: 28X28 PIXEL GRAYSCALE IMAGES

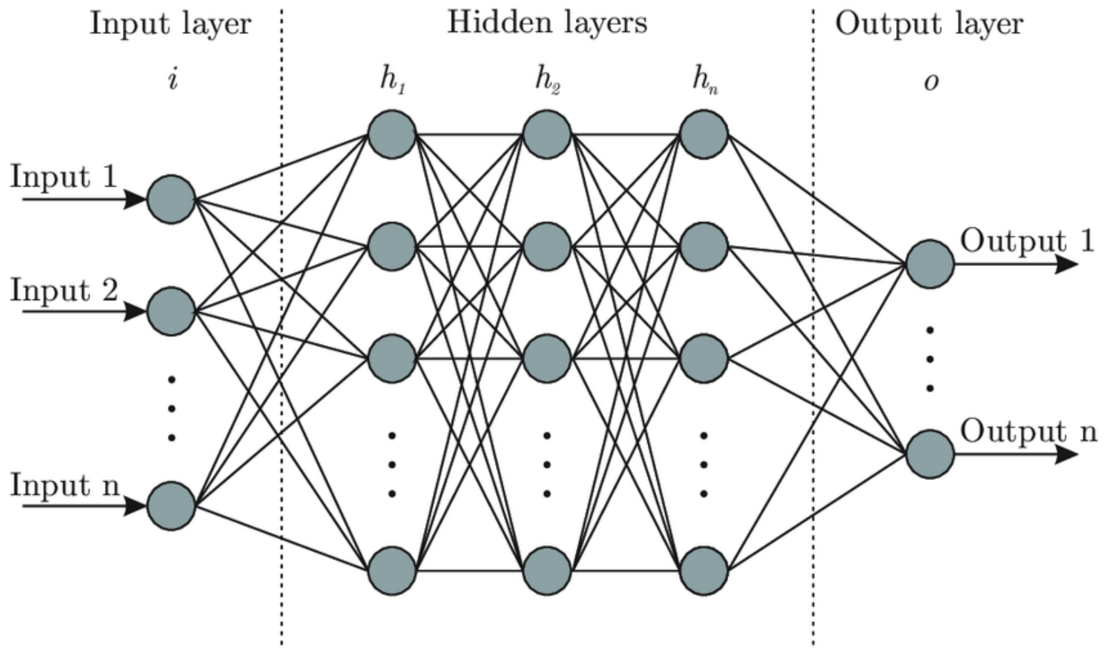
CLASSES: 10 DIGITS (0-9)

TRAINING SET SIZE: 60,000 IMAGES

TEST SET SIZE: 10,000 IMAGES

SOLUTION APPROACH

CAPSULE NN, CNN, 2-LAYER NN



<u>Neural Network Approach</u>: non-linearity of dataset capturing complex patterns, scalability (28x28 pixels)

- **Capsule Neural Network** - advanced neural network architecture that models hierarchical relationships between features, capturing spatial and pose information (orientation, scale)

- **Convolutional Neural Network** - neural network designed to process data with a grid-like topology, using convolutional layers to extract spatially invariant features like edges and textures

- **Traditional Neural Network** - fully connected neural network where each node in one layer is connected to every node in the next

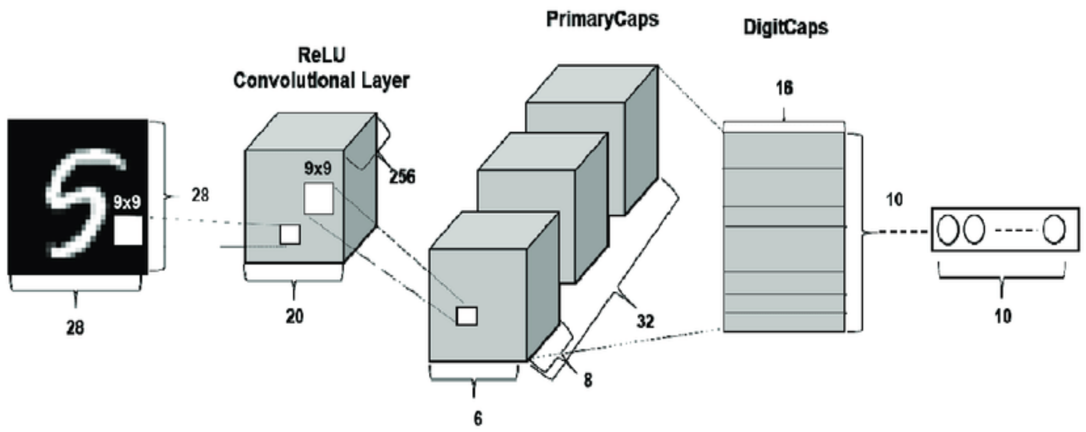
CAPSULE NEURAL NETWORK

Created by Geoffrey Hinton in 2017 in his team's paper "Dynamic Routing Between Capsules" to overcome the limitations of traditional CNNs

Structure: Capsules output vectors to represent features, preserving spatial and pose information.

Key Features:

- Dynamic Routing: Allows lower-level capsules to decide how much influence they have on higher-level capsules.
- Capsules: Groups of neurons that collectively encode properties of features and vectors, enable complex spatial and pose relationships



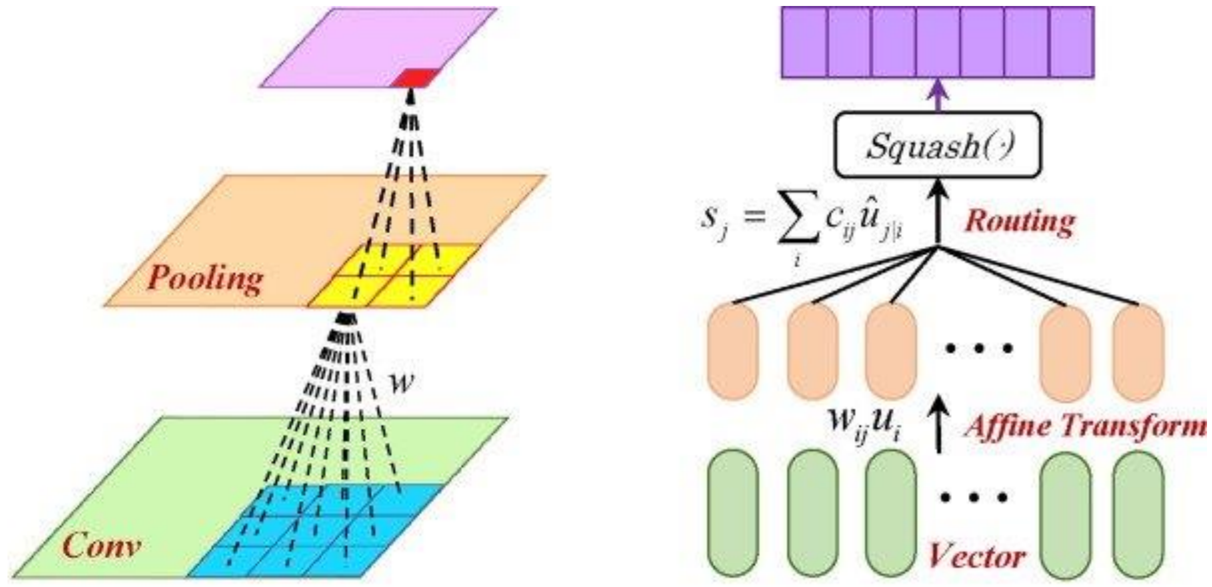
CAPSULE NEURAL NETWORK

Strengths:

- Models hierarchical relationships between features
- Superior accuracy compared to CNN's
- Effectively recognizes objects when rotated or resized

Weaknesses:

- High computation cost (5 hours to run 5 epochs)
- Sensitive to hyperparameter settings
- Limited Availability of Implementation tools

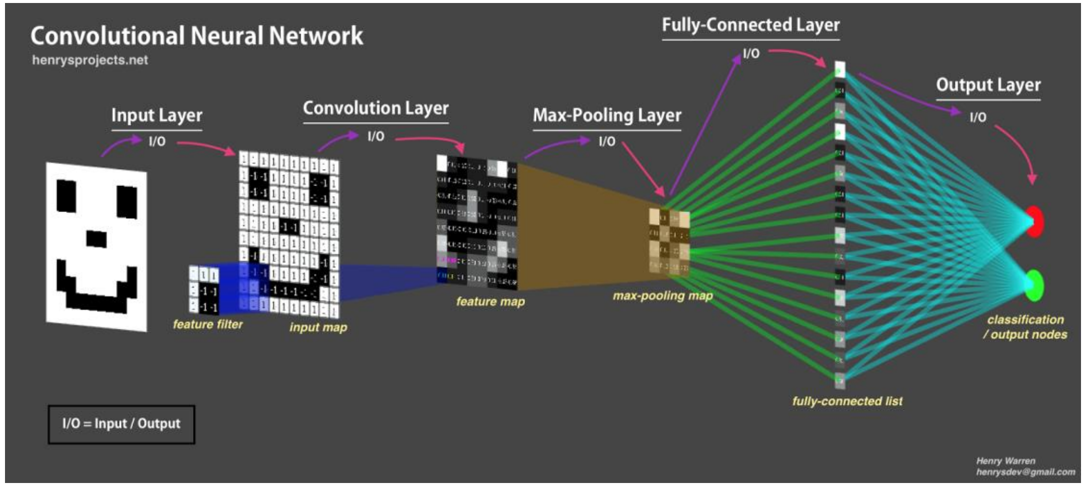


a. Convolutional Neural Network   b. Capsule Neural Network

CONVOLUTIONAL NEURAL NETWORK

Structure:

- Convolutional Layers: Extract features like edges or textures
- Pooling Layers: Reduce image size to improve processing efficiency
- Fully Connected Layers: Combine extracted features for decision-making



Key Features:

- Local Connectivity: Focus on small image regions to detect patterns
- Weight Sharing: Reuse the same filters to process different parts of the image
- Hierarchical Learning: Build from simple to complex patterns

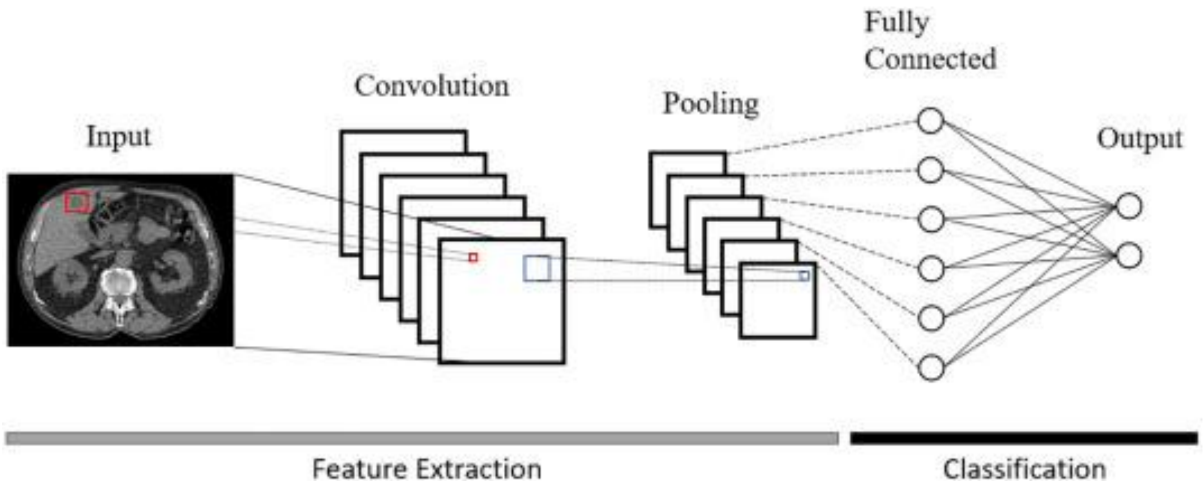
CONVOLUTIONAL NEURAL NETWORK

Strengths:

- Designed for visual data like photos or videos
- Automatic feature extraction
- High accuracy in image classification and recognition tasks

Weaknesses:

- Requires large datasets for good performance
- Training can be computationally expensive
- Can have trouble recognizing rotated, scaled, or distorted objects



2-LAYER NEURAL NETWORK

Architecture

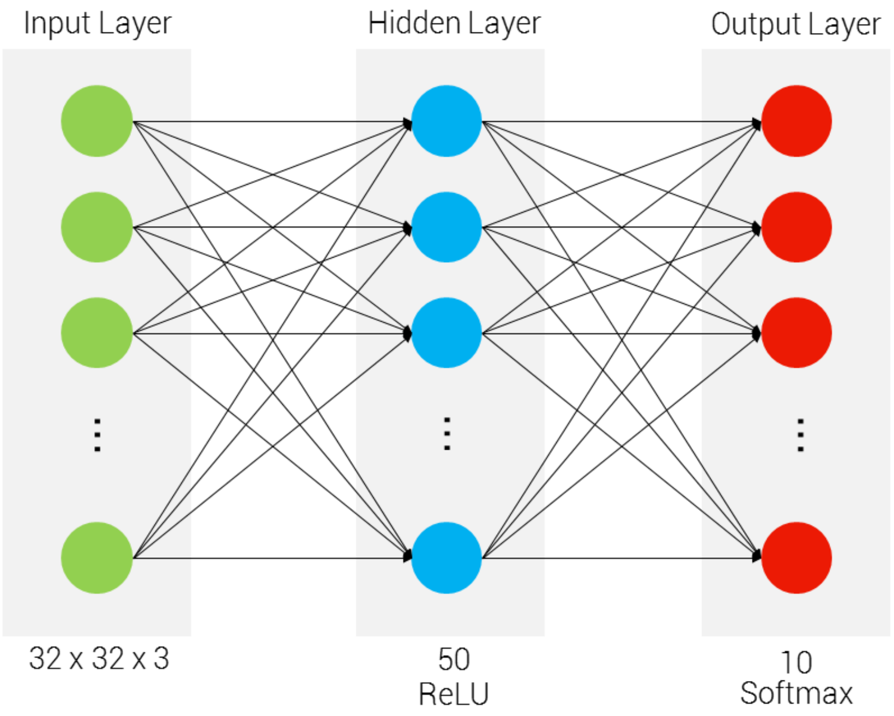
- Input: 784 Neurons
- 300 Neurons w/ ReLU activation function
- 10 Neurons w/ Softmax activation function

Techniques

- Kaiming He Initialization (weights)
- Cross-Entropy Loss (loss function)

Optimization Strategies

- Mini-Batch Gradient Descent
- Learning Rate Decay



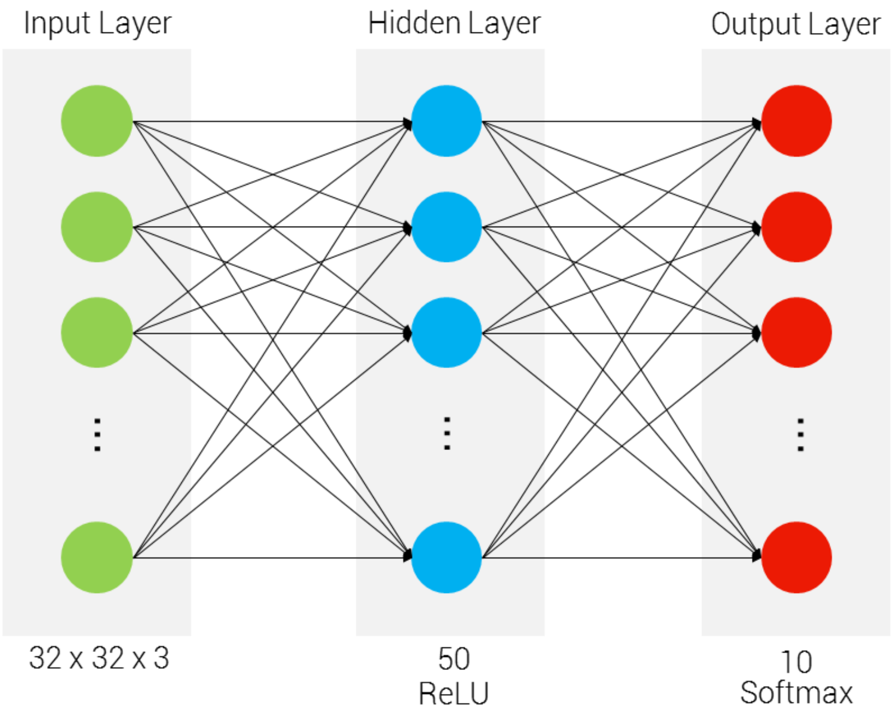
2-LAYER NEURAL NETWORK

Strengths:

- Simplicity of architecture
- Computationally efficient

Weaknesses:

- Spatial Information Loss
- Performance Limitations



INSIGHTS

TEST ACCURACY RESULTS

Feature	Traditional NN	CNN	CapsNet
Test Accuracy	96.54%	97.72%	99.3%

INSIGHTS AND TAKEAWAYS

Traditional Neural Network

Application to MNIST:

- Least accurate and least computationally expensive
- More generalized pattern detection – does not consider spatial information

Convolutional Neural Network

Application to MNIST:

- Achieves high accuracy by learning spatial hierarchies of features
- More efficient than many traditional networks due to local connectivity and weight sharing

Capsule Neural Network

Application to MNIST:

- High accuracy with better robustness than CNNs
- Excels at handling variations in orientation and style

THANK YOU