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FACULTY OF SCIENCES
SCHOOL OF INFORMATICS

POSTGRADUATE STUDIES PROGRAM ON INFORMATICS AND COMMUNICATIONS
SPECIALIZATION ON DIGITAL MEDIA AND COMPUTATIONAL INTELLIGENCE

Content-based Image Retrieval

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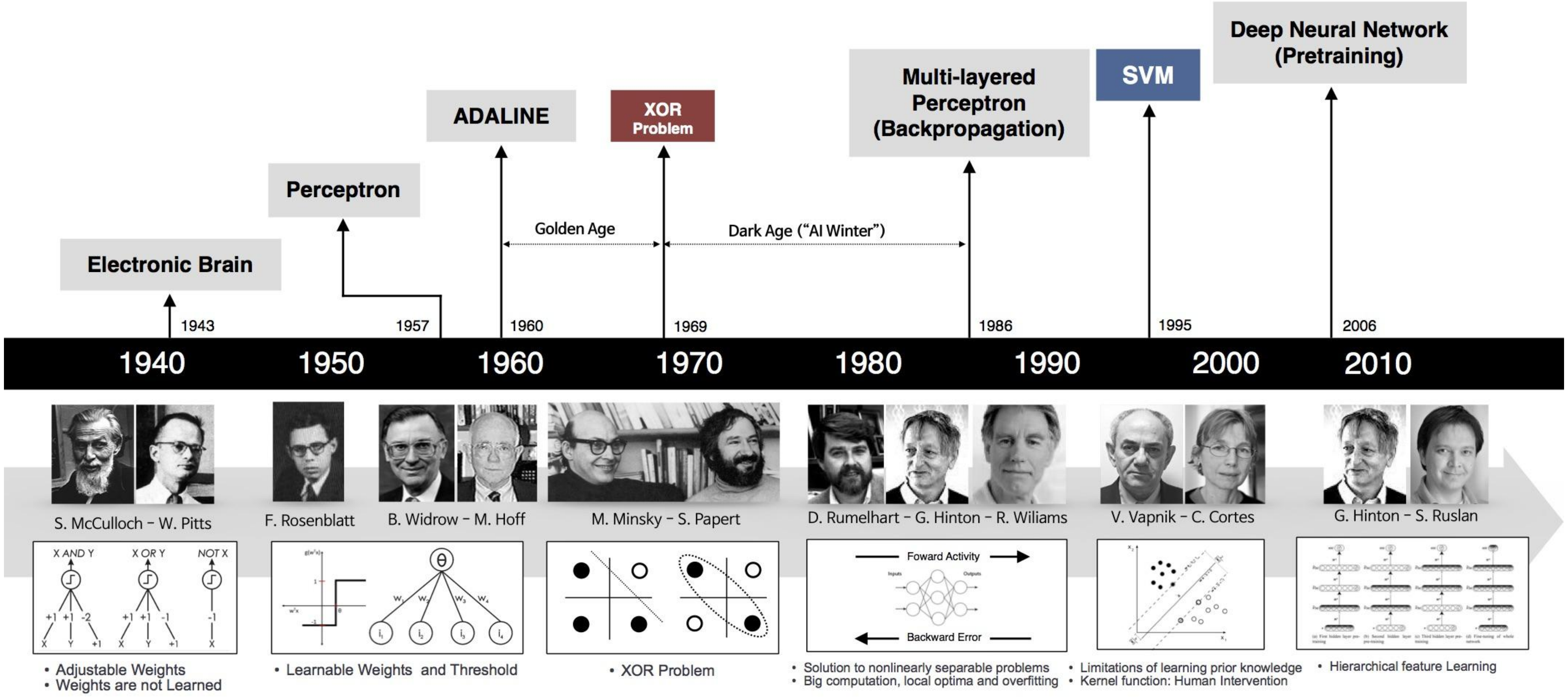
Introduction

Important history of "Artificial Intelligence"

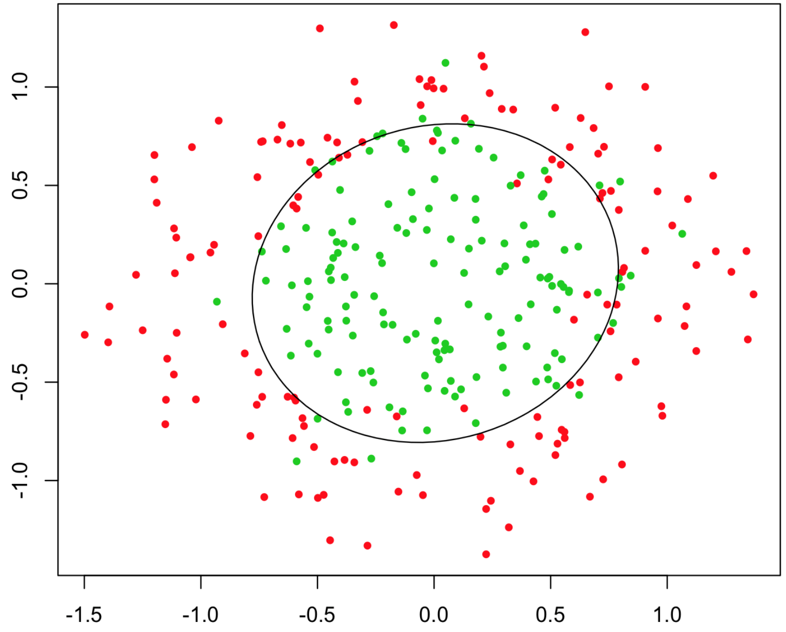
We had a long journey… and we are still at the birth of it...

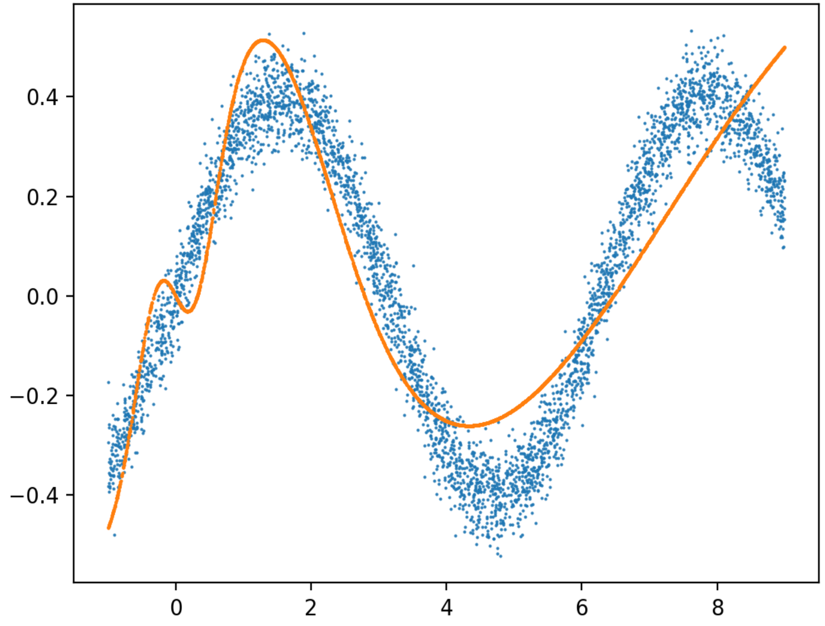


Introduction

Advantages of Artificial Neural Networks

- Satisfactory separation of non-linear separable input data
- Satisfactory function approximation using only input data

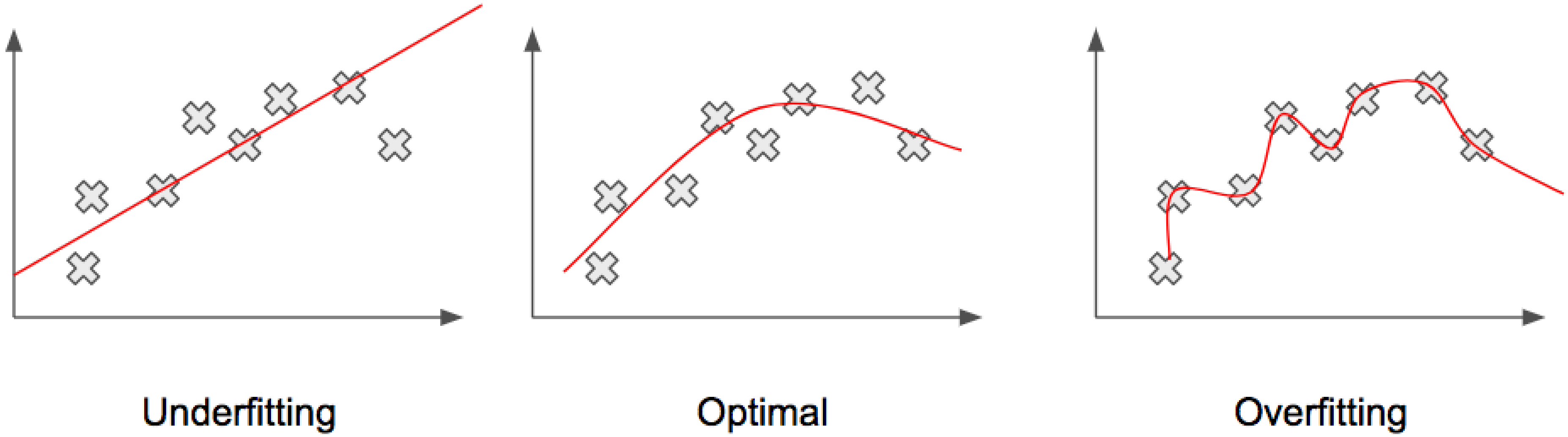




Introduction

Advantages of Artificial Neural Networks

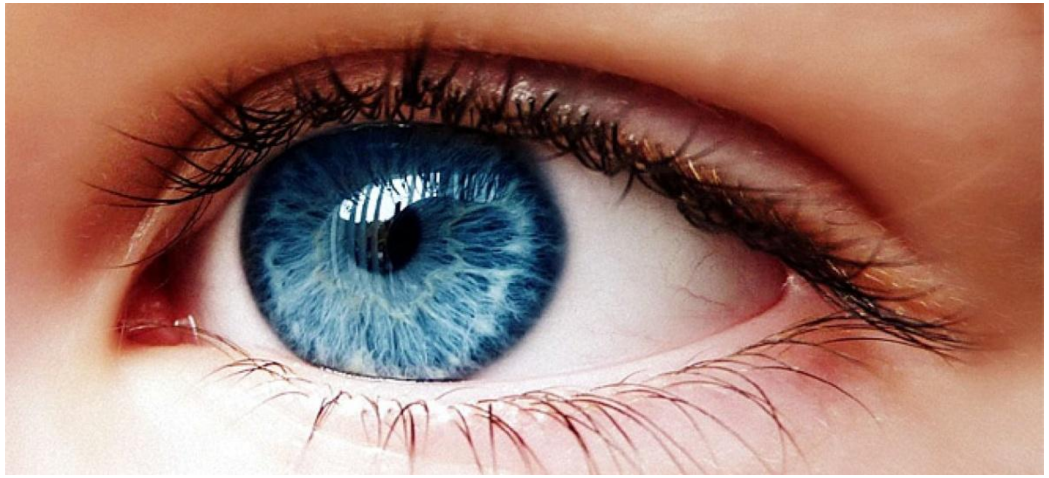
- Good generalization that captures the general manifold of data



Introduction

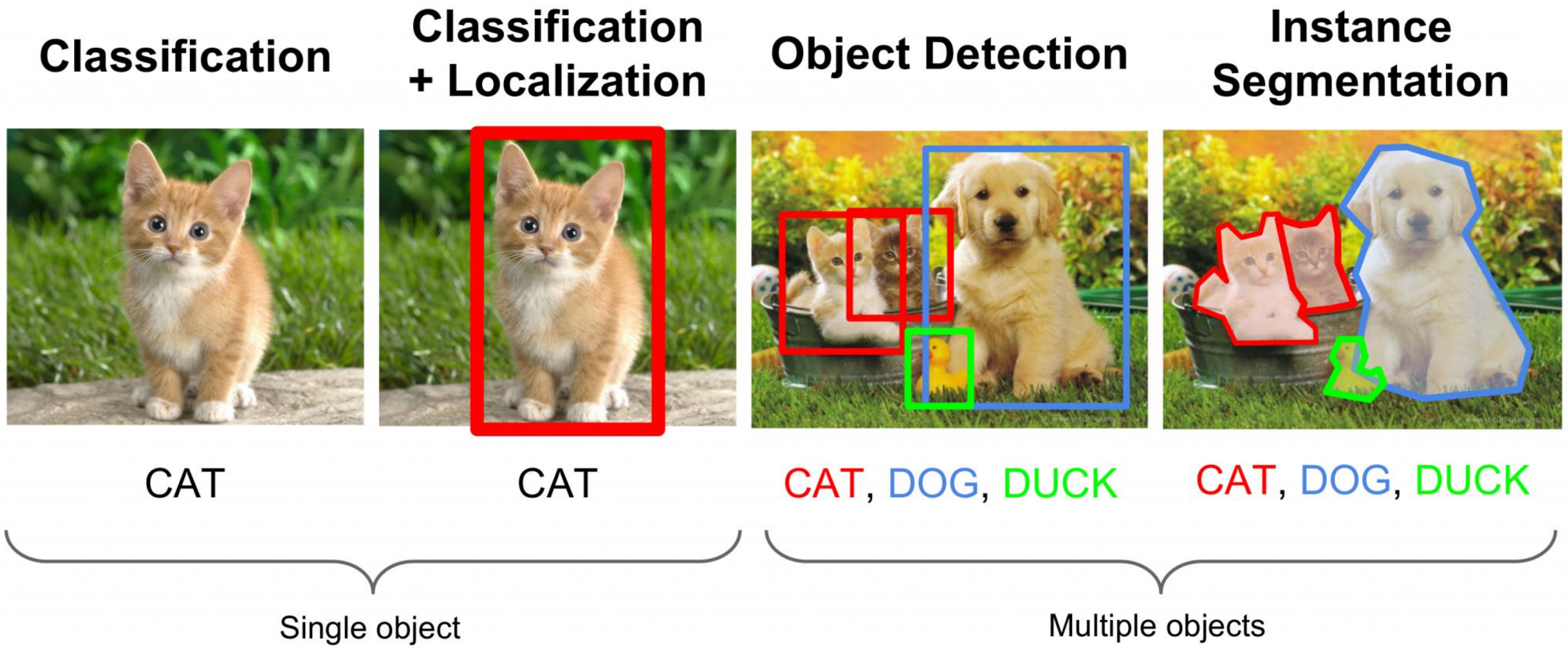
Computer Vision and its future goal

- The strongest sense of most animal species
- Simulate how brains see and understand the world through vision sense



Computer Vision

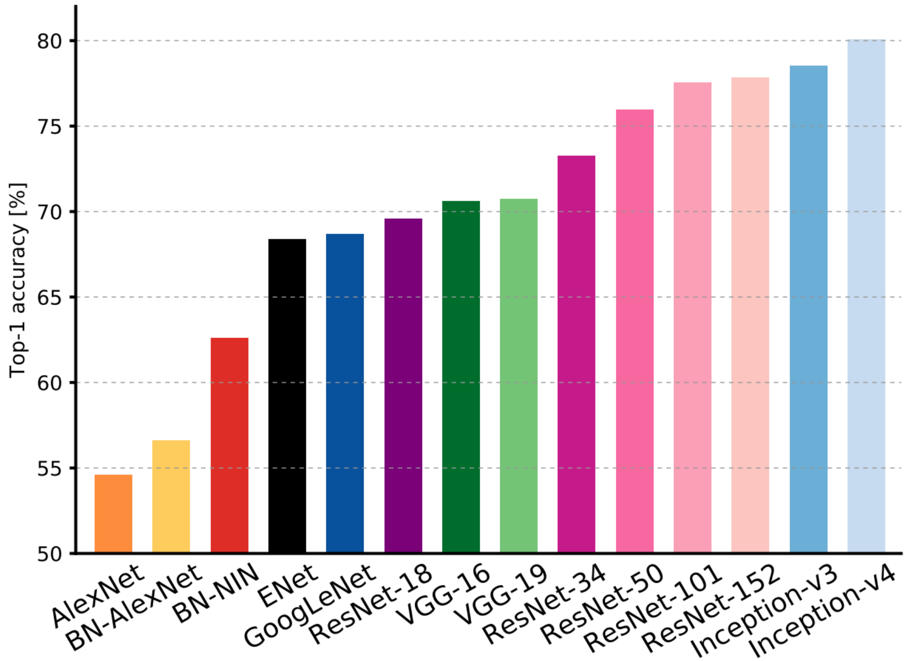
Well-known tasks of high-level image understanding

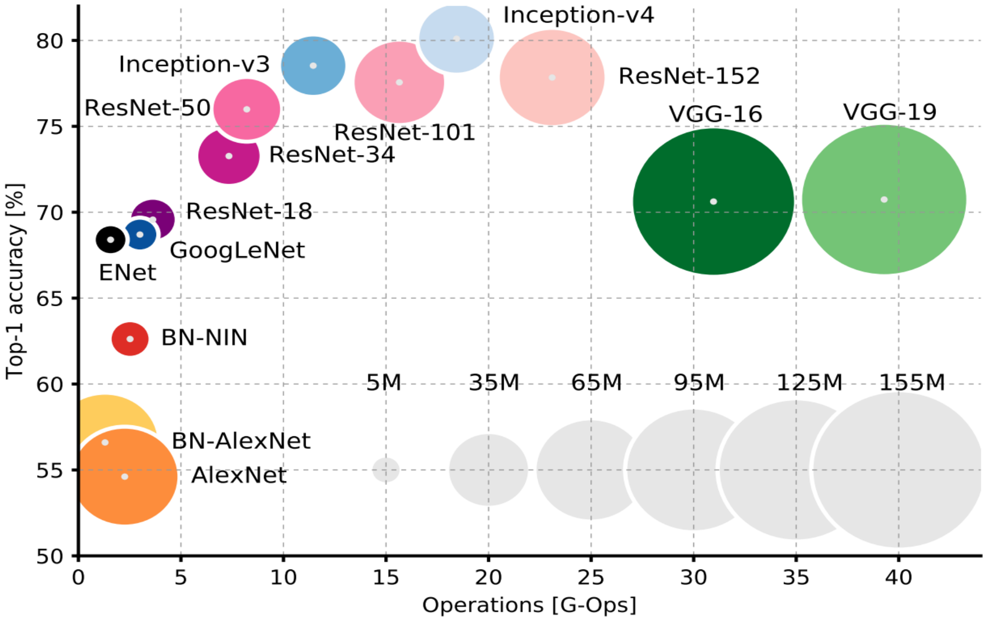


Computer Vision

State-of-the-art Image Classification

ImageNet Large Scale Visual Recognition Challenge (ILSVRC)





Dataset

Fashion MNIST

Dataset

Fashion MNIST

Characteristics:

- total of 70000 grayscale images
- 28x28 pixels (image resolution)
- 10 class labels
- 60000 training images (6000 images per class label)
- 10000 testing images (1000 images per class label)

Dataset

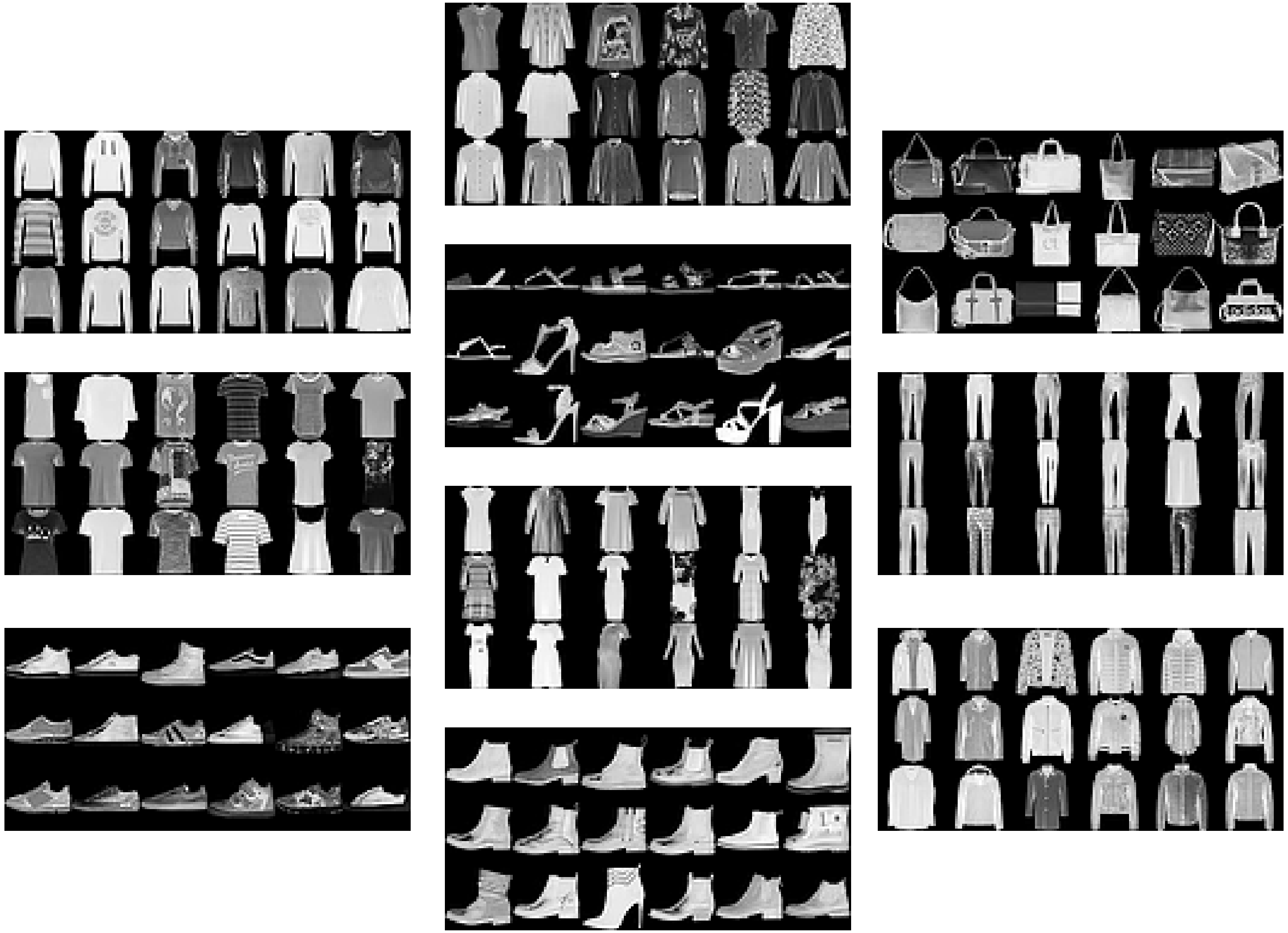
Fashion MNIST

Class labels:

- T-shirt/top
- Trouser
- Pullover
- Dress
- Coat
- Sandal
- Shirt
- Sneaker
- Bag
- Ankle boot

Dataset

Fashion MNIST



Content-based Image Retrieval

Using KNN, convolutional feature extractors and similarity metrics

Steps:

- Train a convolutional neural network for multi-label classification
- Use the trained convolutional feature extractors and extract the image feature vectors
- Fit a KNN model with the extracted image feature vectors
- For an input query image:
  - Extract its image feature vector using the same feature extractors
  - Use the KNN model and find the closest K neighbors using the cosine similarity
- Run various experiments and report precision and recall curves

Convolutional Neural Network Topology

Summary and architecture of the neural network

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 64)        320
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 14, 14, 64)        0
_________________________________________________________________
dropout_1 (Dropout)          (None, 14, 14, 64)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 14, 14, 32)        8224
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 7, 7, 32)          0
_________________________________________________________________
dropout_2 (Dropout)          (None, 7, 7, 32)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 1568)              0
_________________________________________________________________
dense_1 (Dense)              (None, 256)               401664
_________________________________________________________________
dropout_3 (Dropout)          (None, 256)               0
_________________________________________________________________
dense_2 (Dense)              (None, 10)                2570
=================================================================
Total params: 412,778
Trainable params: 412,778
Non-trainable params: 0
```

Conv(64, Kernel(2, 2), Padding(Same))+Relu
MaxPooling(PoolSize(2, 2), Strides(2, 2))
Dropout(0.3)
Conv(32, Kernel(2, 2), Padding(Same))+Relu
MaxPooling(PoolSize(2, 2), Strides(2, 2))
Dropout(0.3)
FC(256)+Relu
Dropout(0.5)
FC(10)+Softmax

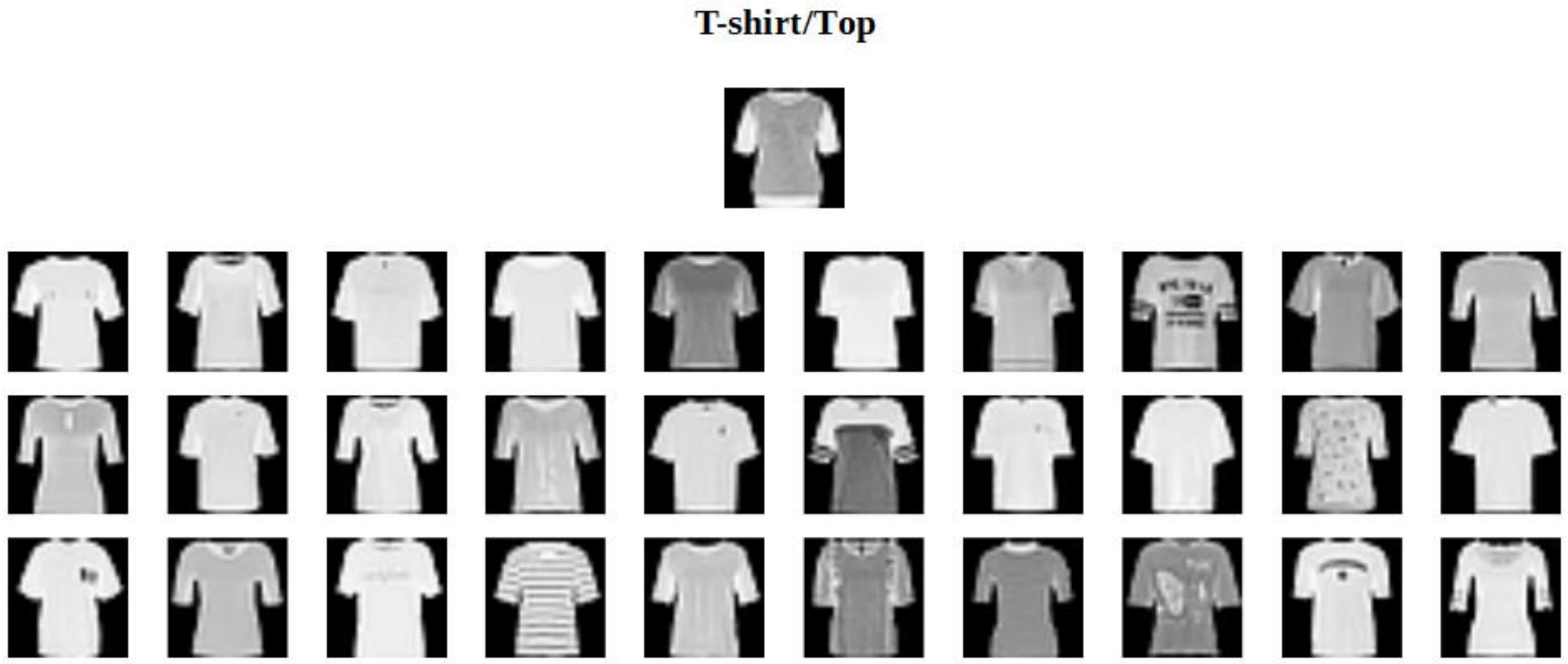
Convolutional Neural Network Topology

Training information

Dataset	Fashion MNIST
Total Classes	10
Total Images	70000
Training Images	65000
Validation Images	5000
Testing Images	10000
Images Resolution	28x28
Images Normalization	MinMax
Learning Rate	1e-3
Training Algorithm	Backpropagation
Optimization Method	Adam
Loss Function	Cross-entropy
Batch Size	64
Training Epochs	10

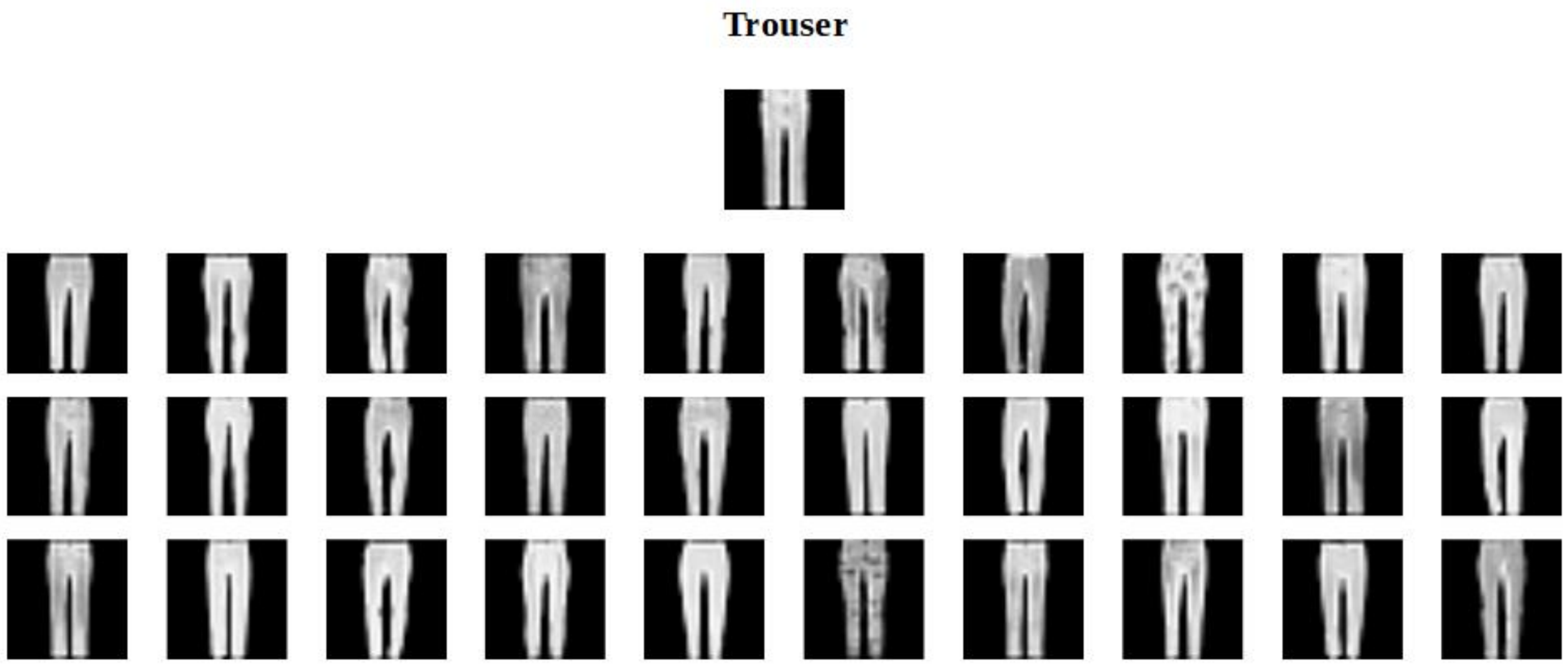
Example Queries

Example 1 (closest K=30 neighbors)



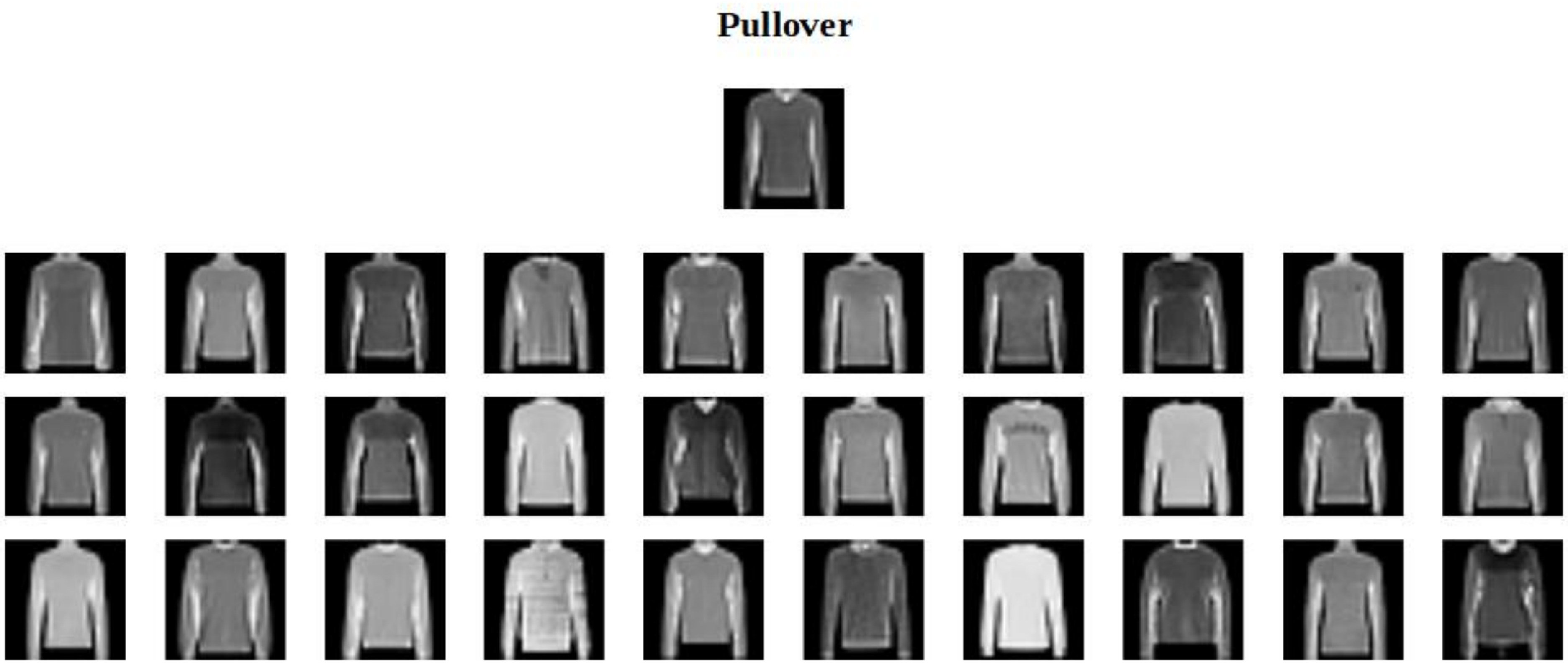
Example Queries

Example 2 (closest K=30 neighbors)



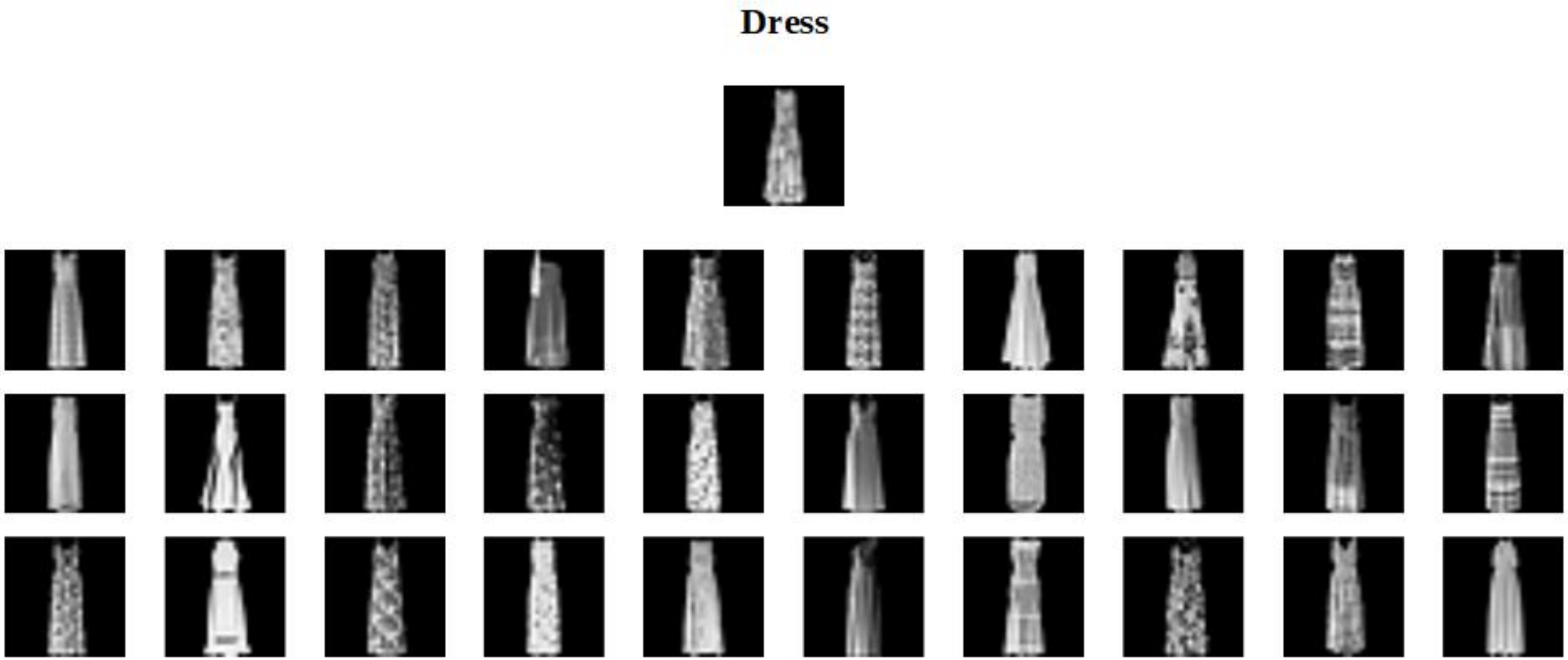
Example Queries

Example 3 (closest K=30 neighbors)



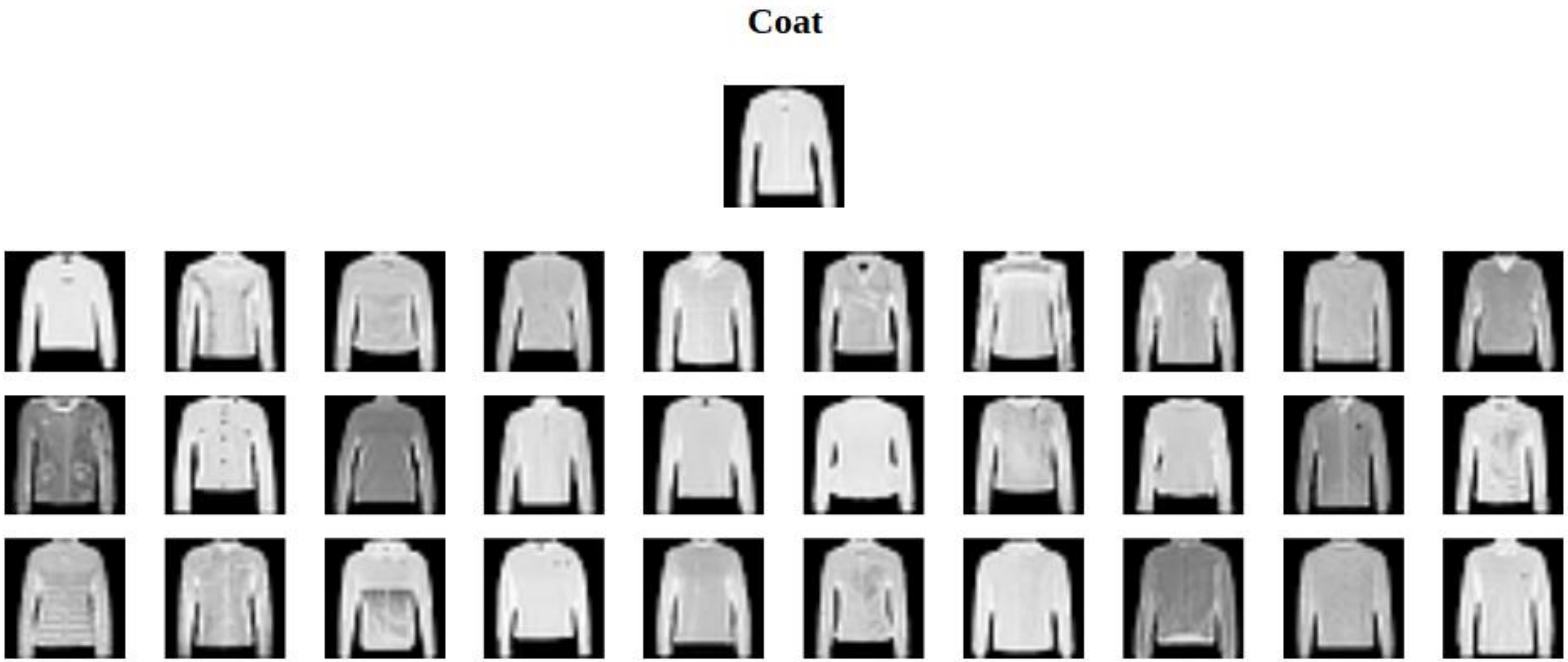
Example Queries

Example 4 (closest K=30 neighbors)



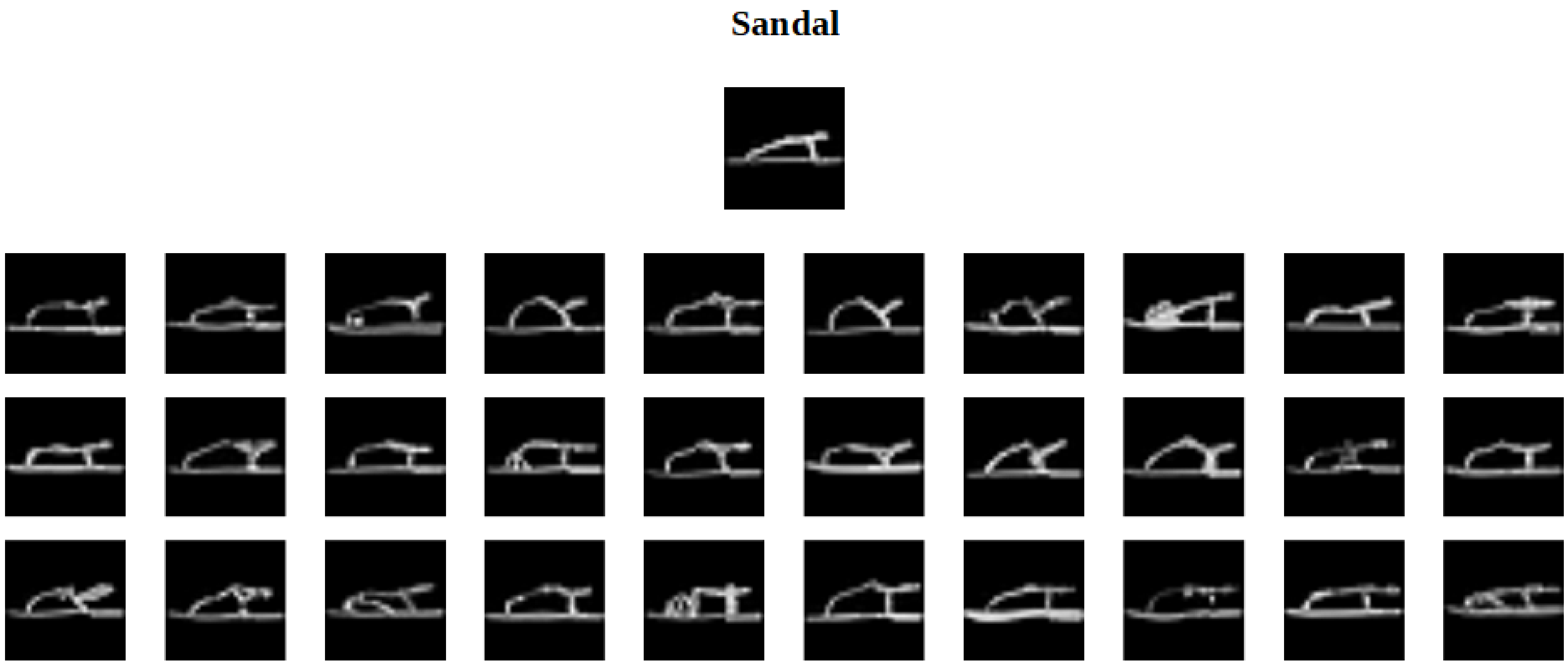
Example Queries

Example 5 (closest K=30 neighbors)



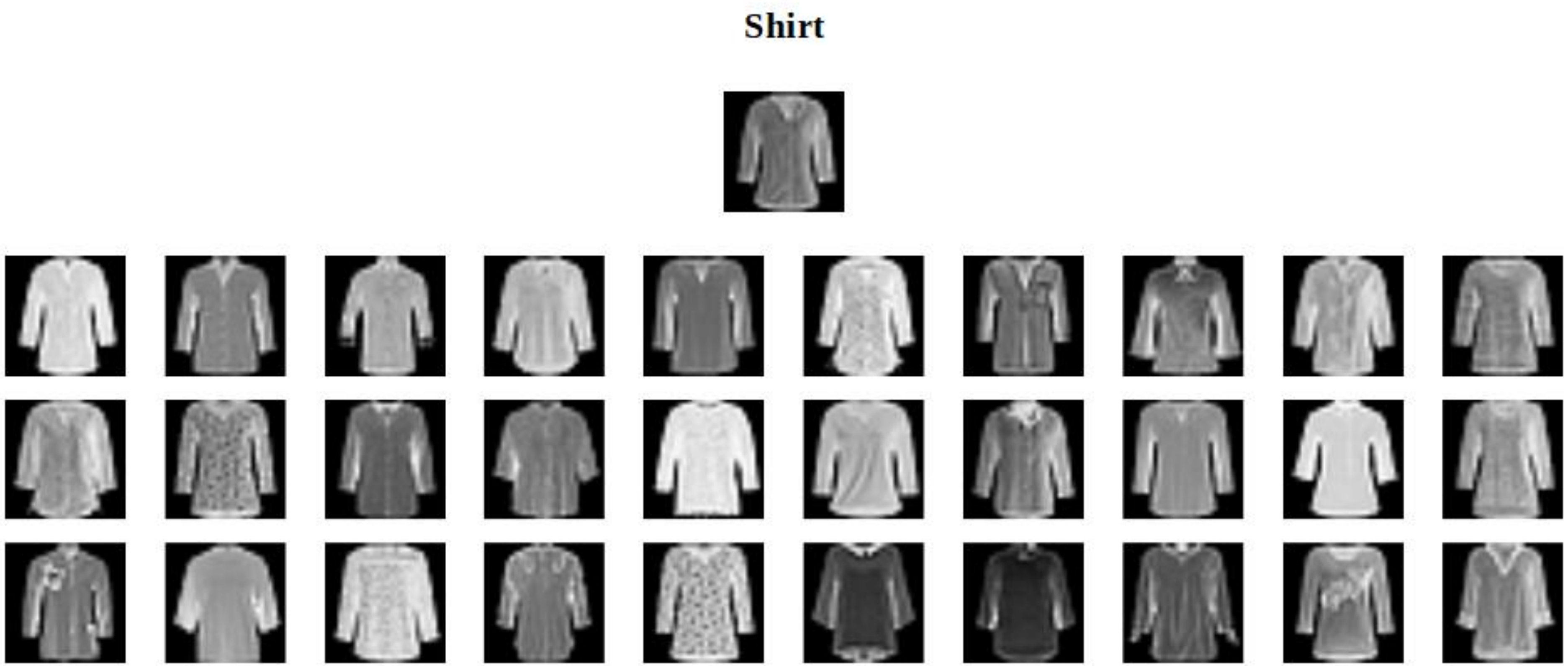
Example Queries

Example 6 (closest K=30 neighbors)



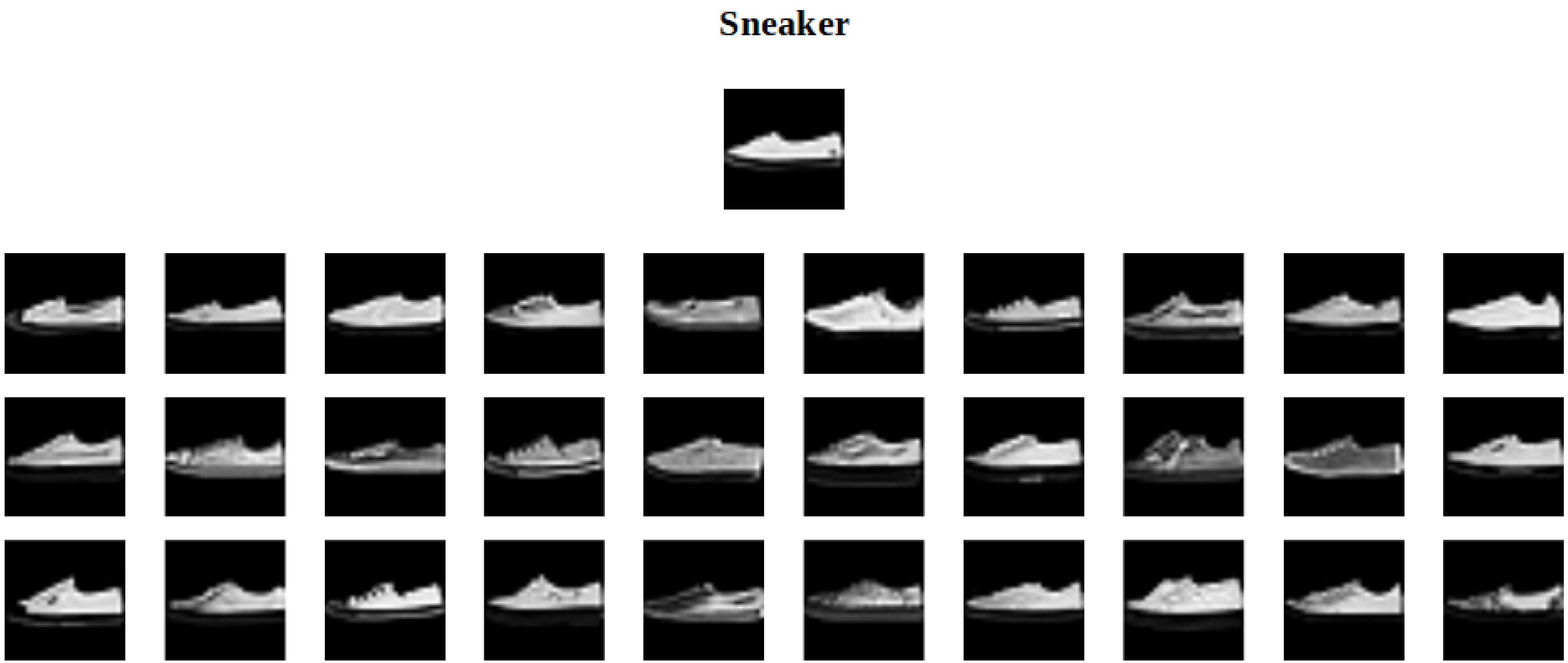
Example Queries

Example 7 (closest K=30 neighbors)



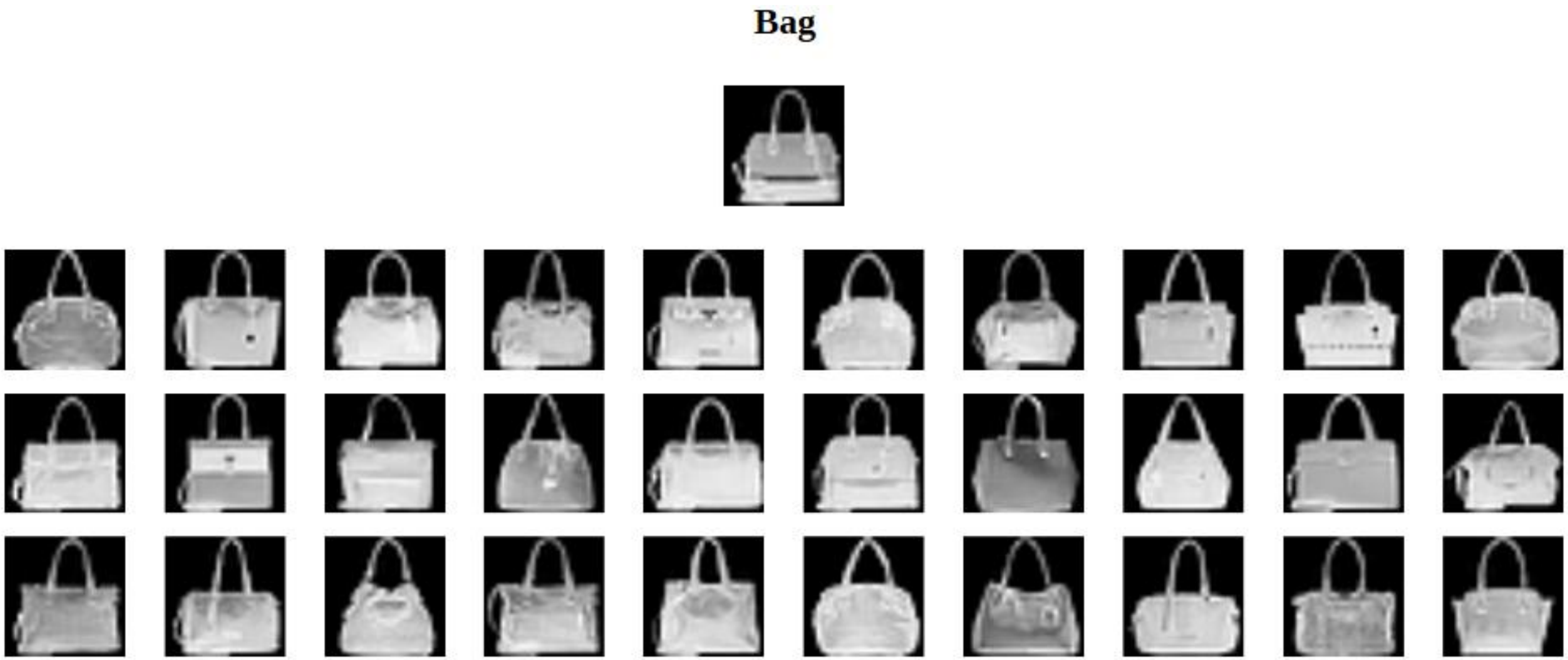
Example Queries

Example 8 (closest K=30 neighbors)



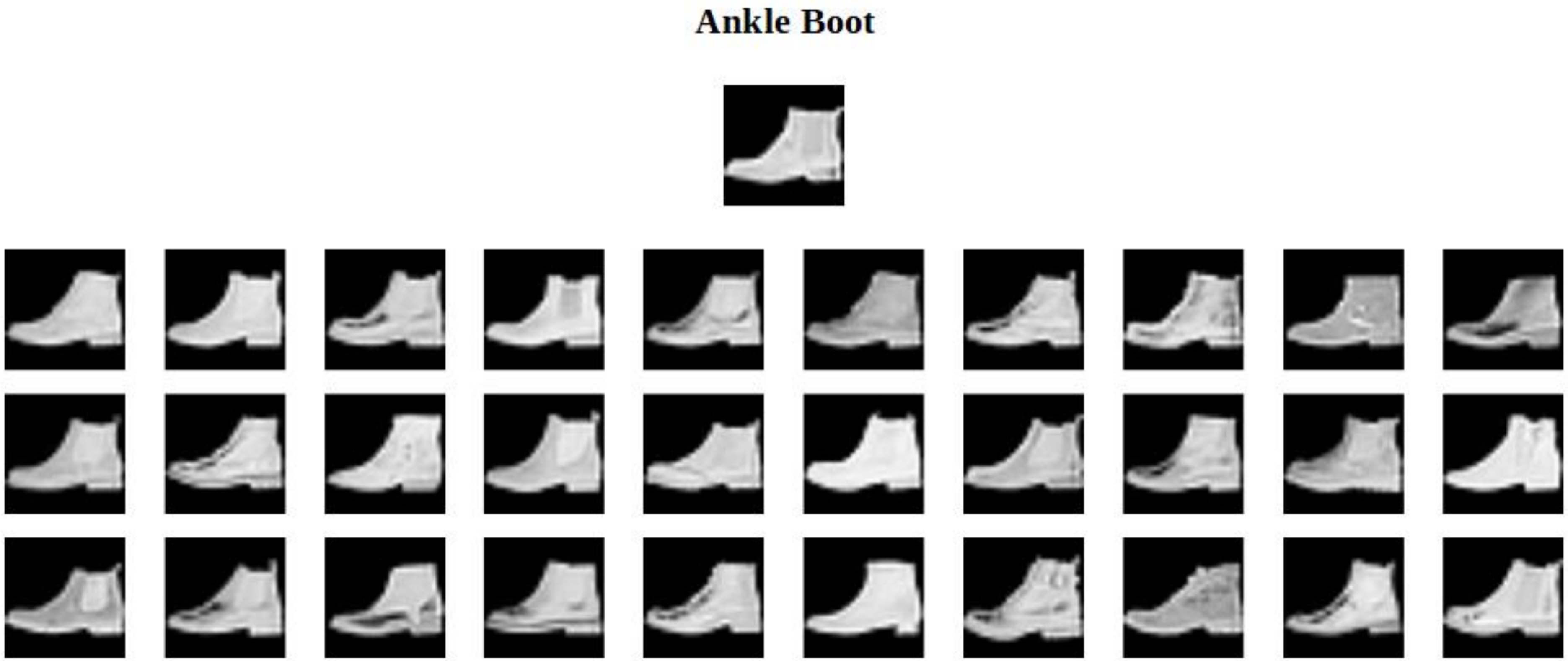
Example Queries

Example 9 (closest K=30 neighbors)



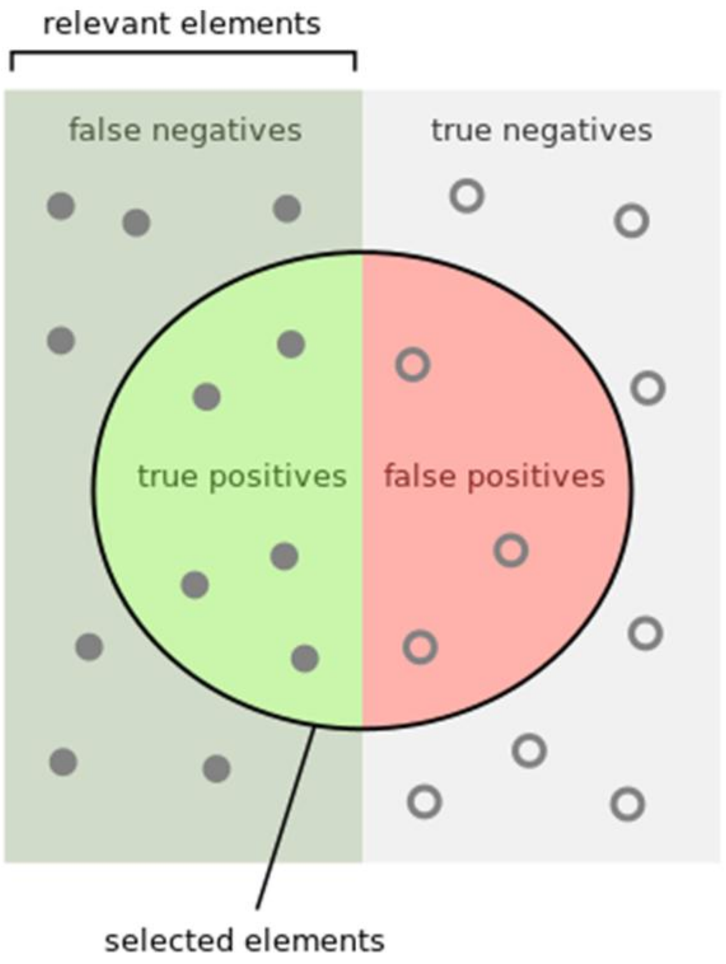
Example Queries

Example 10 (closest K=30 neighbors)



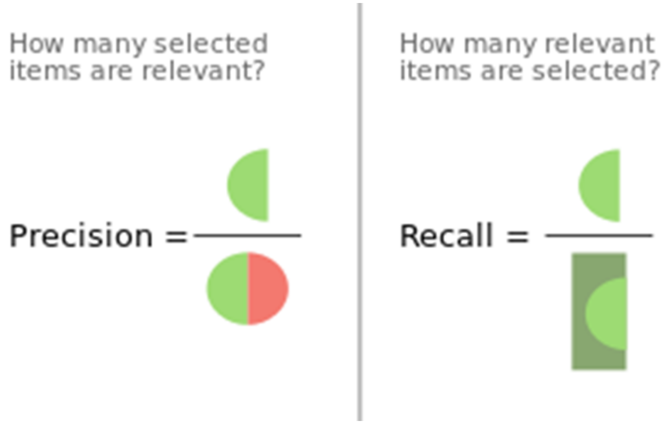
Metrics

Precision & Recall



$$\text{Recall} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$$

$$\text{Precision} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Positives}}$$



Results

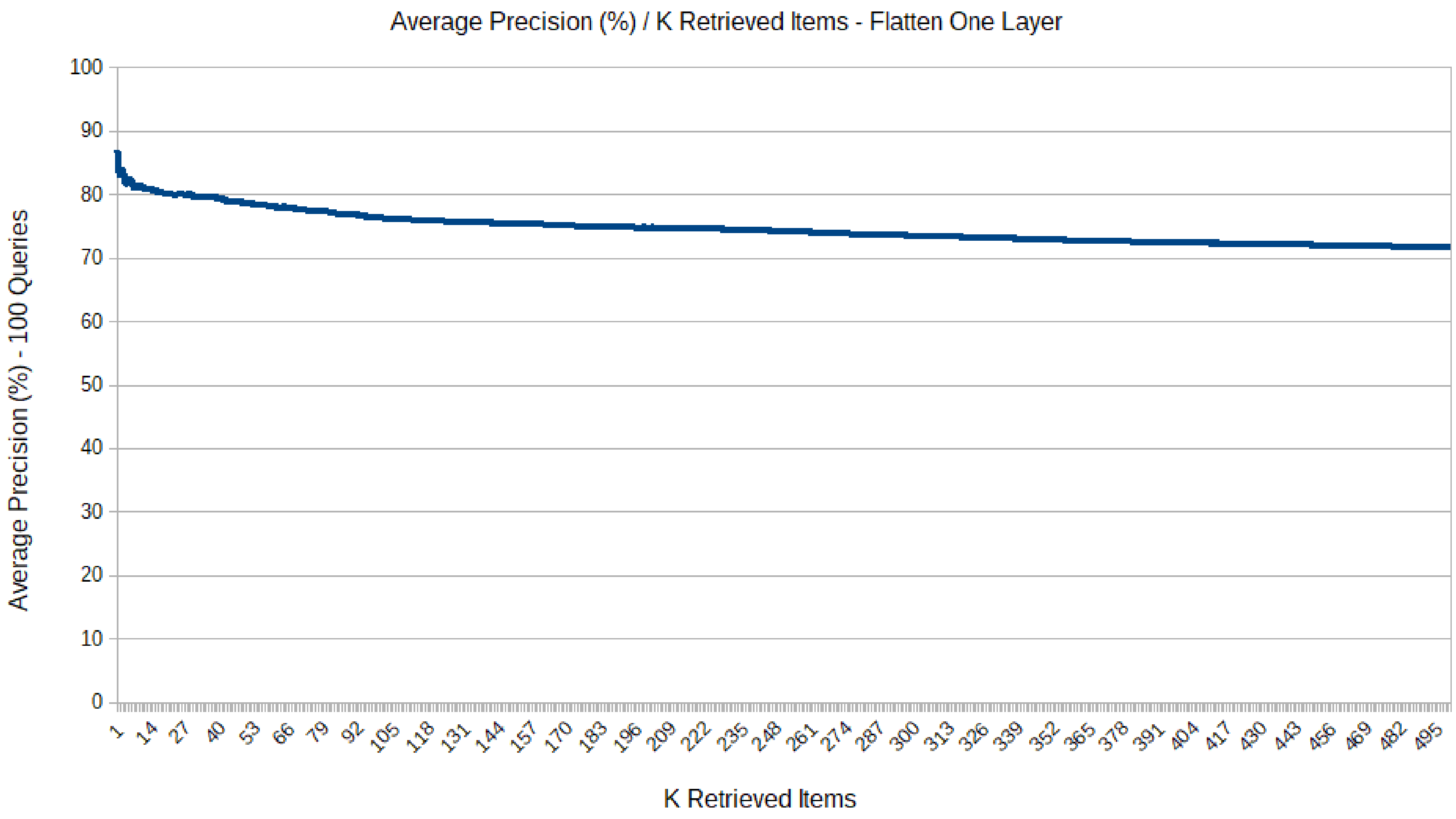
Precision & Recall

Steps:

- We have calculated average precision and recall metrics for various experiments:
  - With 100 different random test images as search queries
  - With different values of K ranging from 1 to 500
  - With features vectors extracted from different neural network layers
  - Using various similarity metrics (Cosine, Euclidean, etc)
- When K increases the precision decreases and recall increases
- The extracted feature vectors from the 'dense_1' layer lead to better metric results
- Cosine similarity produces best results in our experiments
- There is a trade-off between precision and recall

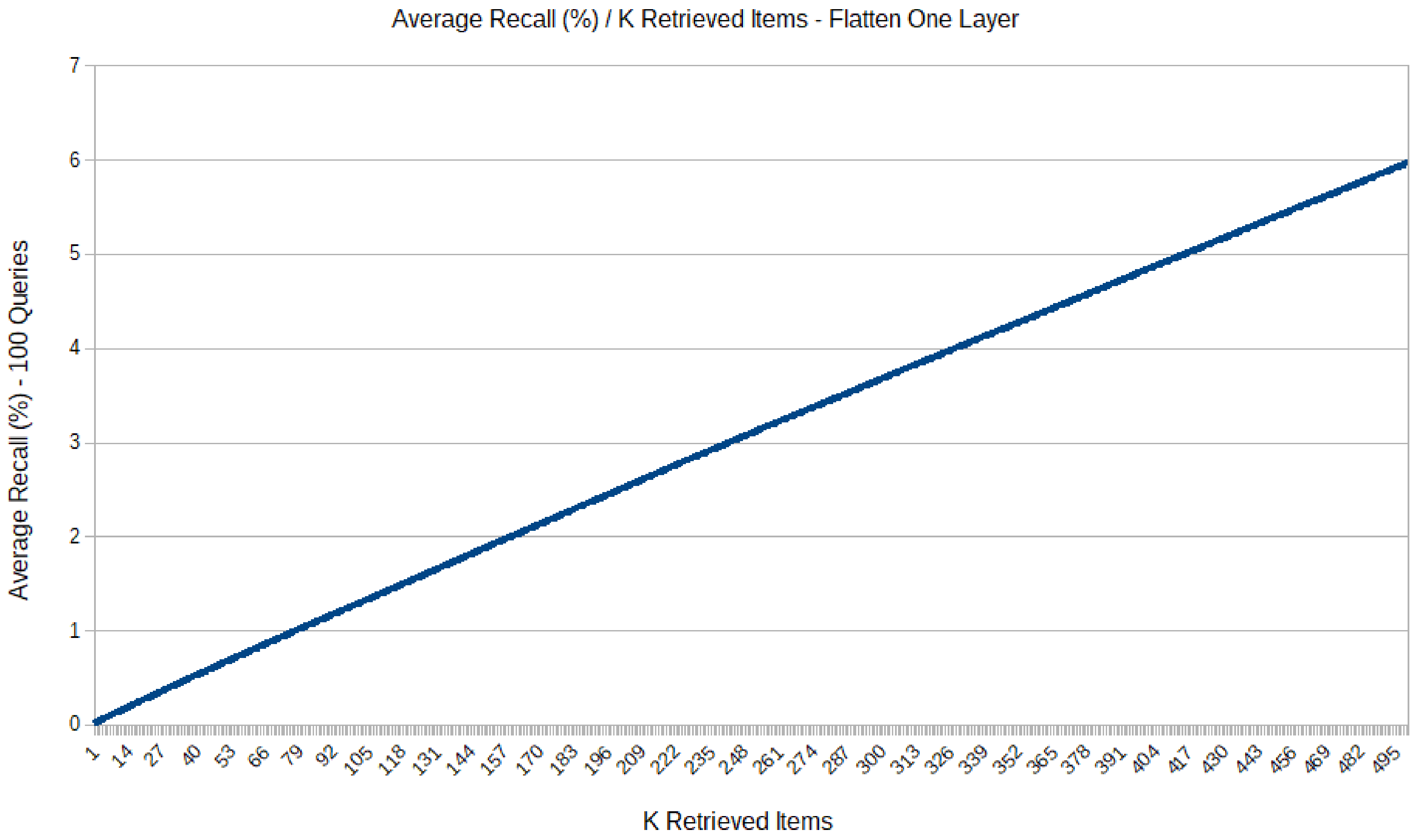
Curves

Average Precision / K Retrieved Items (for flatten_1 layer)



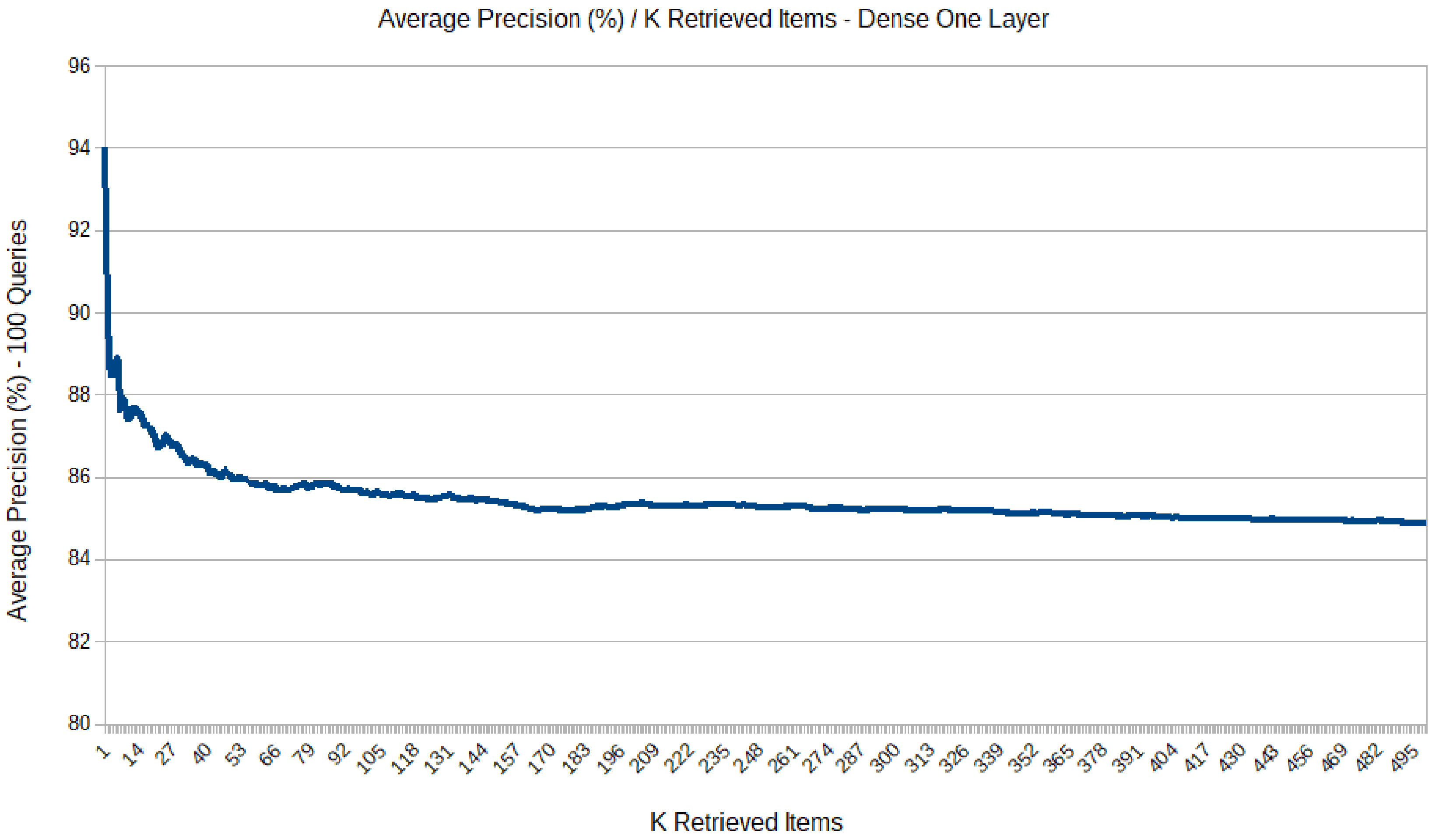
Curves

Average Recall / K Retrieved Items (for flatten_1 layer)



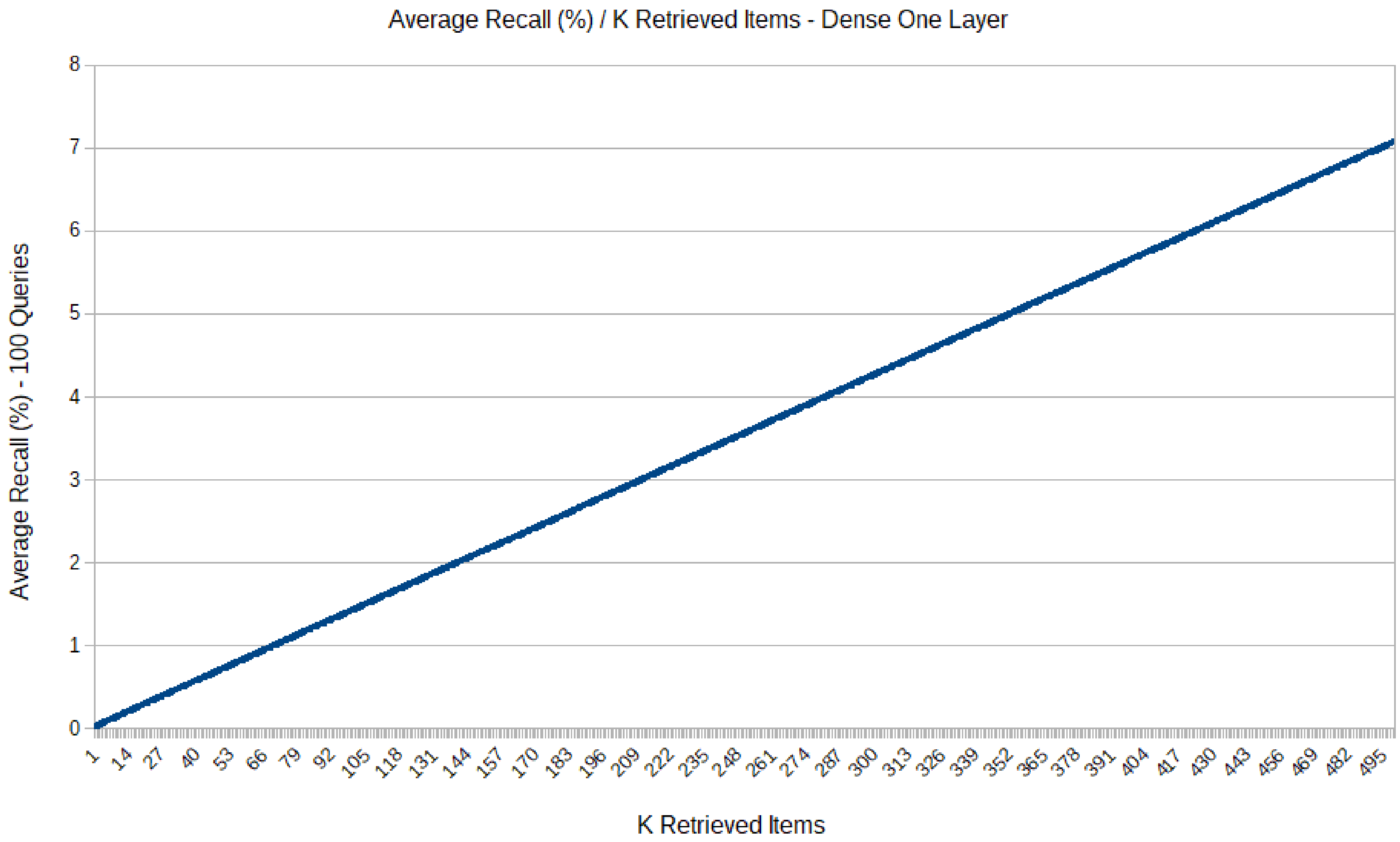
Curves

Average Precision / K Retrieved Items (for dense_1 layer)



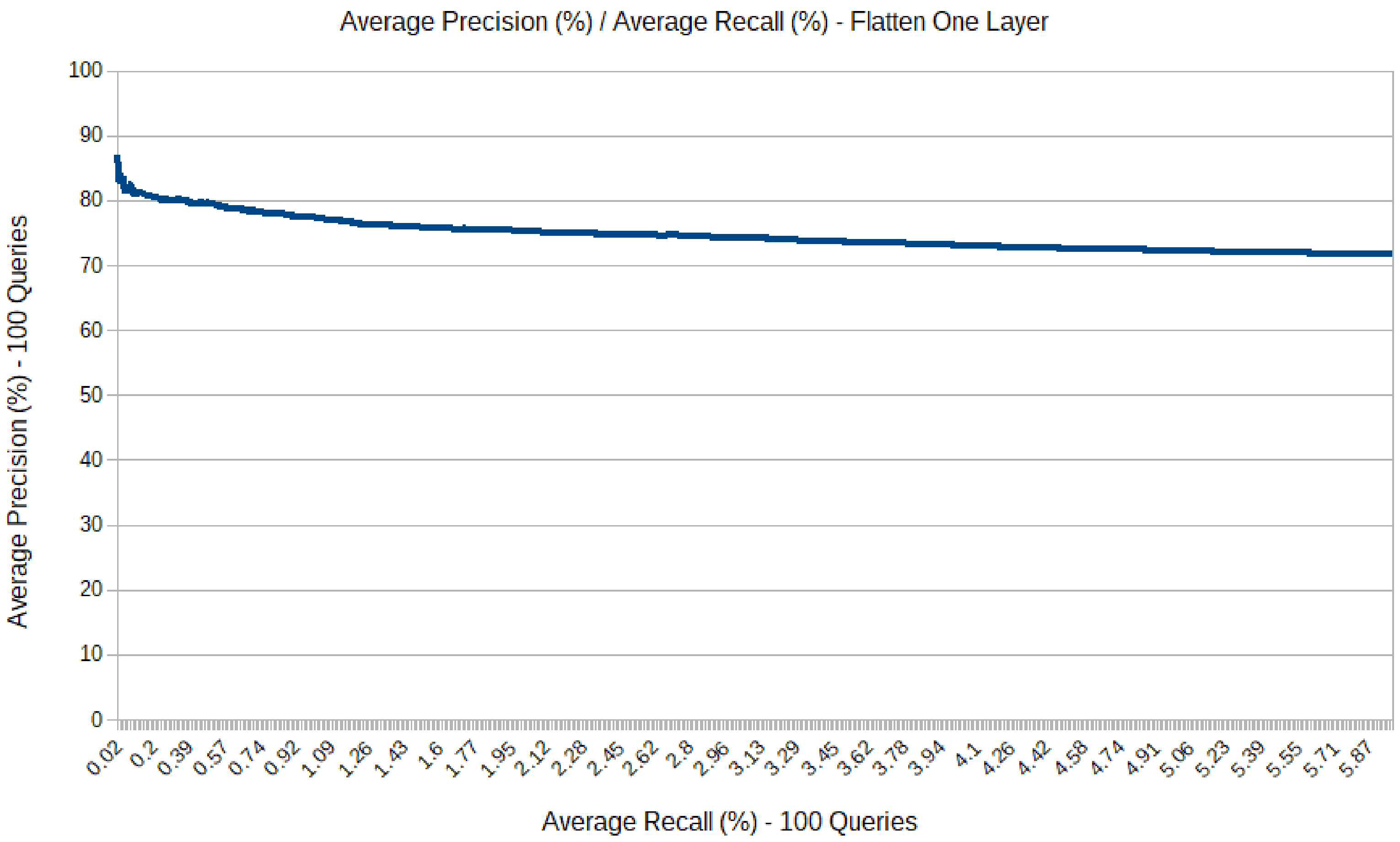
Curves

Average Recall / K Retrieved Items (for dense_1 layer)



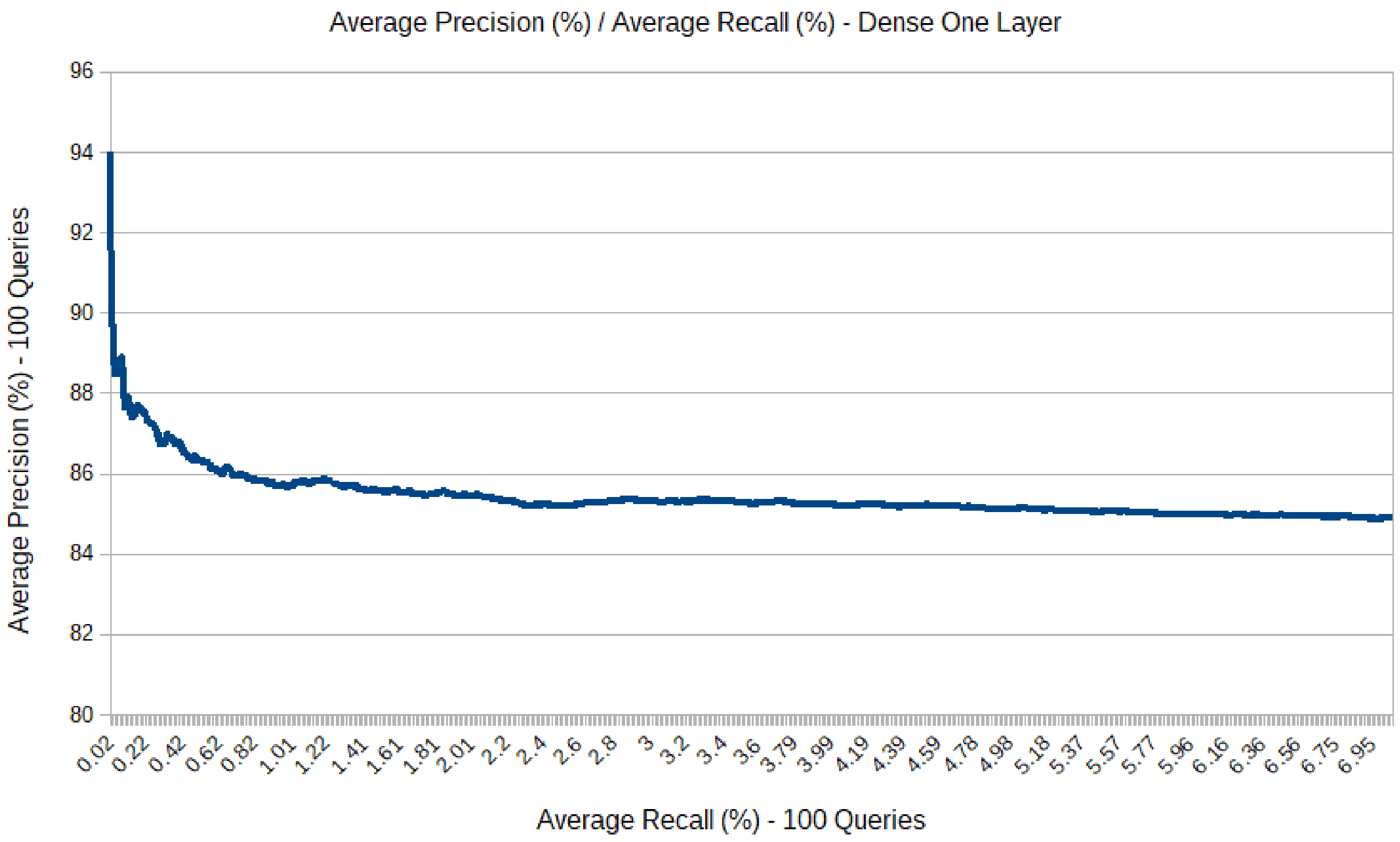
Curves

Average Precision / Average Recall (for flatten_1 layer)



Curves

Average Precision / Average Recall (for dense_1 layer)



Software Requirements

- Programming Languages : Python
- IDE : Spyder
- Application-level Dependency Manager: Anaconda
- Python Modules :

Module	Version
sklearn	0.19.1
numpy	1.14.3
matplotlib	2.2.2
keras	2.1.6
tensorflow	1.8.0

Thank you a lot and have a nice day!