University of Nottingham
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COMP3055 Machine Learning

General Idea for Lab4

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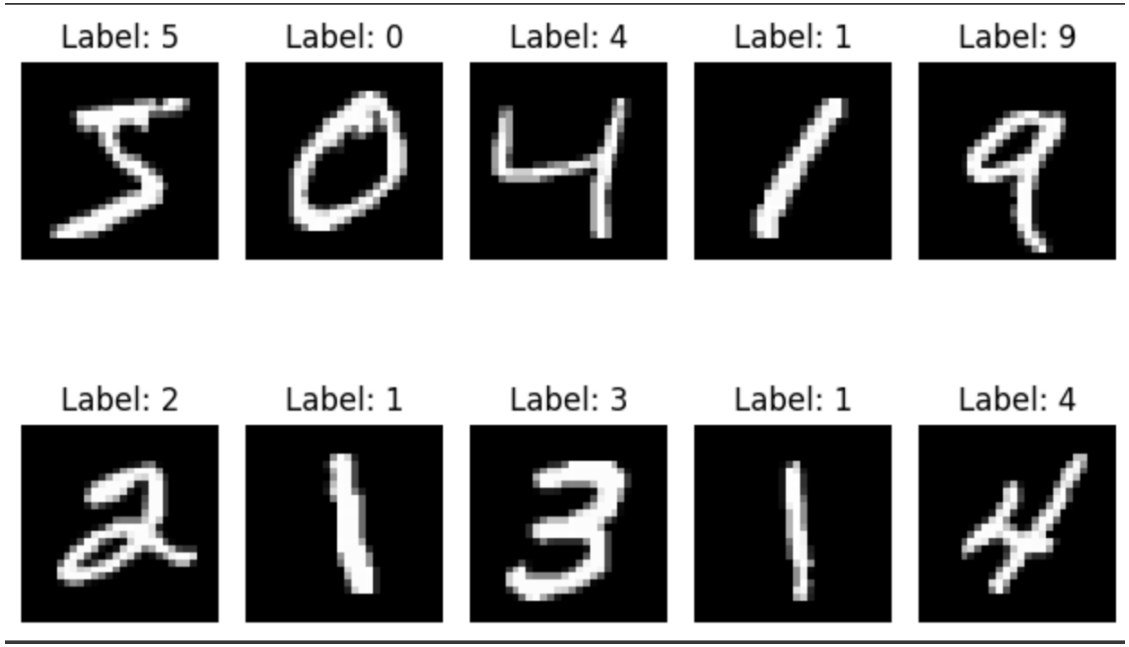
2024 Autumn

MNIST dataset

- **A handwritten digit dataset (number 0 to 9)**
- **Total 70000 images**
- **Each image is 28x28 grayscale image (pixel value 0 represents black, 255 represents white) , flatten into a 784-dimensional vector**



MNIST dataset

- An example of image 5


```
[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
[ 0 0 0 0 0 0 0 0 0 0 0 0 3 18 18 18 126 136 175 26 166
255 247 127 0 0 0 0] [ 0 0 0 0 0 0 0 0 0 30 36 94 154 170
253 253 253 253 253 225 172 253 242 195 64 0 0 0 0] [ 0 0
0 0 0 0 0 49 238 253 253 253 253 253 253 253 253 251 93
82 82 56 39 0 0 0 0 0] [ 0 0 0 0 0 0 0 18 219 253 253 253
253 253 198 182 247 241 0 0 0 0 0 0 0 0 0 0] [ 0 0 0 0 0 0
0 0 0 80 156 107 253 253 205 11 0 43 154 0 0 0 0 0 0 0 0
0 0] [ 0 0 0 0 0 0 0 0 0 14 1 154 253 90 0 0 0 0 0 0 0 0
0 0 0 0 0 0] [ 0 0 0 0 0 0 0 0 0 0 0 139 253 190 2 0 0 0
0 0 0 0 0 0 0 0 0 0] [ 0 0 0 0 0 0 0 0 0 0 0 11 190 253
70 0 0 0 0 0 0 0 0 0 0 0 0 0] [ 0 0 0 0 0 0 0 0 0 0 0 0 0
35 241 225 160 108 1 0 0 0 0 0 0 0 0 0] [ 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 81 240 253 253 119 25 0 0 0 0 0 0 0 0] [ 0
0 0 0 0 0 0 0 0 0 0 0 0 0 45 186 253 253 150 27 0 0 0 0 0
0 0 0] [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 16 93 252 253 187
0 0 0 0 0 0 0 0 0] [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 249
253 249 64 0 0 0 0 0 0 0] [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
46 130 183 253 253 207 2 0 0 0 0 0 0 0] [ 0 0 0 0 0 0 0 0 0
0 0 0 0 39 148 229 253 253 253 250 182 0 0 0 0 0 0 0 0] [
0 0 0 0 0 0 0 0 0 0 24 114 221 253 253 253 253 201 78 0 0
0 0 0 0 0 0 0 0] [ 0 0 0 0 0 0 0 0 0 23 66 213 253 253 253
253 198 81 2 0 0 0 0 0 0 0 0 0 0] [ 0 0 0 0 0 0 0 18 171
219 253 253 253 253 195 80 9 0 0 0 0 0 0 0 0 0 0 0 0] [ 0
0 0 0 55 172 226 253 253 253 253 244 133 11 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0] [ 0 0 0 0 136 253 253 253 212 135 132 16 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0] [0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
```

Naïve Bayesian Classifier

- What about using Naïve Bayesian Classifier for our handwritten digit recognition problem?
  - Each pixel is an x_i. There will be 784 x's.
  - Digit label is d_k. Note there will be 10 possible d's.
  - $P(d_k)$ can be calculated by counting number of training images for the digit, divided to total number of training images.
  - $P(x_i|d_k)$ can be calculated by counting number of images for a given digit, given pixel position, and given an intensity value, divided by number of training images with that digit.

Naïve Bayesian Classifier

$P(x_i|d_k)$ can be calculated by counting number of images for a given digit, given pixel position, and given an intensity value, divided by number of training images with that digit.

For example,

$$P(x_1 = 255|d = 0)$$
$$= \frac{Number\ of\ images\ whose\ first\ pixel\ value\ is\ 255\ and\ contain\ digit\ 0}{Total\ number\ of\ images\ contain\ digit\ 0}$$

Naïve Bayesian Classifier

- For a given input image X and given digit label d_k, calculate $P(d_k)$ and all $P(x_i|d_k)$
- For each digit label d_k, calculate
  $P(d_k|X) = P(d_k)P(x_1 = 0|d_k)P(x_2 = 255|d_k) \dots P(x_{784} = 0|d_k)$
- Choose the digit label k that give the max value according to above calculation.

0	255	0	0	0	0	0	0	0	0
0	0	0	0	255	255	0	0	0	0
0	0	0	255	0	0	255	0	0	0
0	0	0	0	0	0	255	0	0	0
0	0	0	0	0	255	0	0	0	0
0	0	0	0	255	0	0	0	0	0
0	0	0	255	0	0	0	0	0	0
0	0	0	255	0	0	0	0	0	0
0	0	0	255	0	0	0	0	0	0
0	0	0	255	255	255	255	255	255	0

Input image X