University of Nottingham
UK | CHINA | MALAYSIA

COMP3055
Machine Learning

Topic 1 – Design a Learning System

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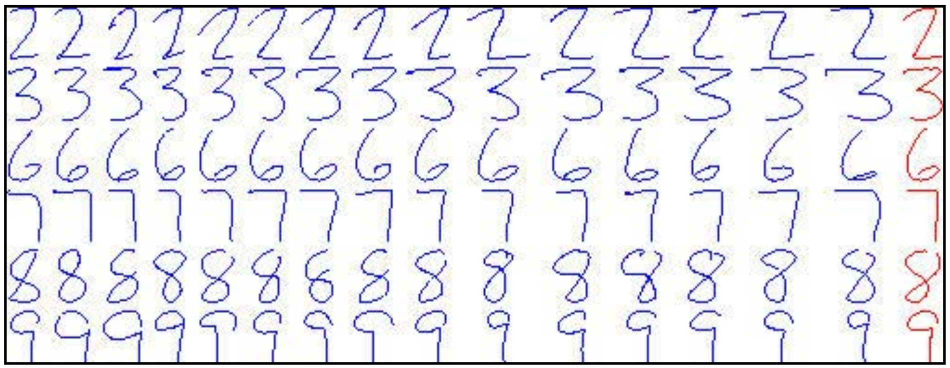
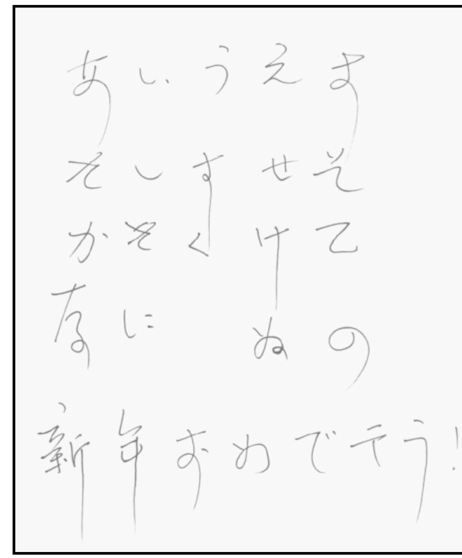
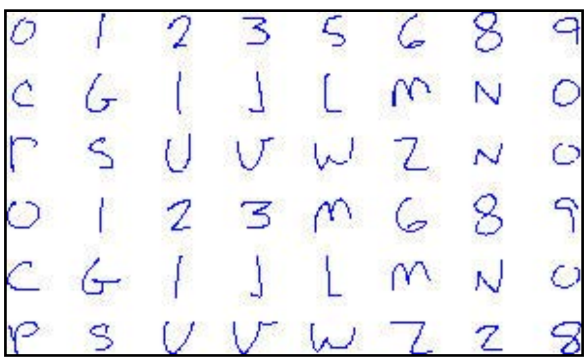
2018 Autumn

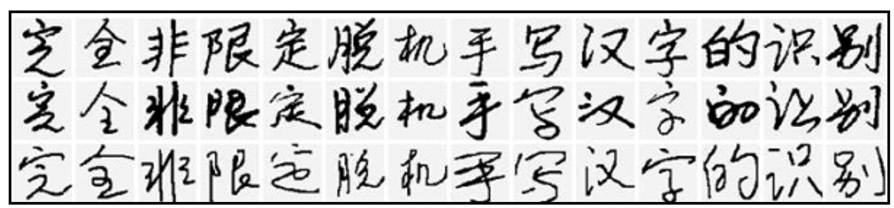
Motivating Problems

Handwritten Character Recognition









Motivating Problems

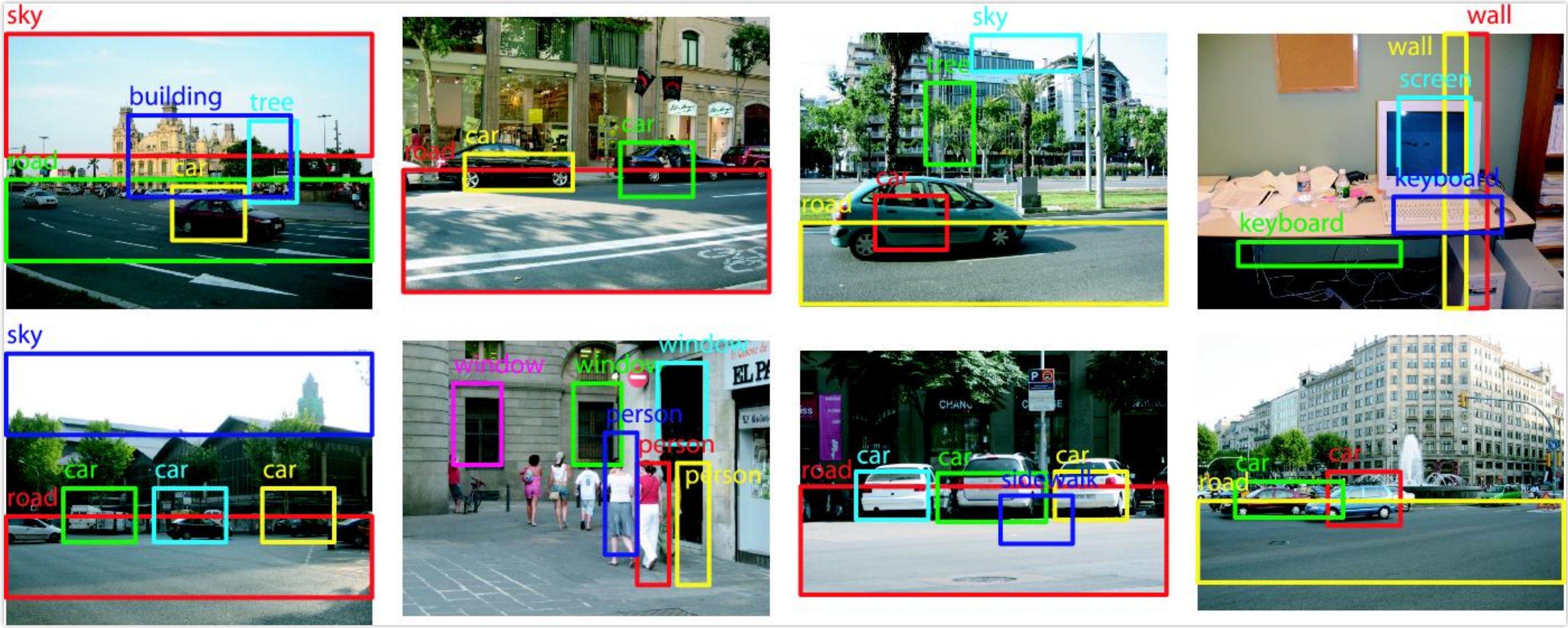
Fingerprint Recognition (e.g., border control)

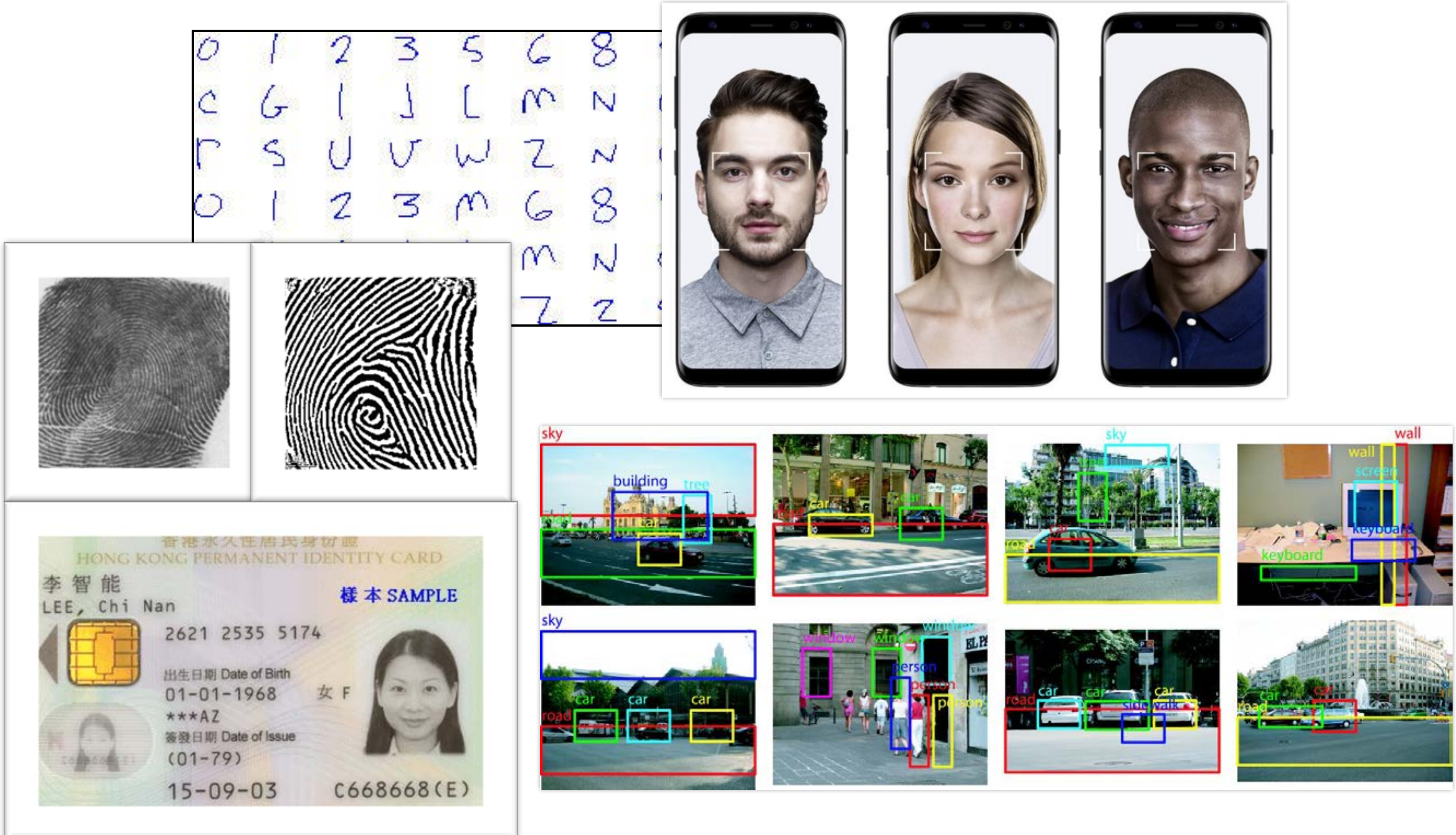
Motivating Problems

Face Recognition

Motivating Problems

Object Recognition





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Can Machines Learn to Solve These Problems?

Definition of Learning

A computer program is said to learn from experience ***E*** with respect to some class of tasks ***T*** and performance measure ***P***, if its performance at tasks in ***T***, as measured by ***P***, improves with experience ***E***.

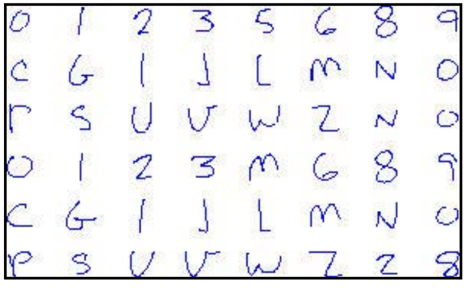
-- from Mitchell, Machine Learning, McGraw-Hill, 1997

Definition of Learning

What does this mean exactly?

For example, handwriting recognition problem

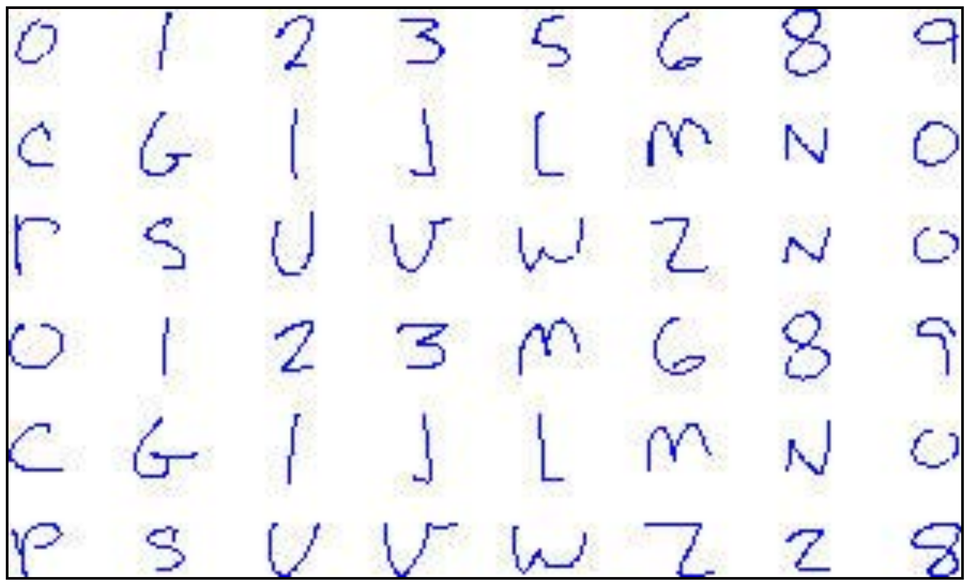
- Task ***T***: Recognizing hand written characters
- Performance measure ***P***: percent of characters correctly classified
- Training experience ***E***: a database of handwritten characters with given classifications



Definition of Learning

What are design issues and approaches?

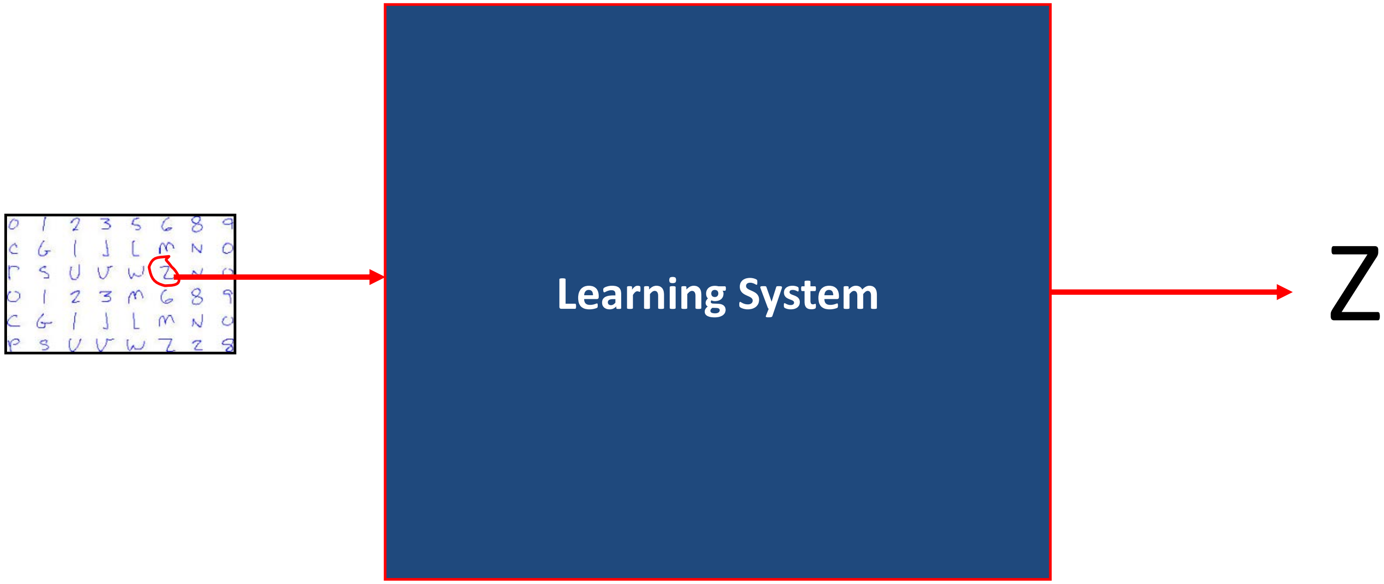
For example, handwriting recognition problem



Design a Learning System

Step 0:

– Lets treat the learning system as a black box

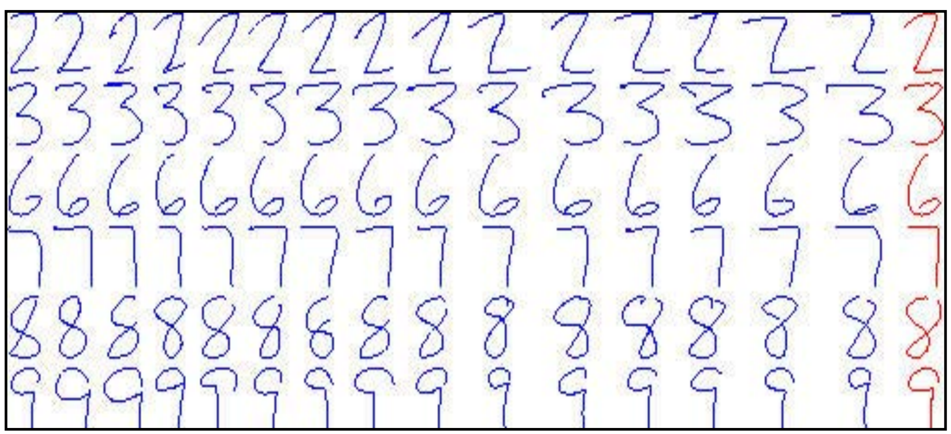


Design a Learning System

Step 1: Collect Training Examples (Experience).

- Without examples, our system will not learn
  - so-called learning from examples

Identify or Class or Label



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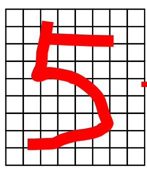
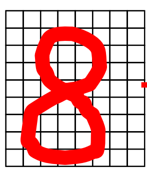
Design a Learning System

Step 2: Representing Experience

– Choose a representation scheme for the experience / examples



(1,1,0,1,1,1,1,1,1,1,0,0,0,0,1,1,1, 1,1,0, …., 1) 64-d Vector



(1,1,1,1,1,1,1,1,1,1,0,0,1,1,1,1,1, 1,1,0, …., 1) 64-d Vector

The sensor input represented by an n-d vector,
called the **feature vector**, **X** = $(x_1, x_2, x_3, \ldots, x_n)$

Design a Learning System

Step 2: Representing Experience

- THE MNIST DATABASE
  http://yann.lecun.com/exdb/mnist/

- The original black and white (bi-level) images from NIST were size normalized to fit in a 20x20 pixel box while preserving their aspect ratio. The resulting images contain grey levels as a result of the anti-aliasing technique used by the normalization algorithm. The images were centered in a 28x28 image by computing the center of mass of the pixels, and translating the image so as to position this point at the center of the 28x28 field.

Design a Learning System

Step 2: Representing Experience

- THE MNIST DATABASE
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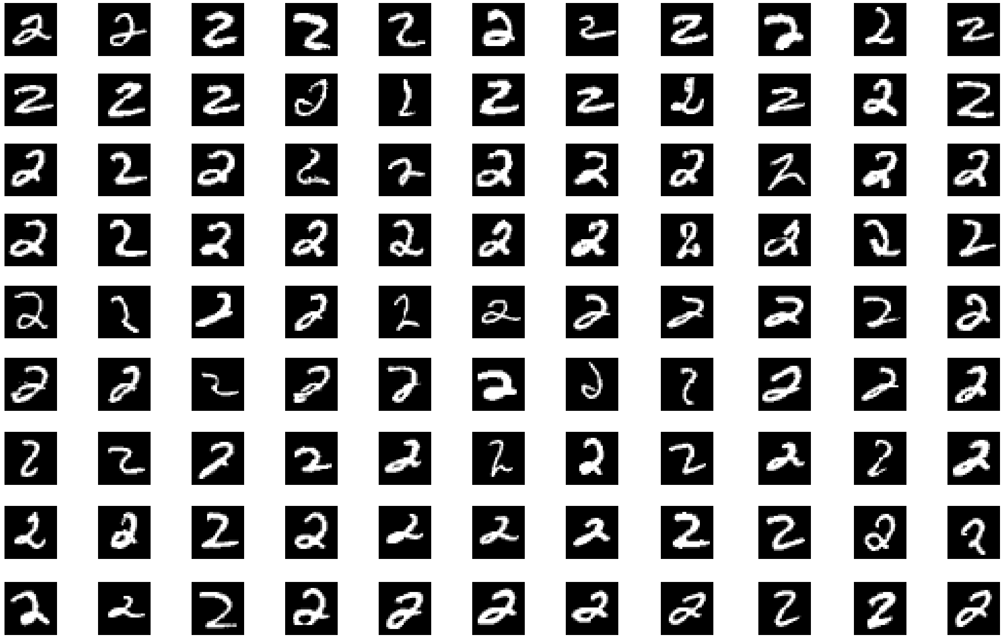

The feature vector of input data is a 784 dimensional vector

Design a Learning System

Step 2: Representing Experience

- Choose a representation scheme for the experience/examples

  - The sensor input represented by an n-d vector, called the feature vector, **X** = (x1, x2, x3, …, xn)

  - To represent the experience, we need to know what **X** is.

  - So we need a corresponding vector **D**, which will record our knowledge (experience) about **X**.

  - The experience **E** is a pair of vectors **E** = (**X**, **D**).

Design a Learning System

Step 2: Representing Experience

- Choose a representation scheme for the experience/examples.

  - The experience **E** is a pair of vectors **E** = (**X**, **D**).

- So, what would **D** be like? There are many possibilities.

Design a Learning System

Step 2: Representing Experience

- So, what would **D** be like? There are many possibilities.
- Assuming our system is to recognise 10 digits only, then D can be a 10-d binary vector; each correspond to one of the digits.

D = (d0, d1, d2, d3, d4, d5, d6, d7, d8, d9)

e.g,

if X is digit 5, then d5=1; all others =0

If X is digit 9, then d9=1; all others =0

Design a Learning System

Step 2: Representing Experience

– So, what would **D** be like? There are many possibilities.

– Assuming our system is to recognise 10 digits only, then D can be a 10-d binary vector; each correspond to one of the digits.

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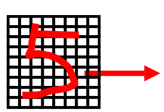
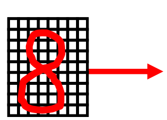


X = (1,1,0,1,1,1,1,1,1,1,0,0,0,0,1,1,1, 1,1,0, …., 1); 64-d Vector

D= (0,0,0,0,0,1,0,0,0,0)



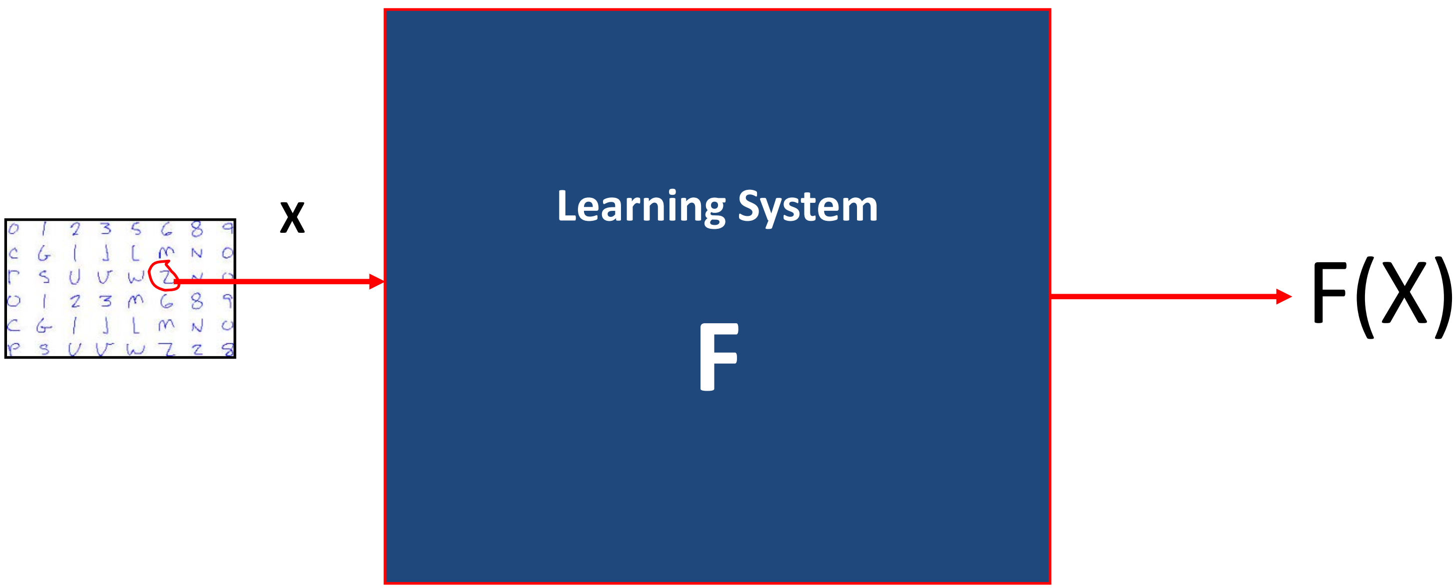
X= (1,1,1,1,1,1,1,1,1,1,0,0,1,1,1,1,1, 1,1,0, …., 1); 64-d Vector

D= (0,0,0,0,0,0,0,0,1,0)

Design a Learning System

Step 3: Choose a Representation for the Black Box

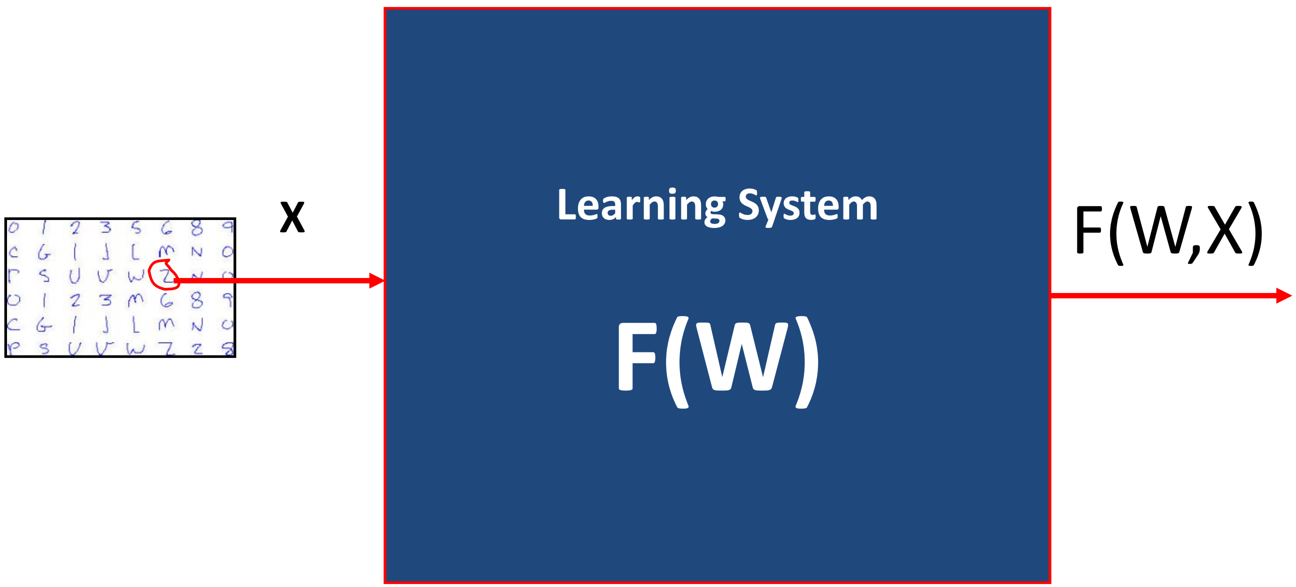
– We need to choose a function F to approximate the block box. For a given X, the value of F will give the classification of X. There are considerable flexibilities in choosing F.



Design a Learning System

Step 3: Choose a Representation for the Black Box

– F will be a function of some adjustable parameters, or weights, W = (w1, w2, w3, …w_N), which the learning algorithm can modify or learn



Design a Learning System

Step 4: Learning/Adjusting the Weights

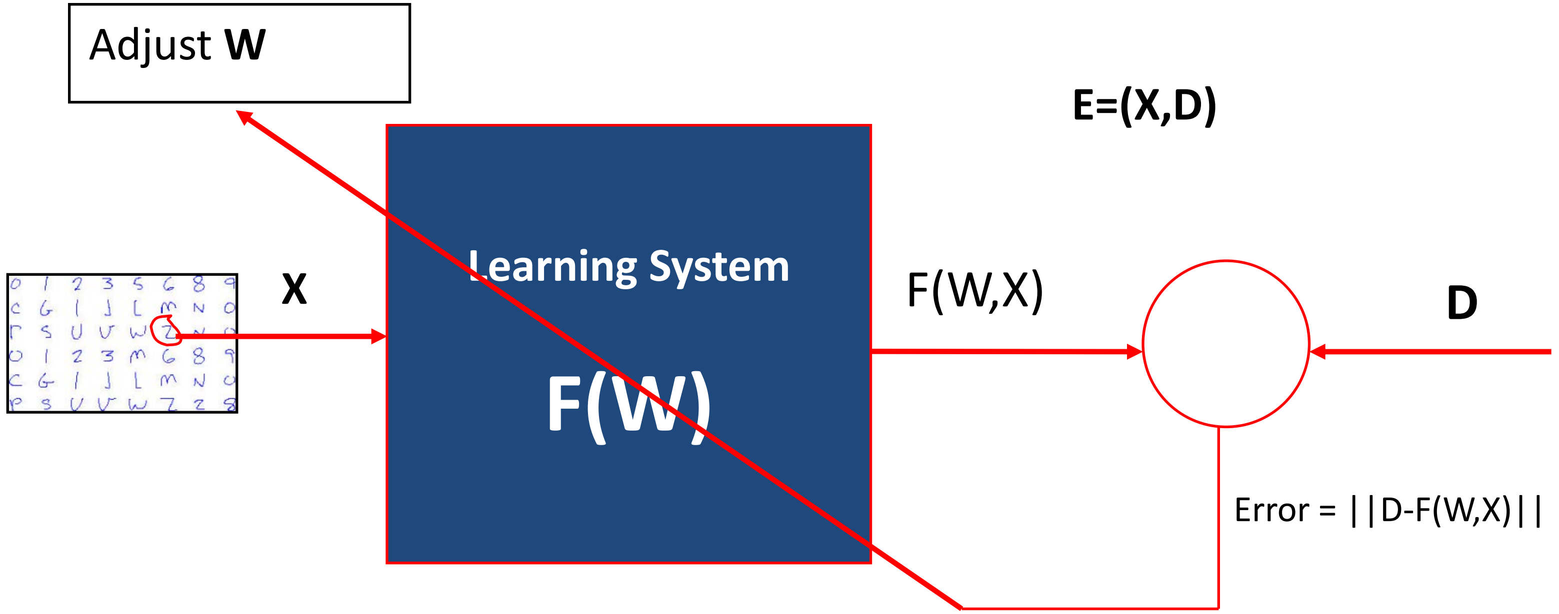
- We need a learning algorithm to adjust the weights such that the experience/prior knowledge from the training data can be learned into the system:

$$E=(X,D)$$

$$F(W,X) = D$$

Design a Learning System

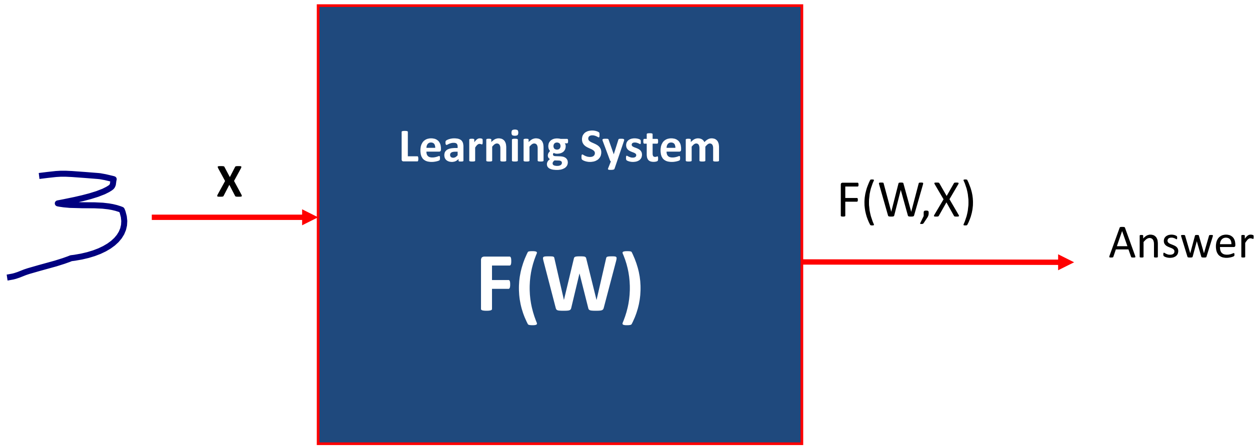
Step 4: Learning/Adjusting the Weights



Design a Learning System

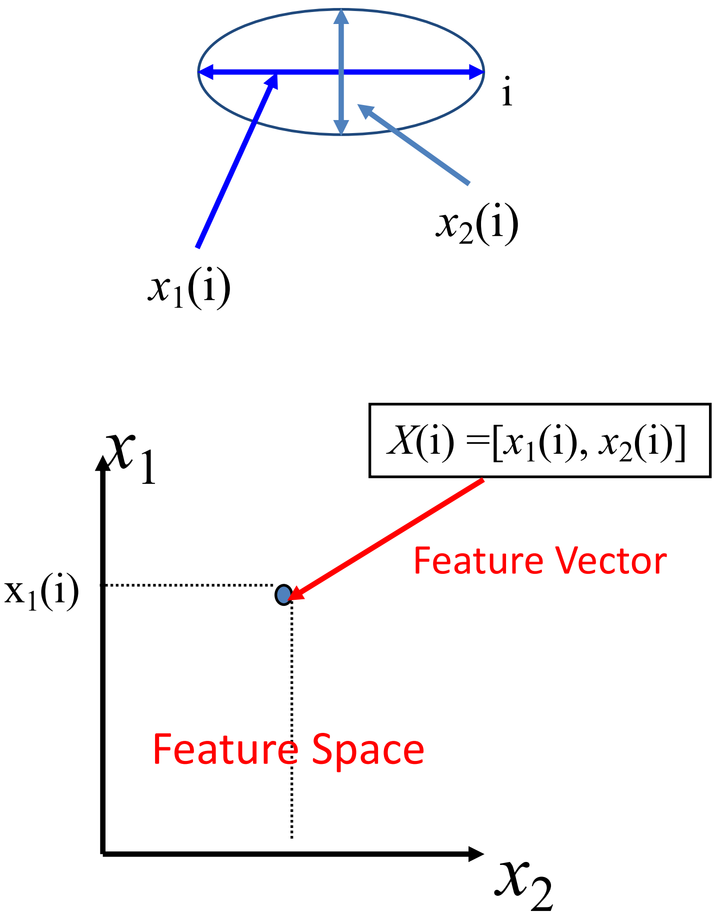
Step 5: Use/Test the System

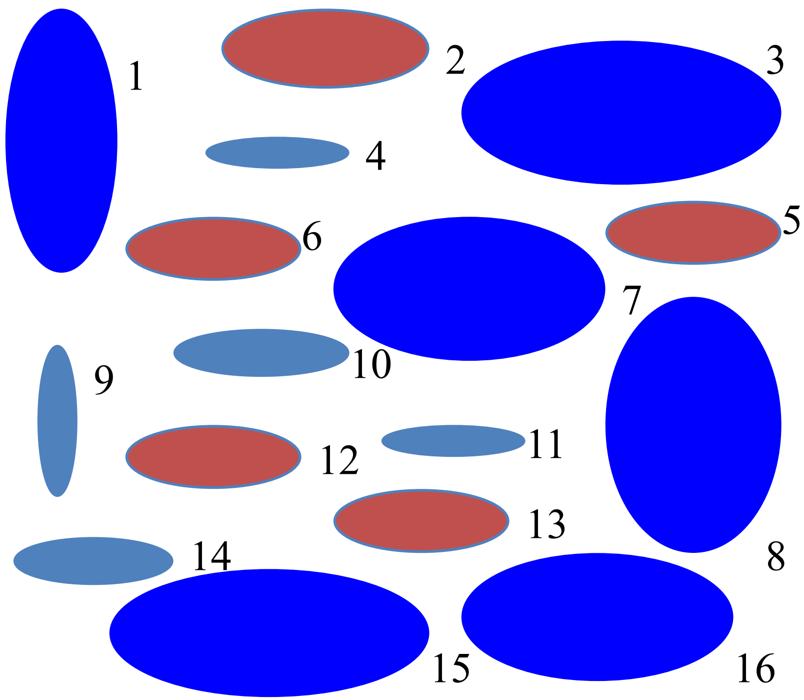
- Once learning is completed, all parameters are fixed. An unknown input **X** is presented to the system, the system computes its answer according to F(**W**,**X**)



Feature Space

Representing real world objects using **feature vectors**

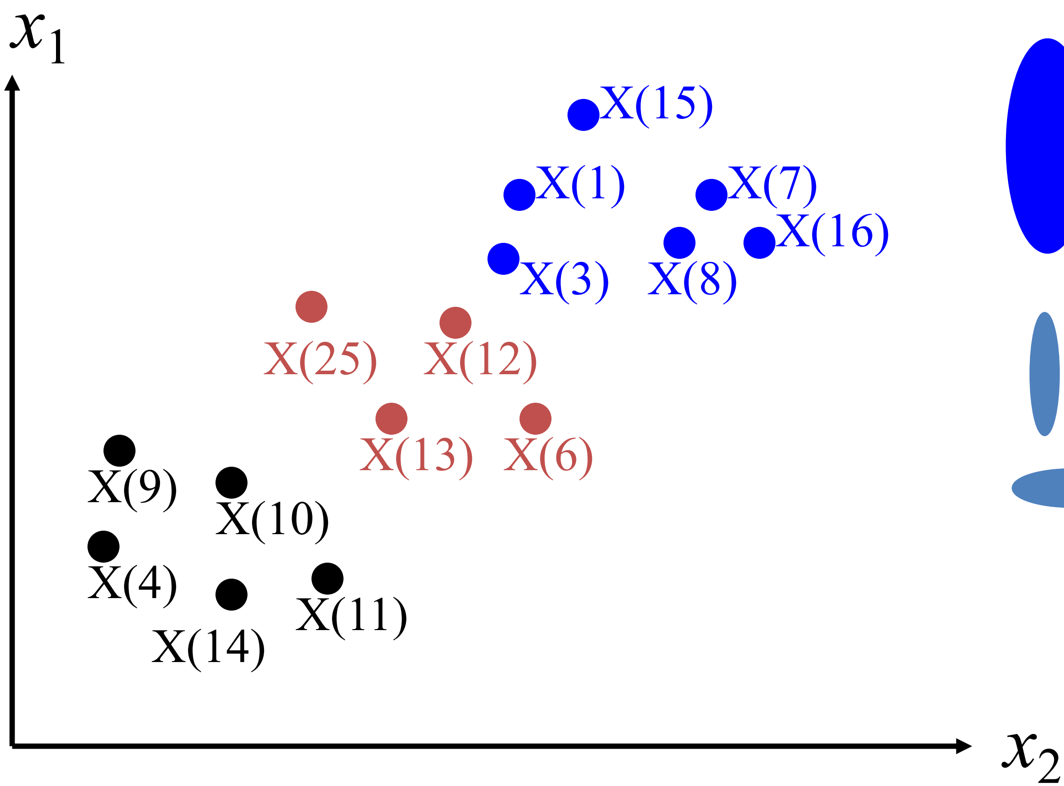


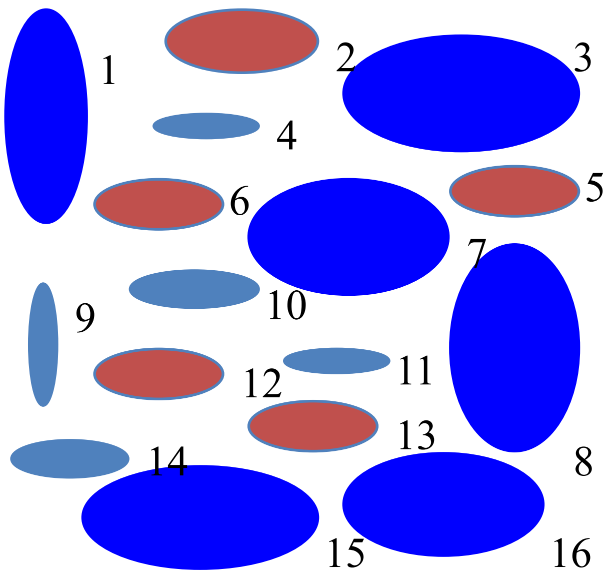


Elliptical blobs (objects)

Feature Space

From Objects to Feature Vectors to Points in the Feature Spaces





Elliptical blobs (objects)

Feature Space

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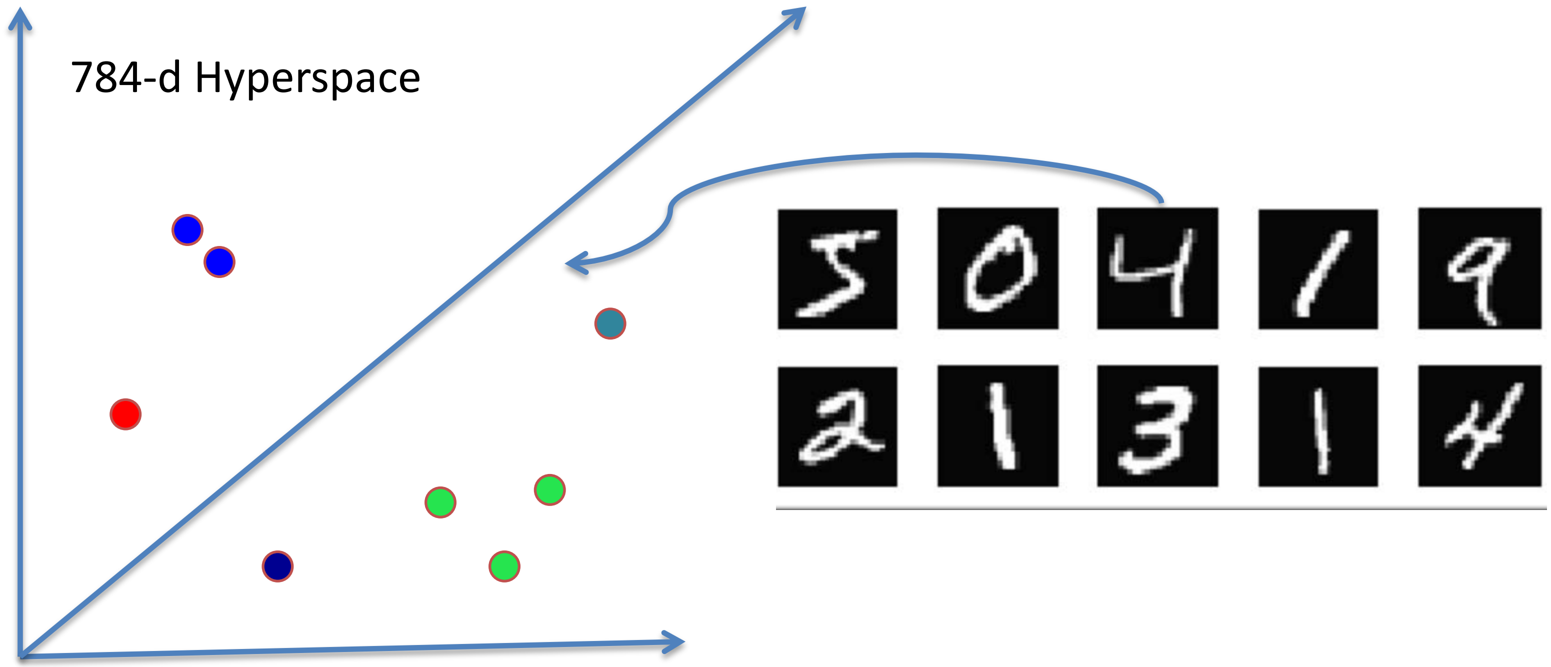

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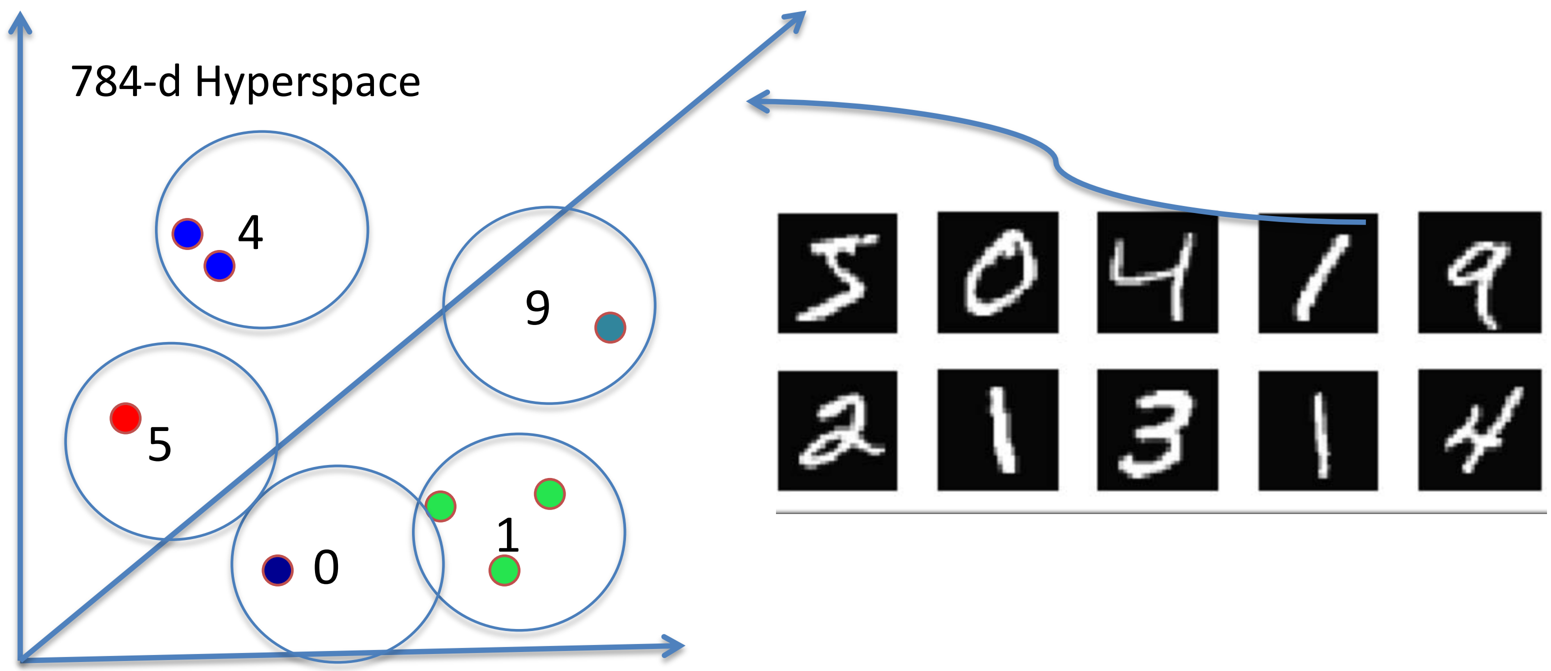

Representing General Objects

Feature vectors of

Faces

Cars

Fingerprints

Gestures

Emotions (a smiling face, a sad expression etc)

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Further Reading

Chapter 1, T. M. Mitchell, Machine Learning, McGraw-Hill International Edition, 1997