Fundamental Theories and Applications of Neural Networks

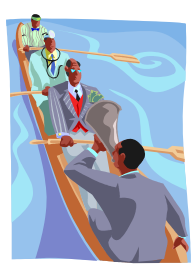
Lecture 1: Introduction

Contents of this lecture

- After this lecture, you will know
  - What is a neural network ?
  - Why should we study neural network ?
  - Some applications

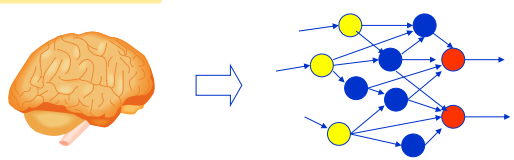
A Coordinative System

- A network is a system with many basic elements or components connected together.
- A good network usually has the 1+1>2 property.
- This kind of network is called a coordinative system.
- Examples of coordinative system include the human society, companies, etc.



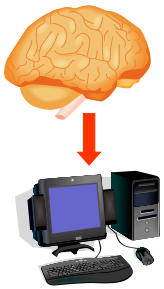
What is a neural network?

- A neural network is a coordinative system with neurons as the basic elements.
- A neuron is a brain cell in bio-neural networks.
- A neuron is a simple processing unit in artificial neural networks.



Why neural networks?

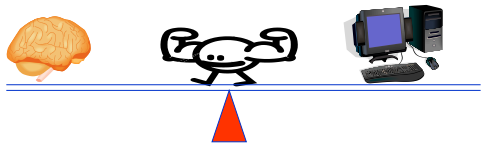
- Neural network is an analog of human brain.
- The whole network can make very fast decisions although each element is slow.
  - Massively parallel and decentralized computing.
- The whole network can be very reliable although each element is weak.
  - Reliable → Robust to noises or disturbances.
  - Fault tolerant.
- The whole network can be very intelligent although each element is stupid.
  - Each element is a simple unit.
  - The whole is an intelligent system.



Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Why neural networks?

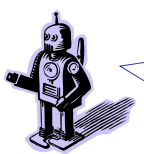
- Neural network is a different kind of computer .
- It has been proved theoretically that any computable problems can be solved by a Turing machine, and any Turing machine can be realized by a neural network.
- Thus, neural network is as powerful as the conventional computer, and can be used as universal computer.



Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Why neural networks?

- Neural network opens a way to solve problems without making programs.
- Neural networks can learn from experience, and can solve different kinds of problems through learning.
- Neural networks can learn in real-time, and can adapt to changing environments flexibly.



Mama, are you still making programs for that stupid computer?

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Disadvantages of neural networks

- Not good for fast, precise, and repeated arithmetic computations.
- Difficult to provide understandable and re-usable knowledge .
- Interpreting a learned NN is in general a hard problem.
- NN should be combined with existing computing technology to be more practically useful.

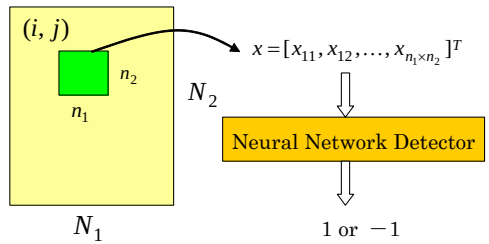
Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Applying NN to Face Detection

- Face detection is to search for a face in a given image.
- The image can be a still picture taken by a digital camera, or moving pictures captured by a video camera.
- This problem is important for many security related systems, internet based media search, etc.
- The problem is highly non-linear.
- NN can solve this problem effectively.

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Mechanism of the NN detector



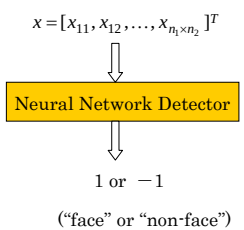
Test image

("face" or "non-face")

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Problem to solve

- A NN is represented by many parameters called weights.
- The basic problem is to find these weights using some available data, so that the NN outputs 1 if the input is a face; and outputs -1 if the input is not a face.
- The process for finding the weights is called learning or training.



("face" or "non-face")

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

How to find the weights?

- It is easy to fine-tune a radio because there is only one parameter, i.e., the frequency.
- It is usually very difficult to fine-tune the weights of an NN because the number of weights can be extremely large.
- Efficient learning is one of the main problems to be solved in the study of NNs.

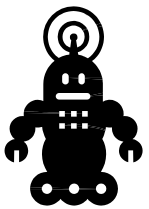
Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

What is pattern classification ?

- Face detection is an example of pattern classification or pattern recognition.
- In general, pattern recognition is the problem to classify given patterns into several classes.
  - Character recognition
  - Speech recognition
  - Face detection/recognition
- Pattern recognition is the basis for creating machines that can learn and think.

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Applying NN to Control of Mobile Robots



- There are many kinds of mobile "robots":
  - Wheel-chair
  - Cleaning robot
  - Patrolling robot
  - Guidance robot

- All these robots can be controlled, in principle, by neural network.

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

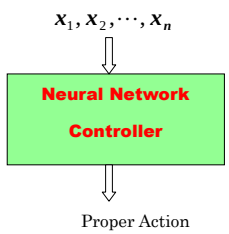
Why NN can control a robot?

- Control/navigation of a mobile robot is in fact a special case of pattern recognition.
- The problem is to make some proper decision based on the sensor inputs.
- For example,
  - For a patrolling robot, it is necessary to detect abnormal events and make a correct reaction.
  - For a cleaning robot, it is necessary to detect the garbage to clean, and find the shortest way to approach the garbage.

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Problem to solve

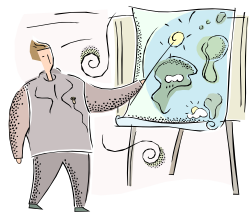
- As before, the main problem is to find the NN parameters so that for a given sensor input array (vector), the NN can select a correct action.
- After doing this action, the problem can be solved partially or completely.



Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Applying NN to Function Approximation

- Given the temperatures measured at full hours, guess the one at say 1:30.
- Given the electricity power needed so far, guess the one for the next 1 hour.
- Given stock values observed in the past few days, guess if we should buy or sell tomorrow.



Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

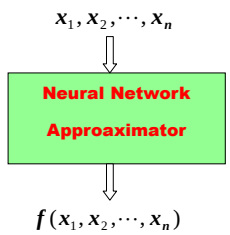
What is function approximation ?

- In general, function approximation is to find an unknown function from observed data.
- Function approximation is a common problem for many applications.
  - System control, design and identification.
  - Signal or image restoration and reconstruction.
  - Even design of neural networks is a special case of function approximation.

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Problem to solve

- As in face detection, the basic problem is to find the weights of the NN, so that for any point in the n-dimensional space, we can have an estimated value of the unknown function.



Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Stock prediction is an example of function approximation

- Stock index prediction/estimation is a good example of function approximation.
- Typical inputs include the 4 prices of each day, the moving average (MA) of 5 days, the volumes, etc.
- Typical outputs are the opening price of tomorrow, up or down, buy or sell, etc.
- Again, because there are many parameters, we must have an efficient mechanism for training the NN approximator .

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

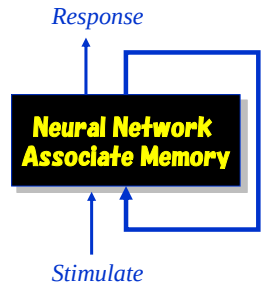
Applying NN to Content Based Information Retrieval

- Content based data retrieval is often called associative memory.
- The content can be slightly different from the ones stored in the memory.
- We can recognize the input pattern, find the most similar one in the memory, and output that pattern.

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Dynamic neural network approach

- The human brain may work in a completely different way.
- Possibly, the mechanism used in the human brain for associative memory is a dynamic system like an automaton.
- The given input pattern is used as the initial state.
- The system's state will change until converges to some equilibrium point, which will be used as the output.



Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Example of associate memory

(from the Textbook written by Prof. Zurada)

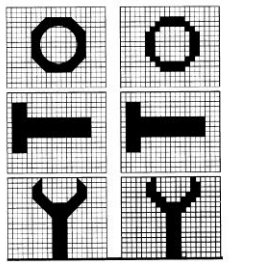


Figure 1.7 Memory network applications: (a) images of three mechanical parts and (b) images converted to bit-map forms.

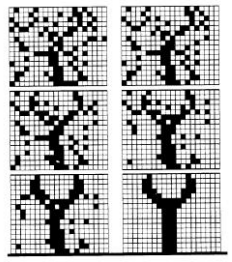


Figure 1.8 Restoration of the wrench image.

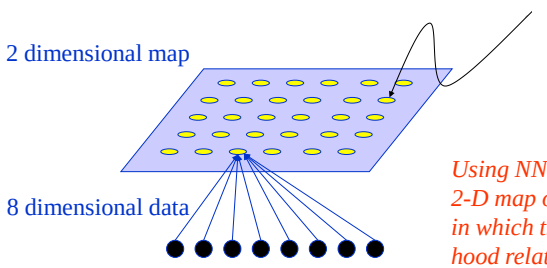
Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

Applying NN to Information Visualization

- Data mining is a relatively new field for data analysis.
- The purpose is to extract rules or relations between data, and use these knowledge to gain profit.
- Data visualization is an important way to SEE the relation between data points in a high-dimensional space.
- Self-organized feature map is a kind of neural network for this purpose.

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

How to visualize high dimensional data?

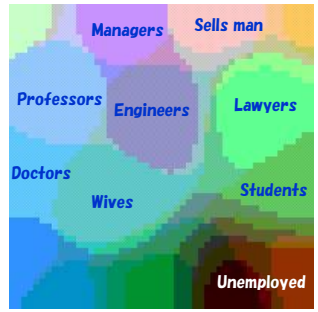


Using NN, we can find a 2-D map of the data, in which the Neighbor-hood relationship is preserved

Produced by Qiangfu Zhao (Since 1997), All rights reserved ©

An example: Issue a credit card or not?

- All users can be categorized into several groups according to their occupations.
- The data can be visualized by mapping them to a 2-D space.
- From this map, we can see if a person is a payable user or not.



Produced by Qiangfu Zhao (Since 1997), All rights reserved ©