Fundamental Theories and Applications of Neural Networks

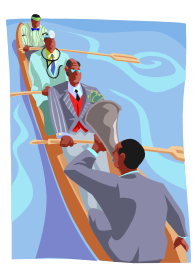
Lecture 1: Introduction

Contents of this lecture

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

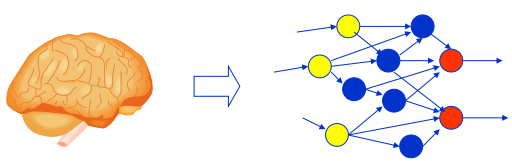
A Coordinative System

- 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.



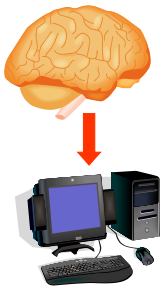
What is a neural network?

- 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.



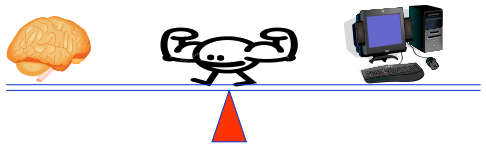
Why neural networks?

- 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.



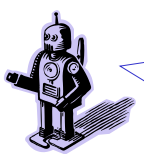
Why neural networks?

- 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.



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?

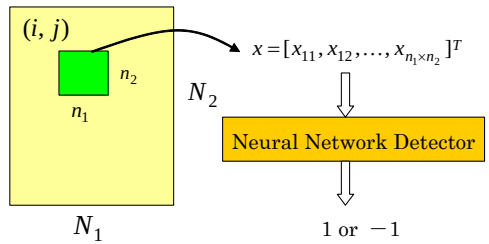
Disadvantages of neural networks

- 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.

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.

Mechanism of the NN detector

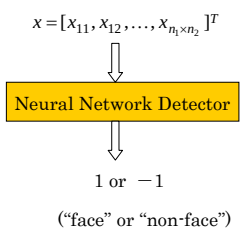


Test image

("face" or "non-face")

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")

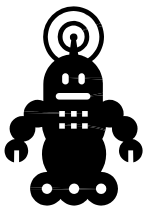
How to find the weights?

- 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.

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.

Applying NN to Control of Mobile Robots



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

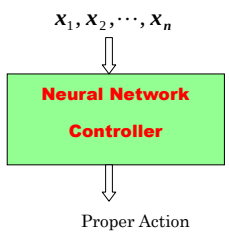
- All these robots can be controlled, in principle, by neural network.

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.

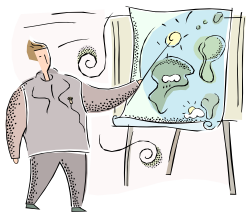
Problem to solve

- 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.



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.

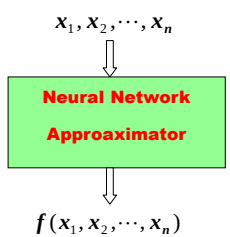


What is function approximation ?

- 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.

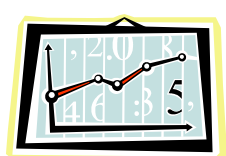
Problem to solve

- 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.



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 .

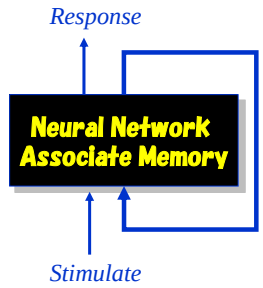


Applying NN to Content Based Information Retrieval

- 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.

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.



Example of associate memory

(from the Textbook written by Prof. Zurada)

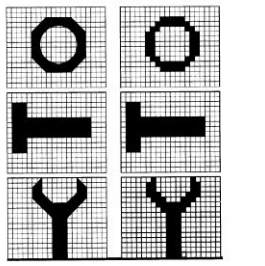


Figure 1.7 Memory network applications: (a) images of three mechanical parts and (b) images converted to bit-map forms.

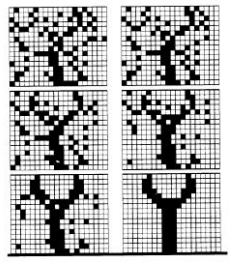
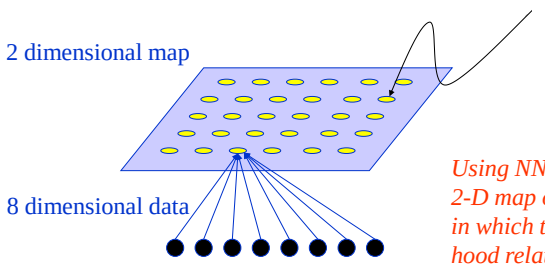


Figure 1.8 Restoration of the wrench image.

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.

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

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.