Lecture 1: An Introduction to Neural Nets and Fuzzy Systems

Instructor: Mahdi Jalili
• **AI**: Applying nature-inspired computations in engineering, mathematics …

• **Bioinformatics**: Applying engineering and mathematical tools for biological problems

• **AI computing tool**
  - Artificial neural networks
  - Fuzzy systems
  - Genetic algorithms
  - Swarm intelligence
  - …
Fuzzy Systems and logic

- real-world systems are not crisp
- uncertainty in the system
- fuzzy approach as a solution
- conventionally applied to Control problems
- often based on a number of rules
- for example:
  - If it's Sunny and Warm, drive Fast
    Sunny(Cover) ∧ Warm(Temp) ⇒ Fast(Speed)
  - If it's Cloudy and Cool, drive Slow
    Cloudy(Cover) ∧ Cool(Temp) ⇒ Slow(Speed)
  - Driving Speed is the combination of output of these rules...
  - How fast will I go if it is
    - 21 C°
    - 25 % Cloud Cover?
Indeed

- Fuzzy Logic provides way to calculate with imprecision and vagueness
- Fuzzy Logic can be used to represent some kinds of human expertise
- We use Fuzzy Membership Sets
- We use Fuzzy Linguistic Variables
- We use Fuzzy AND and OR
Fuzzy system applications

- Pattern recognition and classification
- Fuzzy clustering
- Image and speech processing
- Fuzzy systems for prediction
- Fuzzy control
- Monitoring
- Diagnosis
- Optimization and decision making
- Group decision making
- …
Fuzzy system applications

Vehicle Control

A number of subway systems, particularly in Japan and Europe, are using fuzzy systems to control braking and speed. One example is the Tokyo Monorail.
Fuzzy system applications

Appliance control systems

- Fuzzy logic is starting to be used to help control appliances ranging from rice cookers to small-scale microchips (such as the Freescale 68HC12).

- You may have heard of
  - intelligent washing machine
  - intelligent refrigerator
  - intelligent ....

- Many of them are based on fuzzy logic
In order to illustrate some basic concepts in Fuzzy Logic, consider a simplified example of a thermostat controlling a heater fan illustrated in the Figure.

The room temperature detected through a sensor is input to a controller which outputs a control force to adjust the heater fan speed.
Conventional Thermostat

• A conventional thermostat works like an on-off switch.
• If we set it at 28°C then the heater is activated only when the temperature falls below 24°C.
• When it reaches 32°C the heater is turned off.
• As a result the desired room temperature is either too warm or too hot.
Fuzzy Thermostat

• A fuzzy thermostat works in shades of gray where the temperature is treated as a series of overlapping ranges.
• For example, 28°C is 60% warm and 20% hot. The controller is programmed with simple if-then rules that tell the heater fan how fast to run.
• As a result, when the temperature changes the fan speed will continuously adjust to keep the temperature at the desired level.
conventional vs fuzzy thermostat

28°C
fuzzy decision making

- It can be difficult to distinguish between various goals and categories at times
  - Is a goal in an e-commerce decision hard or soft?
  - When is a restaurant crowded, or only slightly crowded?
- There have been many projects in which fuzzy logic has been combined with decision support systems
- One common case is in navigational and sensor systems for robotics
Artificial neural networks

- Inspired from neurons in the nervous system
- Nowadays has nothing to do with real systems!
- A single neuron modeled as a system with input, output and transfer (activation) function
- A network of neurons is formed
- Have applications in both supervised and unsupervised cases
- Have applications in modeling dynamic data such as time series
Supervised Applications

- **Classification/Pattern recognition:**
  - The task of pattern recognition is to assign an input pattern (like handwritten symbol) to one of many classes. This category includes algorithmic implementations such as associative memory.

- **Function approximation:**
  - The tasks of function approximation is to find an estimate of the unknown function $f(.)$ subject to noise. Various engineering and scientific disciplines require function approximation.

- **Prediction/Dynamical Systems:**
  - The task is to forecast some future values of a time-sequenced data. Prediction differs from Function approximation by considering time factor.
  
  Here the system is dynamic and may produce different results for the same input data based on system state (time).
Function Approximation: Body Density

Predict the real “body density” (e.g. % body fat) calculated using a submersion test using easier to obtain data:

- Age (years),
- Weight (lbs),
- Height (inches),
- Neck circumference (cm),
- Chest circumference (cm),
- Abdomen 2 circumference (cm),
- Hip circumference (cm),
- Thigh circumference (cm),
- Knee circumference (cm),
- Ankle circumference (cm),
- Biceps (extended) circumference (cm),
- Forearm circumference (cm),
- Wrist circumference (cm)

- Real relationship is unknown, but if outputs of our system match correct values, we have a good model.
Classification

- Similar to function approximation except output is a “class”
  - For example:
    - Outputs = on or off
    - Outputs = Ford, Chevy, or Buick
    - Outputs = Sick or Healthy
Classification: Character Recognition

- NN is used to classify each character
- Extract features as input to NN
- Pixels also can be used as input
- Output is the class of the test character

Classification: Speaker Identification

- Determine the speaker identity
- Selection between a set of known voices

V. Moonasar, G. K. Venayagamoorthy, "Speaker Identification using a Combination of Different Parameters as Feature Inputs to an Artificial Neural Network Classifier", IEEE AFRICON, 1999.
Prediction: Technical Analysis

- Technical analysis rests on the assumption that history repeats itself.
  - Example: future market direction can be determined by examining past prices.
  - Using price, volume, and open interest statistics, the technical analyst uses charts to predict future stock movements.
ANN For Prediction
Time-series prediction

- Financial applications:
  - Predicting Stock trading
Medical Decision Making

- Predicting Blood Transfusion for Emergency Patients
- 1016 patient records are used for training
- Only data of patients upon entry
- ANN is used for predicting the amount of blood needed for transfusion

Estimate the Risk of Mortality

- Use of a Probabilistic Neural Network to Estimate the Risk of Mortality after Cardiac Surgery
- Patient records were randomly divided into training (732) and validation (380)
- The model uses seven variables, each obtainable during routine clinical patient care.

Risk of Mortality Results
Medical Diagnosis

- Diagnosis of Patients based on their symptoms
- UCI machine learning benchmark repository

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<th>Data set</th>
<th>Input Attributes</th>
<th>Output Units</th>
<th>Output Classes</th>
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## Medical Diagnosis Results

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NN for Diagnosing Breast Cancer from Image

- Extract some features using Image processing methods
- Features:
  - Mass Size
  - Mass shape
  - Mass density
  - Asymmetric density
  - Many other features including patients symptoms and experiment results
- Output: Classify Benign or Malignant?
Control: Siemens ANN Process Control

• Used in parallel to old system to control the parameters of the steel process
• Mainly used to tune the parameters to increase the Steel Grade and Steel Sheet Thickness
• Needs Adaption or else the error will increase after a few days

A recurrent neural network compensator for suppressing mechanical vibration in a permanent magnet linear synchronous motor (PMLSM) is studied.

Uses ANN for Oil Spill Detection using Satellite Images (ERS-SAR)

Several Statistical and Image Processing features are extracted from Image

NN for Pharmaceutical Formulation

- Relationship between casual factors and individual pharmaceutical responses.
- NN is used to extract nonlinear relationships between these two.
- Several responses relating to the effectiveness, safety and usefulness must be optimized simultaneously.

And ...

- Much more examples where ANNs are used for modeling, identification, approximation, denoising, and recognition.