Master of Technology in Knowledge Engineering

Unit 7:

Developing Intelligent Systems for Performing Business Analytics

Fuzzy Modelling

Dr. Zhu Fangming
Institute of Systems Science,
National University of Singapore.
E-mail: isszfm@nus.edu.sg

Why Fuzzy Modelling

- **In general, we design a fuzzy inference system based on the past known behaviour of a target system. The fuzzy system is then expected to be able to reproduce the behaviour of the target system.**
  - » **E.g.:**
    Target system: **a human operator in charge of a chemical reaction process**
    Fuzzy system: **a fuzzy controller**
  - » **E.g.:**
    Target system: **a medical doctor**
    Fuzzy system: **a fuzzy expert system for medical diagnosis**

- **The process called *Fuzzy modelling* is the standard method for constructing a fuzzy inference system.**

What is Fuzzy Modelling

- **Features of fuzzy modelling**
  - » **Fuzzy modelling takes advantage of domain knowledge that might not be easily or directly employed in other modelling approaches.**
  - » **The rule structure of a fuzzy inference system makes it easy to incorporate human expertise about the target system directly into the modelling process.**
  - » **In fuzzy modelling, the use of numerical data also plays an important role.**

- ***Conceptually*, there are 2 stages of fuzzy modelling**
  - » **The identification of the surface structure**
  - » **The identification of deep structure**

Identification of Surface Structure — the first stage of fuzzy modelling

- **Generally, it includes four tasks:**
  - » **Select relevant input and output variables**
  - » **Choose a specific type of fuzzy inference system**
  - » **Determine the number of linguistic terms associated with each input and output variables. The membership function of linguistic terms is determined in the second stage**
  - » **Design a collection of fuzzy if-then rules (fuzzy rule base) in a *symbolic* style:**
    - ♦ **i.e. IF *x* is *A* THEN *y* is *B***
- **In this stage, we basically rely on**
  - » **Our own knowledge (common sense, simple physical laws, etc) of the target system**
  - » **Information provided by human experts who are familiar with the target system (which could be the human experts themselves)**

Identification of Deep Structure
— the second stage of fuzzy modelling

- **Specifically, it may include the following tasks:**
  - » **Choosing an appropriate family of *parameterised* membership functions used in the rule base**
    - ♦ **Piecewise linear function**
      - **Triangular**
      - **Trapezoidal**
    - ♦ **non-linear, differentiable function:**
      - **Gaussian**
      - **Bell**
  - » **Interview human experts familiar with the target systems to determine the parameters of the membership functions used in the rule base**
  - » **Learning/Refining the parameters by certain optimisation techniques**
    - ♦ **Learning membership functions from training data: NN approaches**
    - ♦ **Optimisation: GA**

Brief Review of Fuzzy Inference System

- **Basic architecture**
  - » **rule base**
  - » **data base**
  - » **reasoning mechanism**
- **Different fuzzy models**
  - » **Mamdani fuzzy model**
    - ♦ **first attempt to control system**
  - » **Sugeno fuzzy model (TSK model)**
- **Main steps**
  - » **Fuzzification**
  - » **Rule evaluation**
  - » **Defuzzification**

Visualising Fuzzy Rules

- **A fuzzy associative matrix (FAM) shows the maximum set of possible rules for a problem**
- **In the example there are nine possible rules to control a heater.**

temperature →

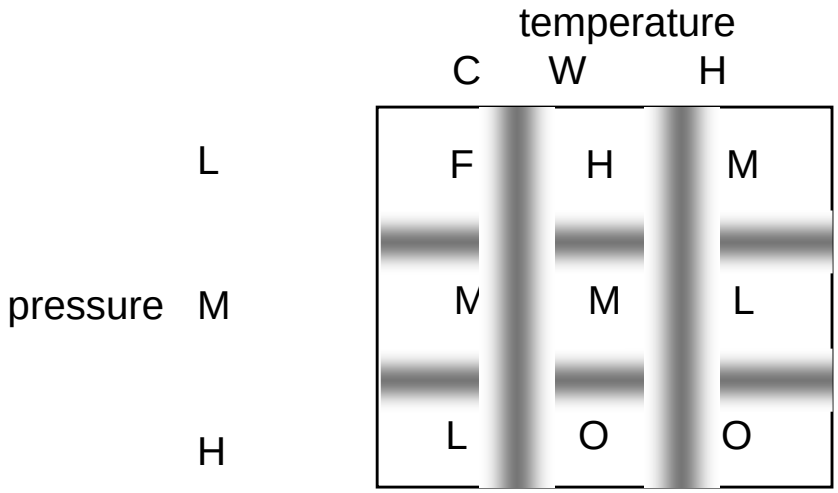
pressure ↓	*cold*	*warm*	*hot*
low	Full	High	Medium
medium	Medium	Medium	Low
high	Low	Off	Off

- **Which box corresponds to the rule below?**

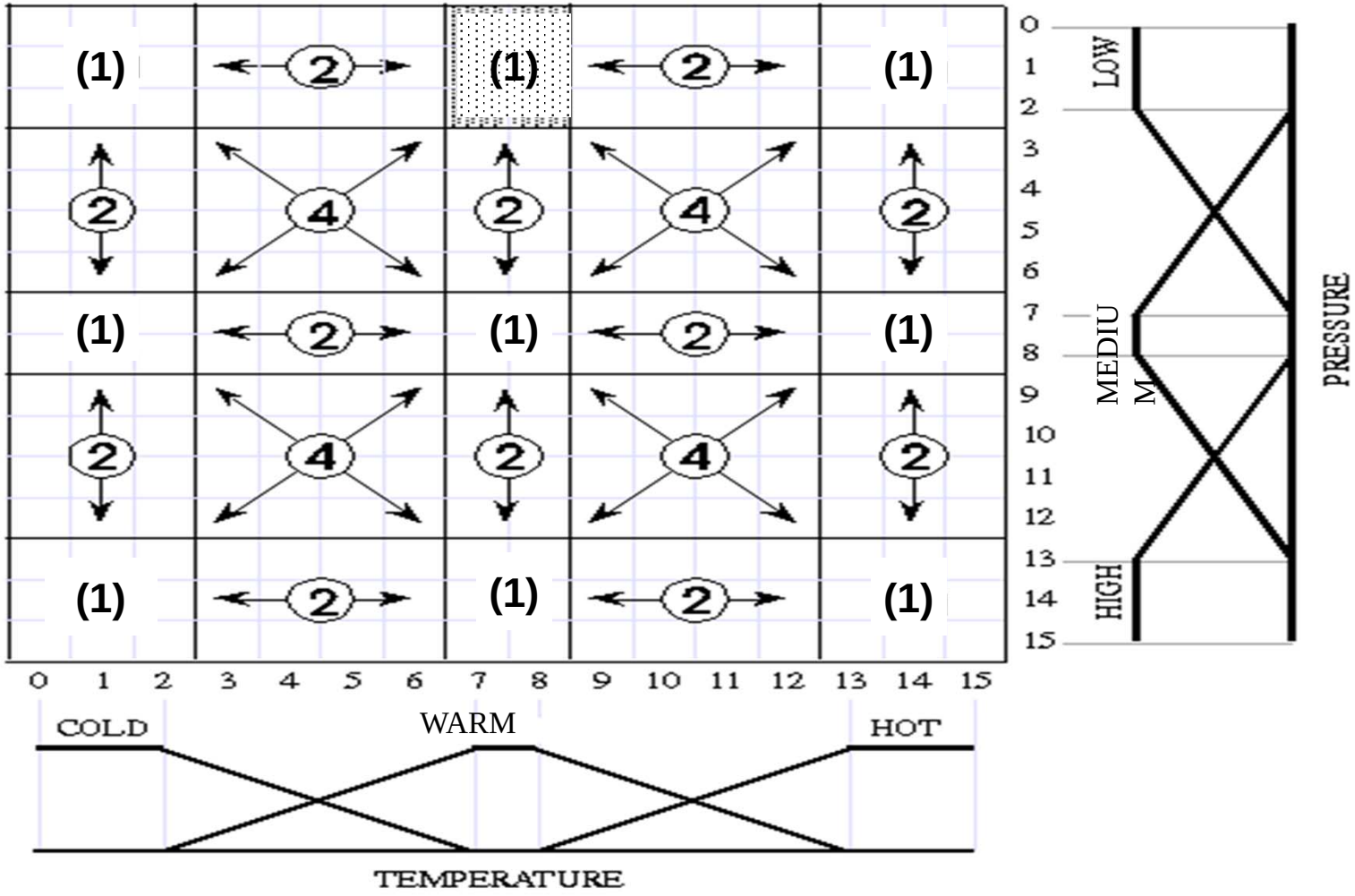
  "If Temperature is WARM and Pressure is LOW Then set Heat to HIGH"

Visualising Fuzzy Rules (cont.)

- **Both Temperature and Pressure are linguistic variables, the boundaries between their values (i.e. cold and warm) are not sharp**



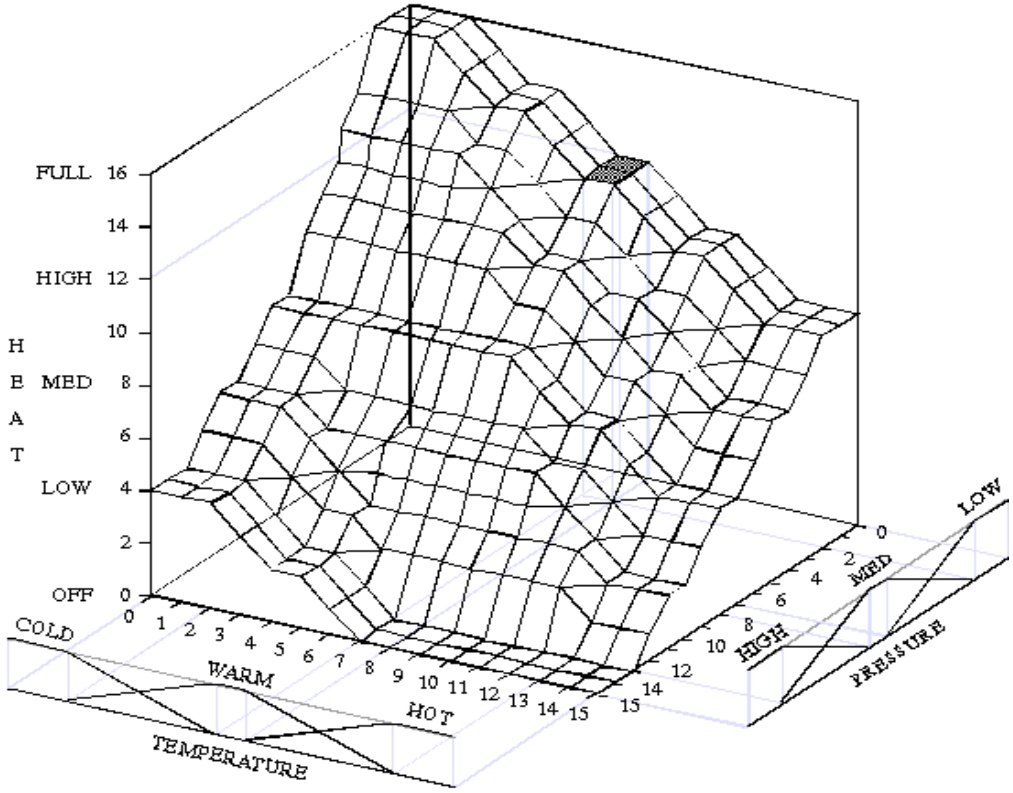
Visualising Fuzzy Rules (cont.)



- **The numbers indicate how many rules can apply to that box.**

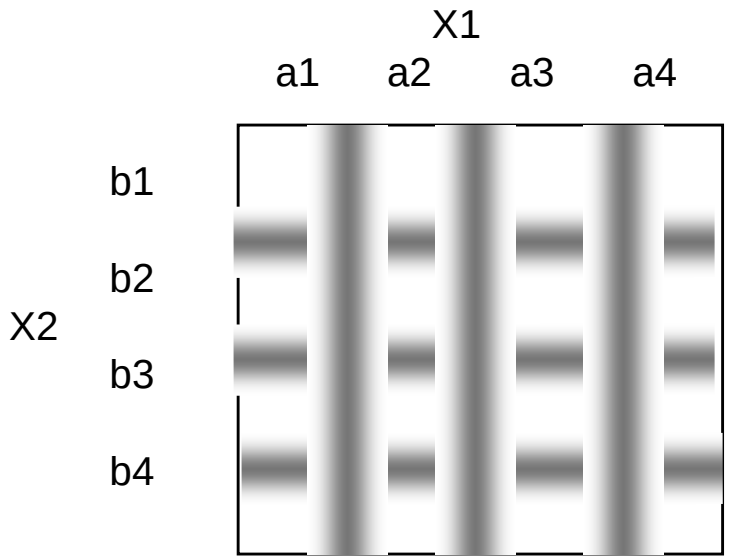
Visualising Fuzzy Rules (cont.)

- In the areas where more than one rule contributes to the output level, defuzzification is used to calculate a weighted average of the contributing rules. The result can be plotted as a control (or decision) surface.



Input Space Partitioning — Grid partition

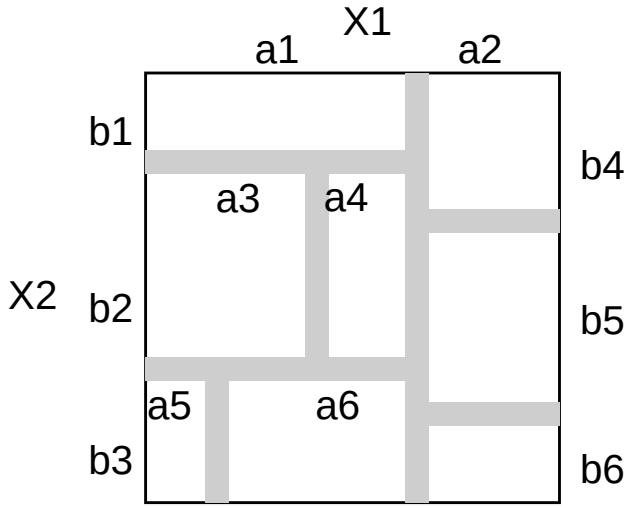
- **Grid partition**
  - » **Needs a small number of membership functions for each input.**
  - » **Encounters problems when we have a large number of inputs.**



Input Space Partitioning — Tree partition

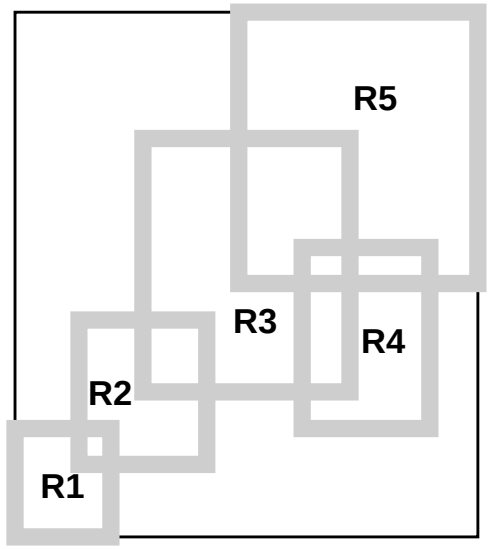
- **Tree partition**
  - » **Each region is uniquely specified using a leaf in a decision tree**
  - » **Relieves the problem of an exponential increase in the number of rules (in grid partition)**
  - » **More membership functions for each input are used**
  - » **Fuzzy membership functions do not usually bear clear linguistic meanings such as "small", "large", etc.**

- **Example: Two inputs, X1 and X2, one output Y**
  - » **X1 has six fuzzy values: a1, a2, a3, a4, a5, a6**
  - » **X2 has six fuzzy values: b1, b2, b3, b4, b5, b6**



Input Space Partitioning — Scatter partition

- **Scatter partition**
  - » **By covering a subset of the whole input space, can limit the number of rules to a reasonable amount**
  - » **It is usually dictated by desired input-output data pairs**



Exercise

- Problem description:

An insurance company invented a new product (policy). The new product provides policy holder a choice of having an "investment" component linked with his/her normal insurance component. Comparing with the normal insurance, of course, the "investment" component takes a higher risk and hopefully obtains a better return.

It is generally believed that young people can bear relatively higher risk. Apart from age, family situation and income level of a customer may also affect his/her bearable level of risk.

So an insurance agent has to recommend a suitable amount of the "investment" based on the customer's age and bearable risk level.

Exercise (cont.)

- Problem description (cont.):

The insurance company has decided:

» **the amount of investment should be within the range of $10,000 ~ $1,000,000**

» **to have an investment component, the customer's age should be between 20 to 50.**

» **The risk level is measured by the agent based on the bearable percentage (0% ~ 100%) of loss. e.g. a customer may provide his bearable loss as 50% of total investment money.**

Some knowledge/experience from Mr. A (an insurance agent):

» **The older the person, the lower the investment amount.**

» **The higher the bearable risk level, the higher the investment amount.**

Exercise (cont.)

- Your task:
  - » **develop a fuzzy expert system to reproduce the work of Mr. A**
- Possible steps of fuzzy modelling:
  - » **identification of surface structure**
    - ♦ **input/output variables**
    - ♦ **type of fuzzy inference system**
    - ♦ **number of linguistic terms (fuzzy partition)**
    - ♦ **design rule base**
  - » **identification of deep structure**
    - ♦ **determine membership function for each linguistic term**