Case Study

Fuzzy Traffic Light Controller

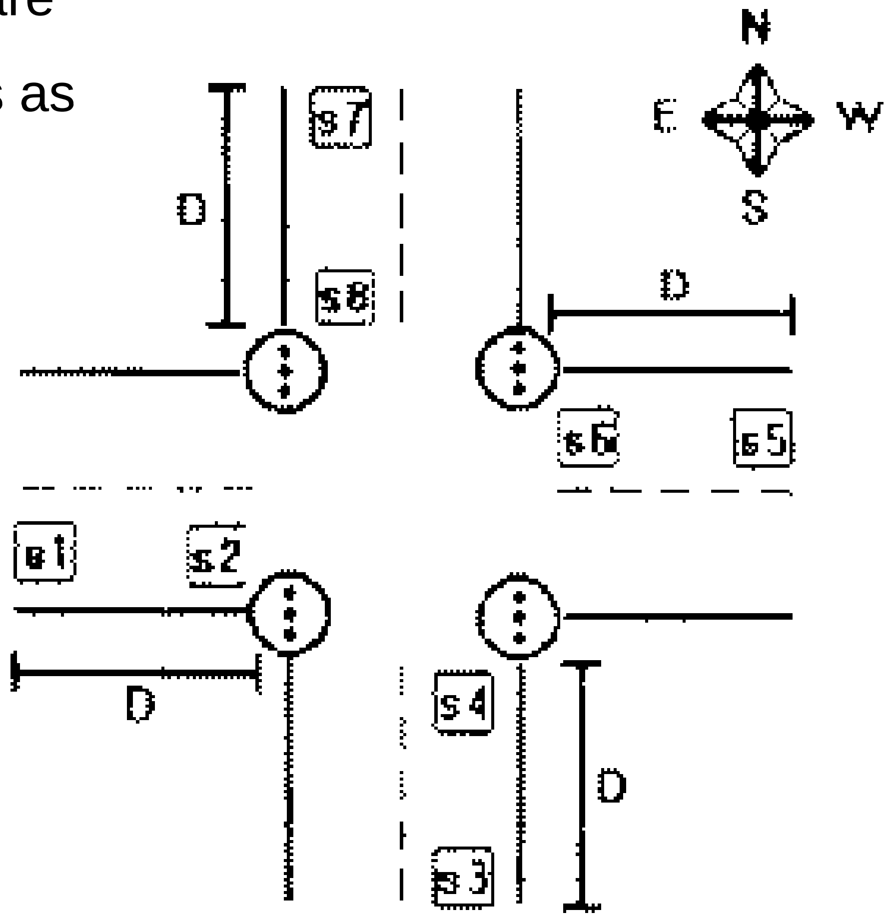
Case Study (cont.)

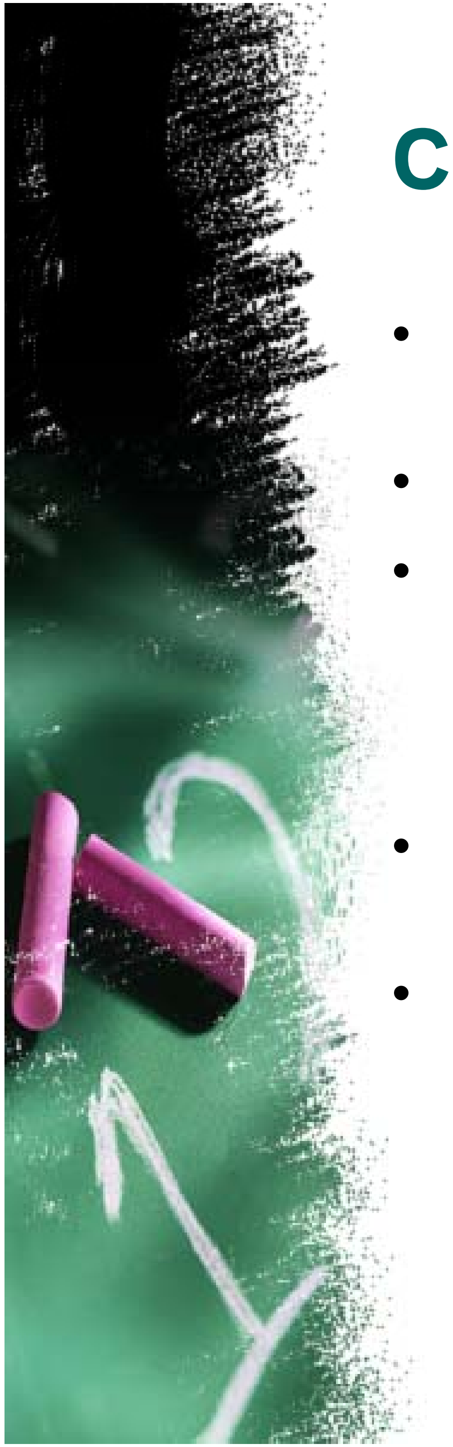
- The design procedures of a real life application of fuzzy logic: *A Smart Traffic Light Controller:*
  - The controller is supposed to change the cycle time depending upon the densities of cars behind green and red lights and the current cycle time.
- Background:
  - *A conventional Traffic light controller: constant cycle time, not optimal, no easily math model found to decide, with F.L much easier*

Case Study (cont.)

Fuzzy Design:

- 8 incremental sensors are put in specific positions as seen:





Case Study (cont.)

- 1st sensor: counts the number of cars coming to the intersection
- 2nd sensor: counts the cars passing the traffic lights
- Amount of cars between the traffic lights is determined by the difference of the reading of the two sensors→
  - *For example, the number of cars behind traffic light North is s7-s8.*
- D=200ft., to determine the maximum density of cars allowed to wait in a very crowded situation
- Done by adding the number of cars between two paths and dividing it by the total distance→
  - *For instance, the number of cars between the East and West street is (s1-s2)+(s5-s6)/400.*

Case Study (cont.)

Fuzzy Decision Process: 3 steps

- Fuzzyification
- Rule Evaluation
- Defuzzification

Case Study (cont.)

Step 1:

- Determine the inputs and outputs of the design
- Assume red light is shown to both North and South streets and distance D is constant
- Inputs:
  - *Cycle Time*
  - *Cars behind red light*
  - *Cars behind green light*
- Output:
  - *The probability of change of the current cycle time*

Case Study (cont.)

- The input and output parameters are divided into overlapping member functions, each function corresponding to different levels:
  - *Levels for No. of cars→*
    - Zero(0,1)
    - Low(0,7)
    - Medium(4,11)
    - High(7,18)
    - Chaos(14,20)

Case Study (cont.)

- *Levels for Cycle time→*
  - Very short(0,14)
  - Short(0,34)
  - Medium(14,60)
  - Long(33,88)
  - Very long(65, 100)
  - Limit(85,100)
- *Levels for Output (Singleton position)→*
  - No(0)
  - Probably no(.25)
  - Maybe(.5)
  - Probably yes(.75)
  - Yes(1)

Case Study (cont.)

Step2:

- Formulate the rules, using a series of IF-THEN statements, combined with AND/OR operators:
  - ➢ *IF cycle time is medium AND cars behind red is low AND cars behind green is medium THEN change is probably no.*
- With 3 inputs, each having 5, 5 and 6 membership functions, there'd be a combination of 150 rules. However using the minimum or maximum criterion some rules are combined to a total of 86.

Case Study (cont.)

Step 3:

- Convert the fuzzy set output to real crisp value. The method used for this system is *center of gravity*.
  - ➢ *Crisp Output={Sum (Membership Degree*Singleton Position)}/Sum (Membership Degree)*→
    - Change Probability:
      - ❑ Yes=0
      - ❑ Probably Yes=0.6
      - ❑ Maybe=0.9
      - ❑ Probably No= 0.3
      - ❑ No=0.1

Crisp Output =

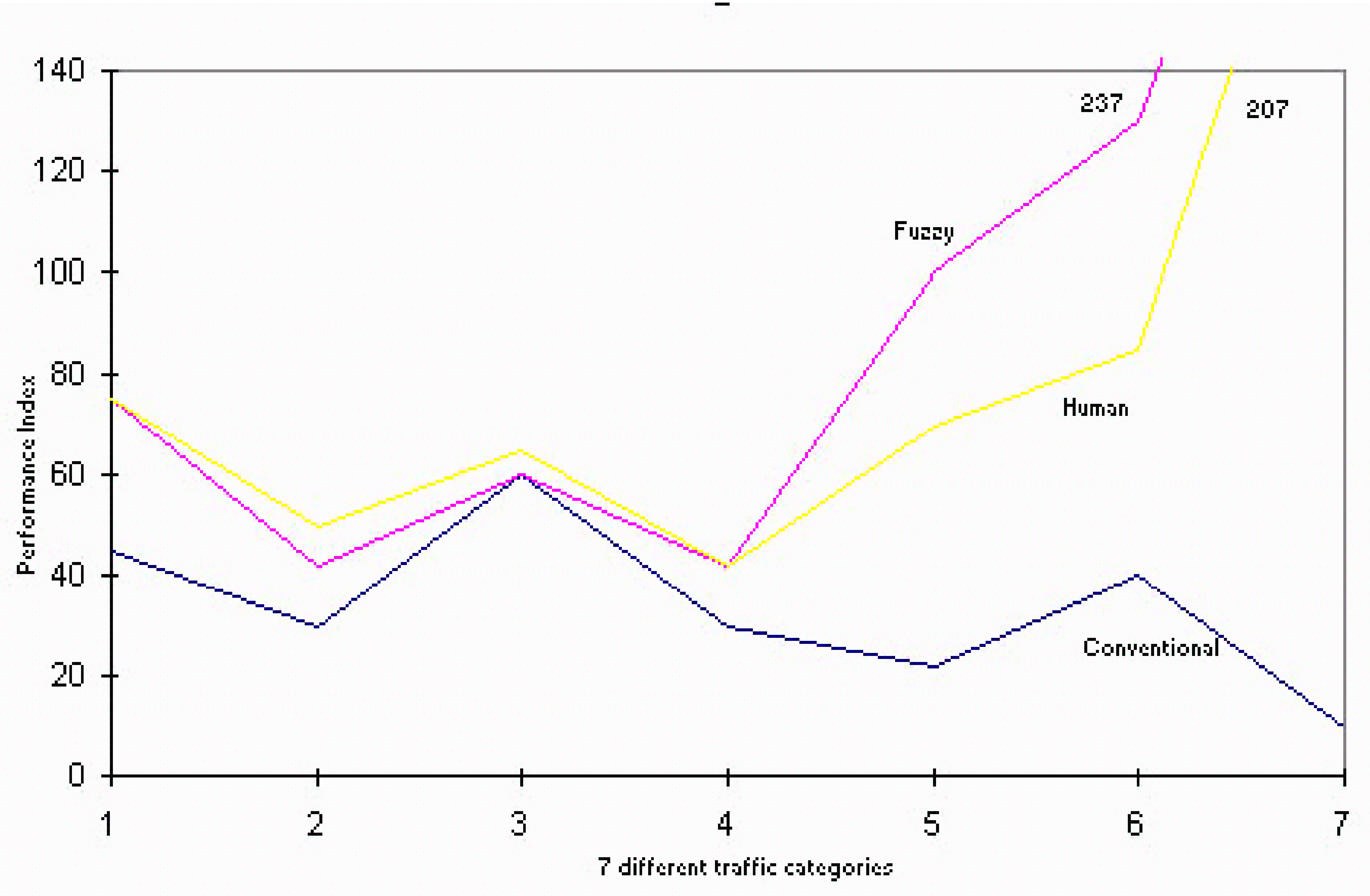
$$(0.1*0.00)+(0.3*0.25)+(0.9*0.50)+(0.6*0.75)+(0*1.00)/0.1+0.3+0.9+0.6+0 = 0.51$$

Case Study (cont.)

Is Fuzzy controller better?

- Testing of the controller: The fuzzy controller has been tested under seven different kinds of traffic conditions from very heavy traffic to very lean traffic. 35 random chosen car densities were grouped according to different periods of the day representing those traffic conditions
- *Performance evaluation:* Compared with a conventional controller and a human expert.
  - *Criteria used: number of cars allowed to pass at one time and average waiting time.*
  - *A performance index which maximizes the traffic flow and reduces the average waiting time was developed.*
  - *A means of calculating the average waiting time was also developed, however, a detailed calculation of this evaluation is beyond the scope of this article.*
  - *All three traffic controller types were compared and can be summarized with the following graph of performance index in all seven traffic categories.*

Case Study (cont.)



Case Study (cont.)

Conclusion:

- The fuzzy controller passed through 31% more cars, with an average waiting time shorter by 5% than the theoretical minimum of the conventional controller. The performance also measure 72% higher. This was expected.
- In comparison with a human expert the fuzzy controller passed through 14% more cars with 14% shorter waiting time and 36% higher performance index. Result: Machine beats Man!!!
- In conclusion, as Man gets hungry in finding new ways of improving our way of life, new, smarter machines must be created. Fuzzy logic provides a simple and efficient way to meet these demands and the future of it is limitless