Hybrid Systems

Sabah Sayed
Department of Computer Science
Faculty of Computers and Artificial Intelligence
Cairo University
Egypt

Hybrid

Genetic Algorithm + Fuzzy Logic

Evolving Fuzzy Systems using Genetic Algorithms

- We want to evolve a fuzzy rule system using a GA.

- **Things to consider:**
- What will be evolved (what parts of the fuzzy system)
- How system elements are represented
- Population initialization
- Fitness evaluations
- Operators used

What will we evolve?

- Usually the rule base is evolved to get the best rules representing a dataset of a particular problem.
- We can also evolve the membership functions used to find the best types (triangular, trapezoidal, …etc) and ranges.

Representing Fuzzy Rules

- Each chromosome will represent a single rule set
- Our system will use Mamdani-type fuzzy rules, for example:

  `if input_1 is not Low, and input_2 is High, then the output is Medium`

  `if input_2 is Low, then the output is High`

- but computers generally can't handle this kind of input (yet)
- Assuming each variable has three fuzzy sets; Low, Medium, High:

  Let Low=1 Medium=2 High=3

  The above two rules can be numerically represented as:

  `-1 3 2 and 0 1 3 (0 means "don't care")`

Population Initialization

- Random initialization of the population.

- Rules are checked for feasibility.
- Each rule must have a non-zero antecedent, *and* a non-zero consequent.
- A rule such as 2 3 1 1 0 is thus non feasible, and is not included in the rule set.

- Re-generate individuals to compensate for the infeasible chromosomes.

Fitness Evaluation

- Percent correct and mean-square error are often used.
- Additional components of fitness may include the number of rules (minimize).

Steps of Evolving a Fuzzy Rule System

- Given a history of data (dataset), to a particular problem:

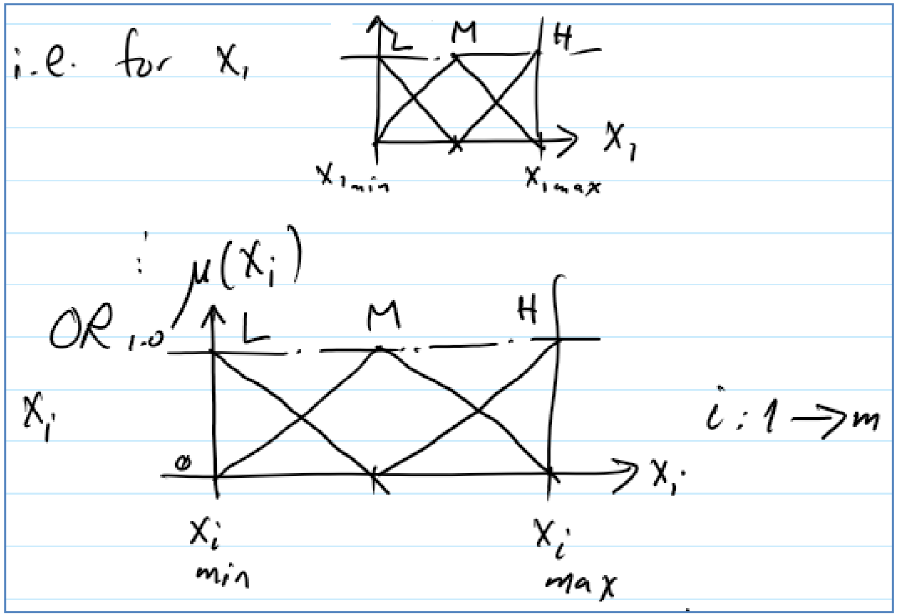
x1	x2	x3	……	xm	y
….	….	….	….	….	….
….	….	….	….	….	….
….	….	….	….	….	….

it is required to evolve a fuzzy system that will classify or predict y.

Evolving a Fuzzy Rule System

- **Step 1:**
  Get min and max of each Xi (column) in dataset => $X_{i\text{-}min}$, $X_{i\text{-}max}$

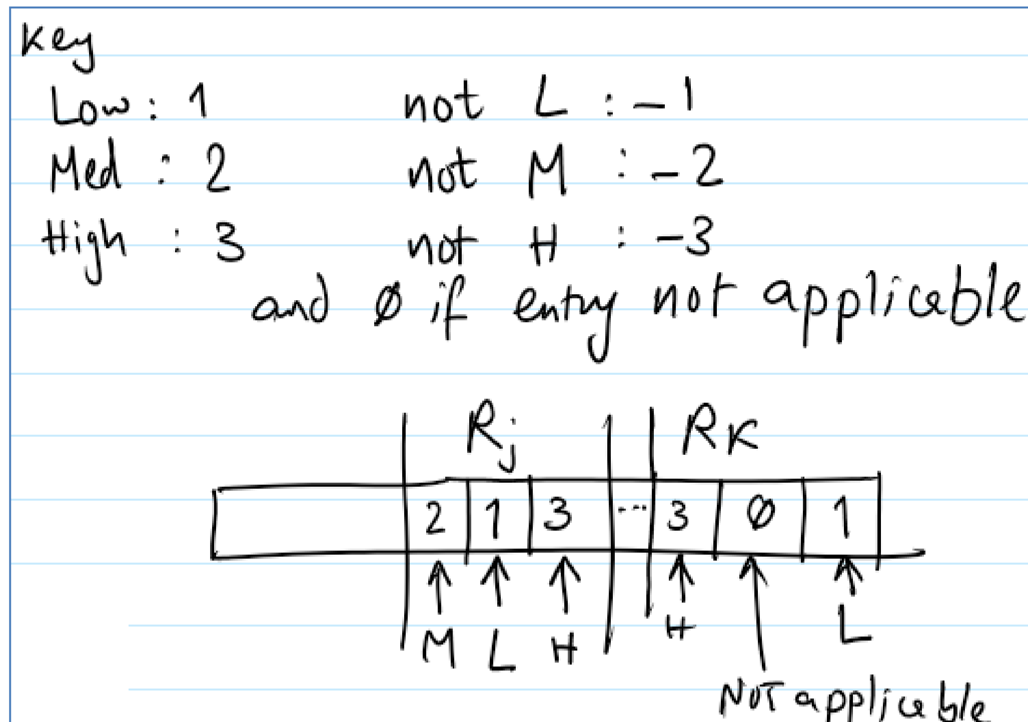
- **Step 2:**
  Design fuzzy sets (select them)



Evolving a Fuzzy Rule System

- **Step 3:**
  Design chromosomes composed of random set of fuzzy rules as follows:

- R_j:
  if x1=M and x2=L
  then y=H
- R_k:
  if x1=H
  then y=L



Evolving a Fuzzy Rule System

- **Step 3:**
  Note that number of rules in chromosome is variable => variable-length chromosome

  chromosome 1:

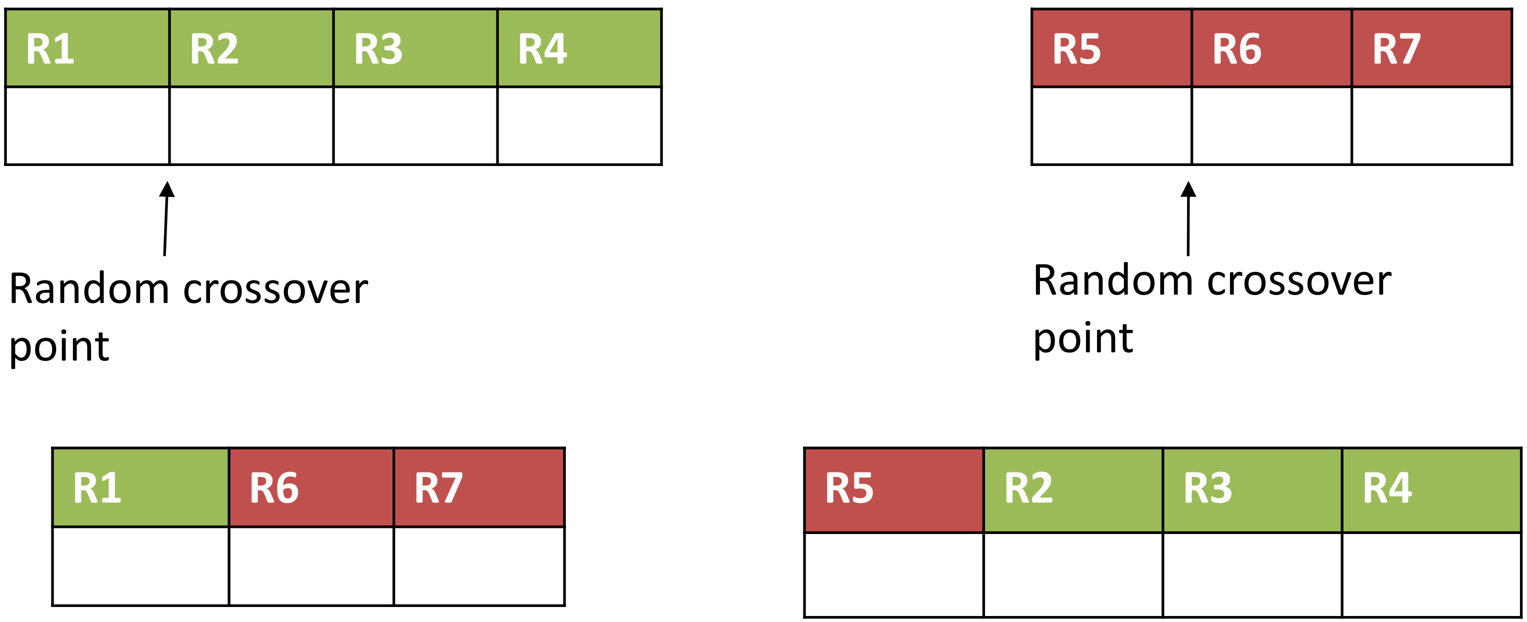
R1	R2	R3	R4

- **chromosome 2:**

R5	R6	R7

Evolving a Fuzzy Rule System

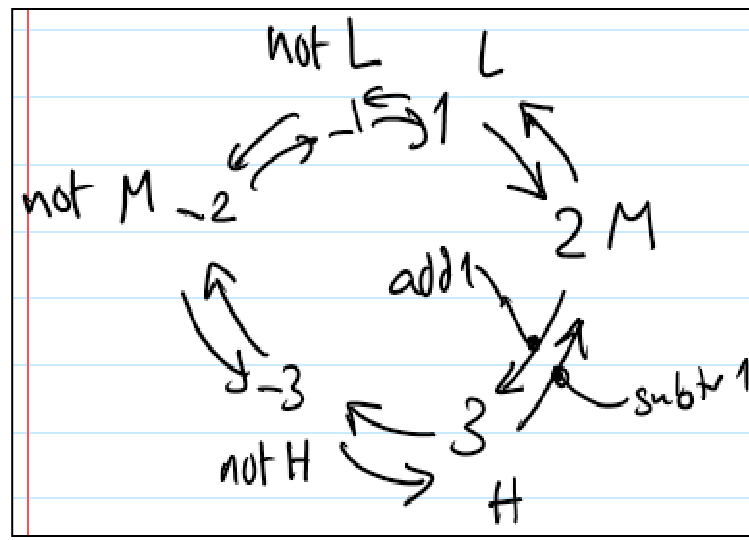
- **<u>Step 4:</u>**
  Design of crossover operator



Evolving a Fuzzy Rule System

- **<u>Step 5:</u>**
  Design of mutation operator

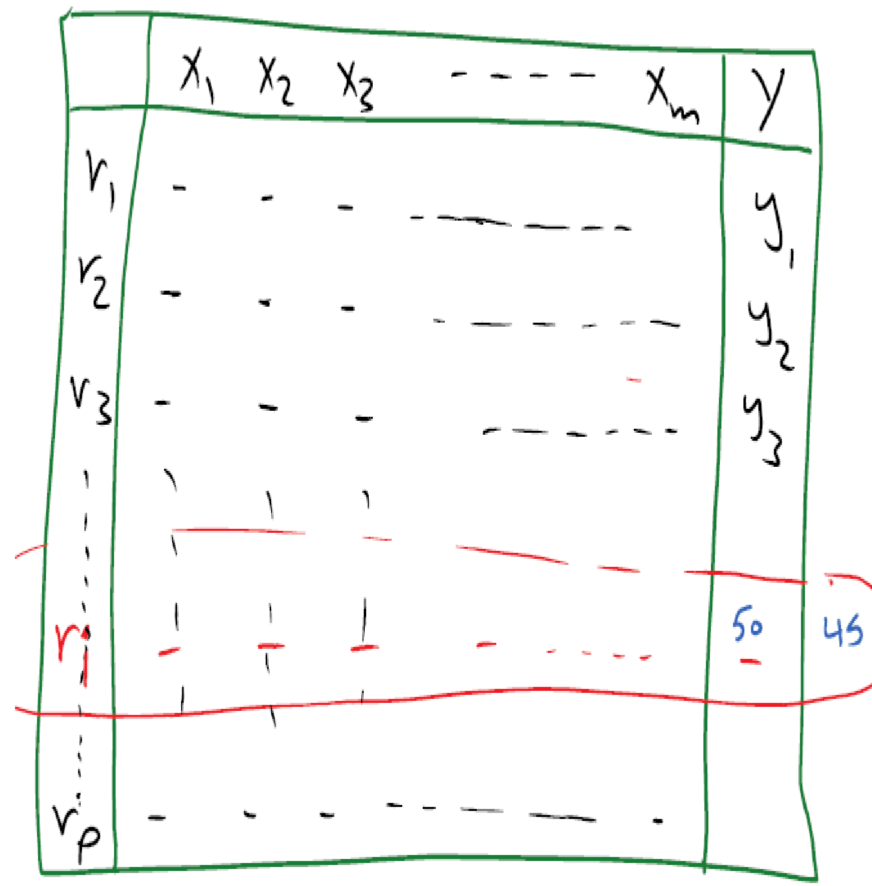
- According to random number **r**, for each entry in rule, either:
  - Add 1 (r: 0- 0.33)
    ex. L to M
  - Subtract 1 (r: 0.34 – 0.66)
    ex. H to M
  - Negate (r: 0.67 - 1)
    ex. L to Not L



Evolving a Fuzzy Rule System

- **Step 6:**
  Fitness function

- Run each fuzzy system (chromosome) as usual on dataset
- Fitness_i = (number of correctly predicted rows)$_i$
- Or $\text{Fitness}_i = 1/\text{MSE}_i$ (mean square error)



Calculate Fitness of Chromosome k: Mean Square Error

chr_K | R_1 | R_2 | R_3 | R_4 |

Ruleset

for each chromosome chr_K in GA population:
{
  Sum-of-SEs = 0
  for each record r_i in the dataset $[r_1, r_2 \ldots r_p]$:
  {
    * Use values of $x_{1i}, x_{2i}, x_{3i} \ldots x_{mi}$ to perform:
      1. Fuzzification
      2. Inference → Rules $R_1, R_2, R_3 \ldots$ in chr_K
      3. Defuzzification → to get $Y_{i\,(predicted)}$
    * Calculate square Error $(SE) = (Y_{i\,(predicted)} - Y_{i\,(actual)})^2$
    * Sum-of-SEs += SE
  }
  MSE_k = Sum-of-SEs / p p = num. of records in data set
  Fitness of $chr_K = 1 / MSE_k$
}

Evolving a Fuzzy Rule System

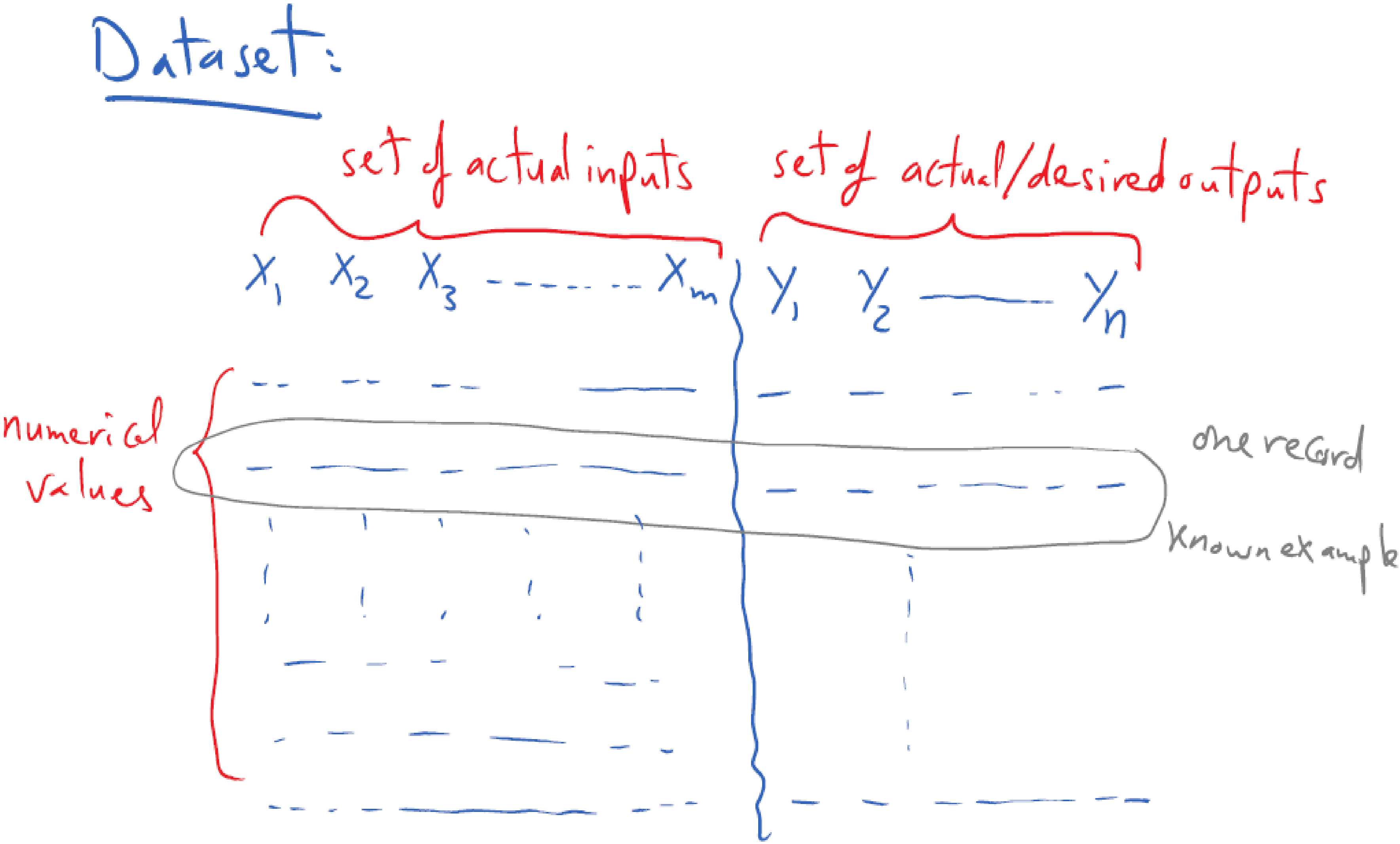
- **Step 7:**
  Selection Strategy:
  Roulette wheel selection

- **Step 8:**
  Replacement strategy:
  Elitism Strategy

Hybrid

Genetic Algorithm + Neural Network

Dataset



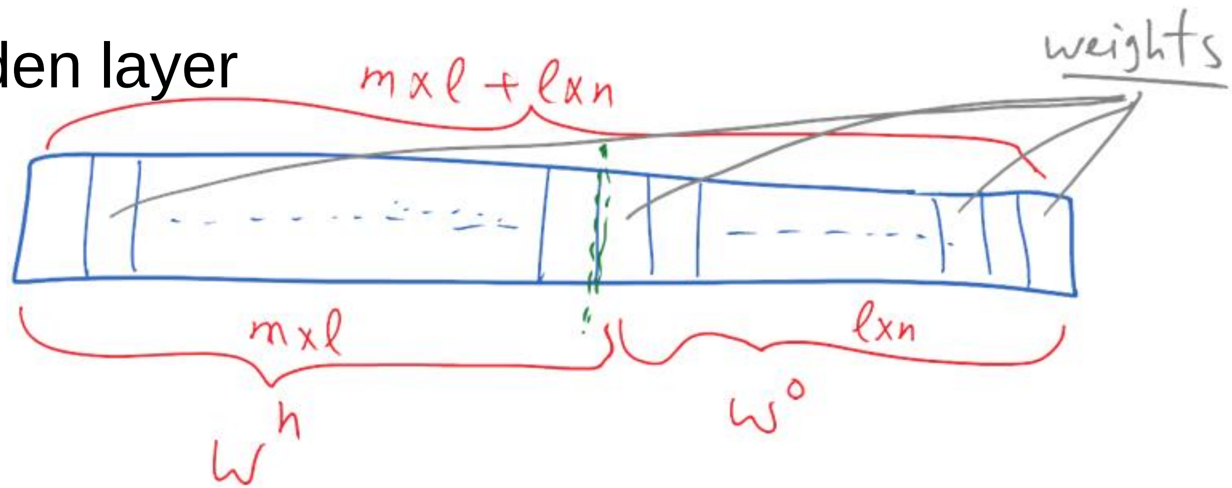
Dataset:
set of actual inputs
set of actual/desired outputs
X1 X2 X3 Xm
Y1 Y2 Yn
numerical values
one record
known example

Training FFNN using Genetic Algorithms

- ➢Each chromosome will represent the set of all weights of the network (fixed length).
- ➢Each gene represent 1 weight value.
- ➢The chromosome encoding is floating point.
- ➢Network structure:
  - ✓M inputs,
  - ✓L nodes in 1 hidden layer
  - ✓N output

w^h and w^o

$[w^h]_{m \times l}$ $[w^o]_{l \times n}$



Design the Genetic Algorithm

- Initialization: Randomly initialize the population
- Fitness: Mean-square error is used.
  - For each chromosome: Run FFNN with chromosome weights over Dataset.
  - Get MSE on output layer.

- Crossover operator: single point
- Mutation operator: Non-uniform floating point
- Selection Strategy: Roulette wheel selection
  - Area of each chromosome = 1/ fitness

- Replacement strategy: Elitism strategy