SOFTCOMPUTING IN MODELING & SIMULATION

9th July, 2002

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The only way not to succeed is not to try

Edward Teller

The lecture will cover:

- **What do we mean by: System, Model, Simulation, Validity?**
- **What does the word "INTELLIGENCE" mean?**
- What do we mean by AI & Soft-Computing?
- What is the difference between SC & AI?
- **What do we mean by Evolution Computation?**
- Fuzzy-Neural Systems.

What a SYSTEM is?

It is a set of **OBJECTS** with a **STRUCTURE**.

We must study:

- its boundaries & concepts.
- its interactions with the environment.

What a MODEL is?

Any image which can be considered as a **SYSTEM** and is used by a **SUBJECT** to obtain information about another system can be thought as a **MODEL**.

The goal of **MODELING** is **OBSERVER**: (Minsky 1985)

An object **A** is a MODEL of an object **B** if an observer can use **A** to answer questions about **B**.

What a SIMULATION is?

It is a process of designing a MODEL of a real system and conducting experiments with this model for the purpose of:

- understanding the system behavior.
- evaluating various strategies for system operation.

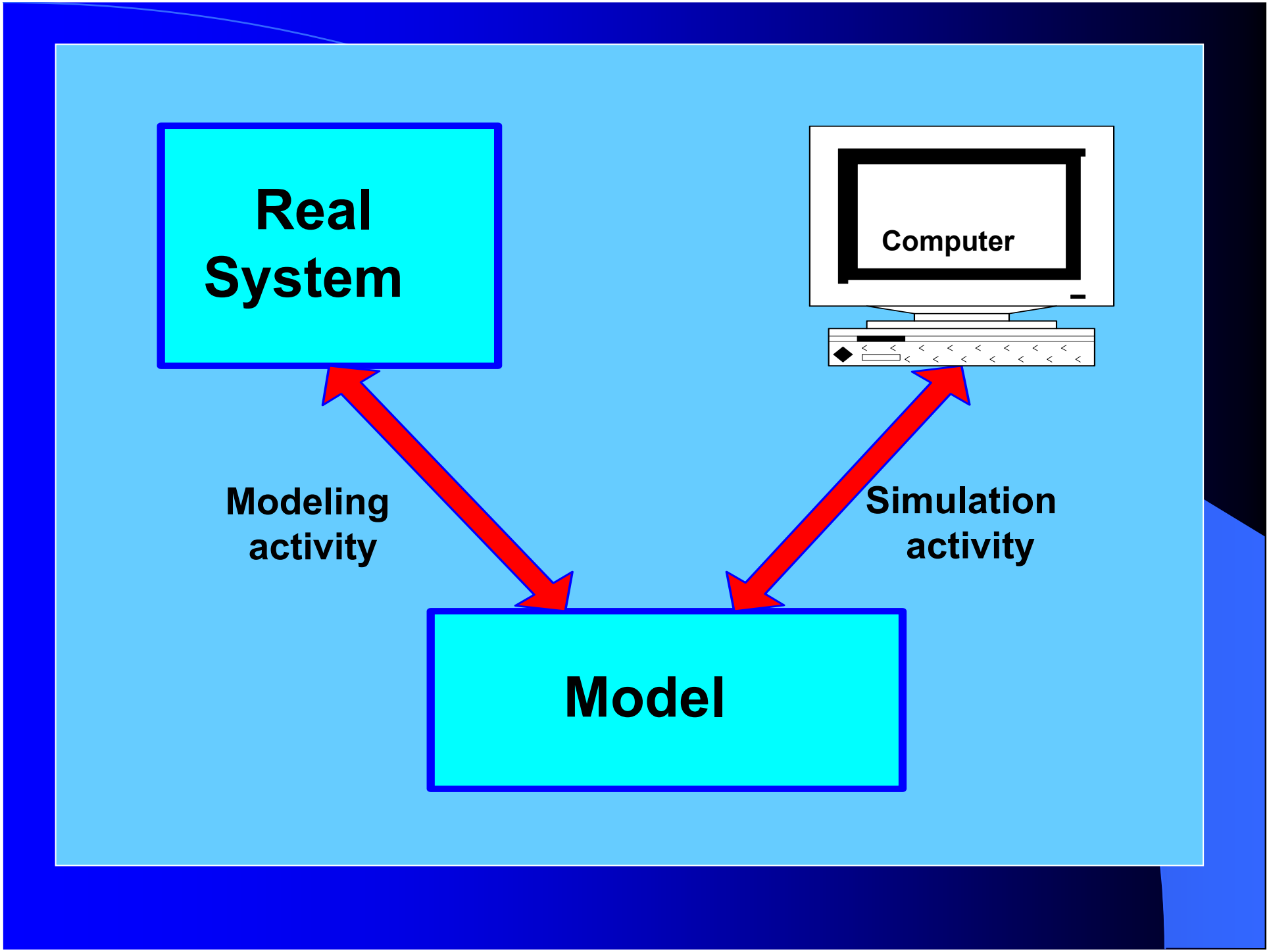
→ **Real system** is a source for raw data.

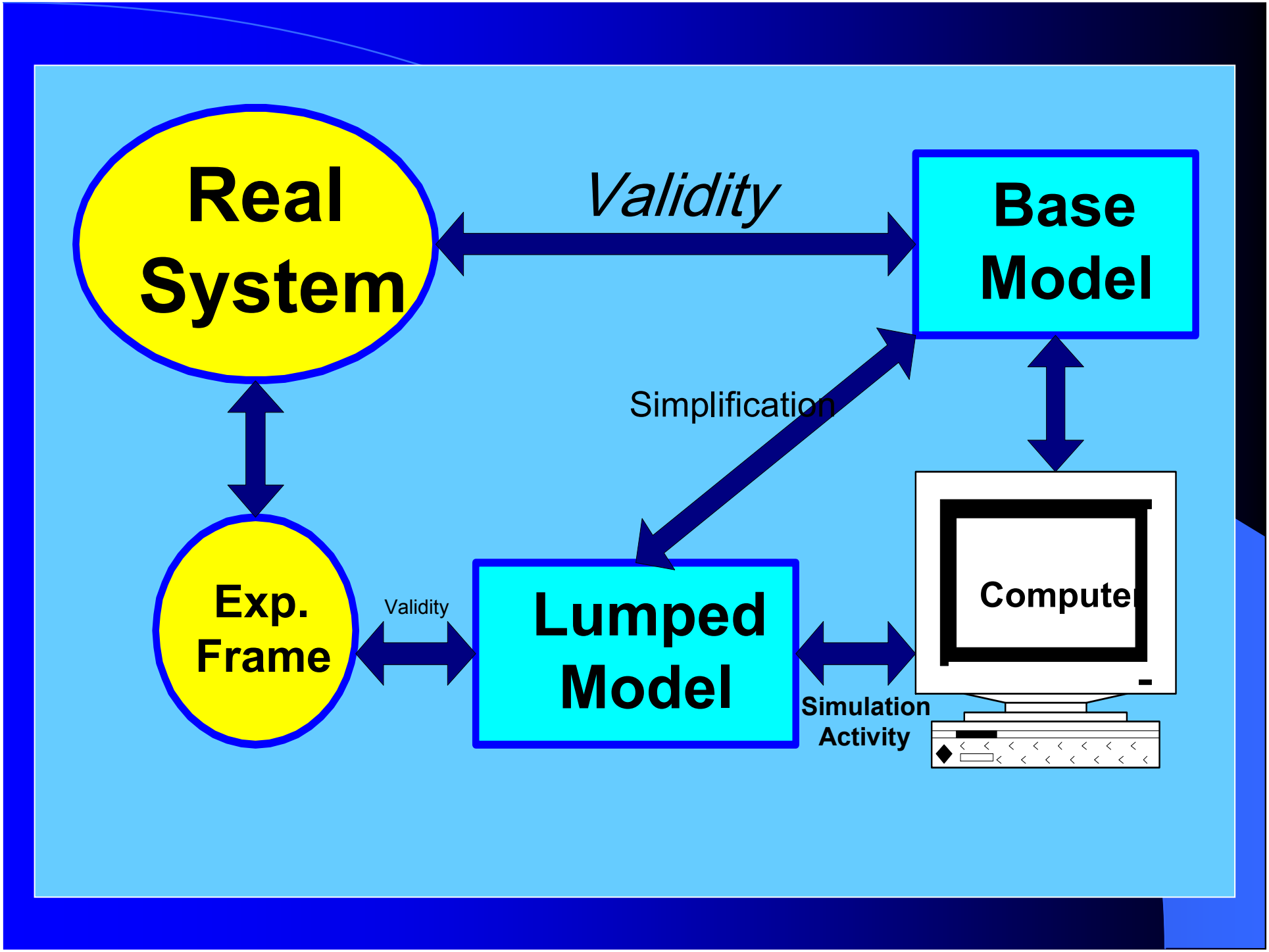
→ **MODEL** is a set of instructions for generating data.

→ **SIMULATION** (processor) is a device for carrying out MODEL instructions.

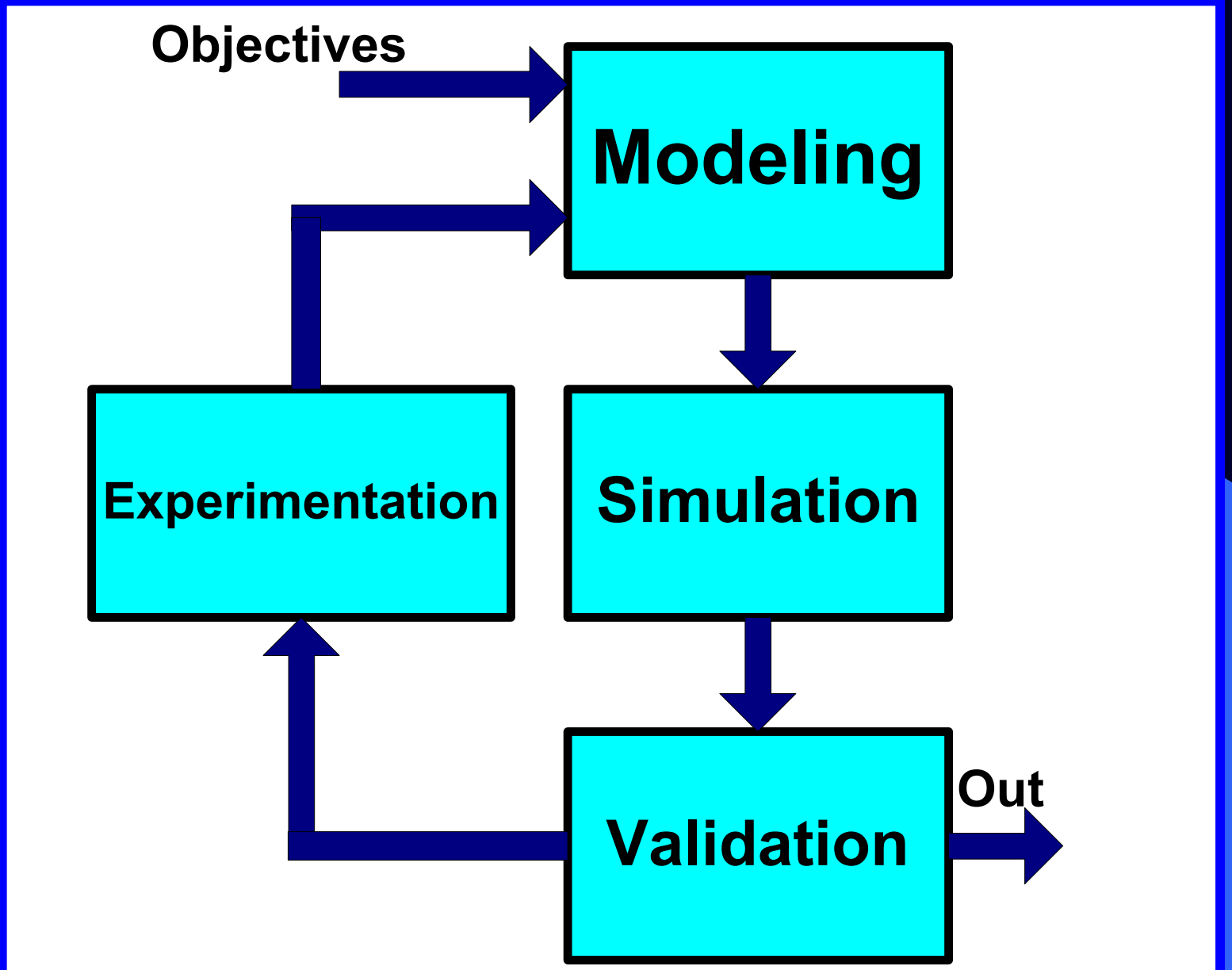
→ **A VALIDATION** model relates to a set of experiments to be performed on a system.

Validation Model {System, Experiment}


Real System
Computer
Modeling activity
Simulation activity
Model


Real System
Validity
Base Model
Simplification
Exp. Frame
Validity
Lumped Model
Computer
Simulation Activity

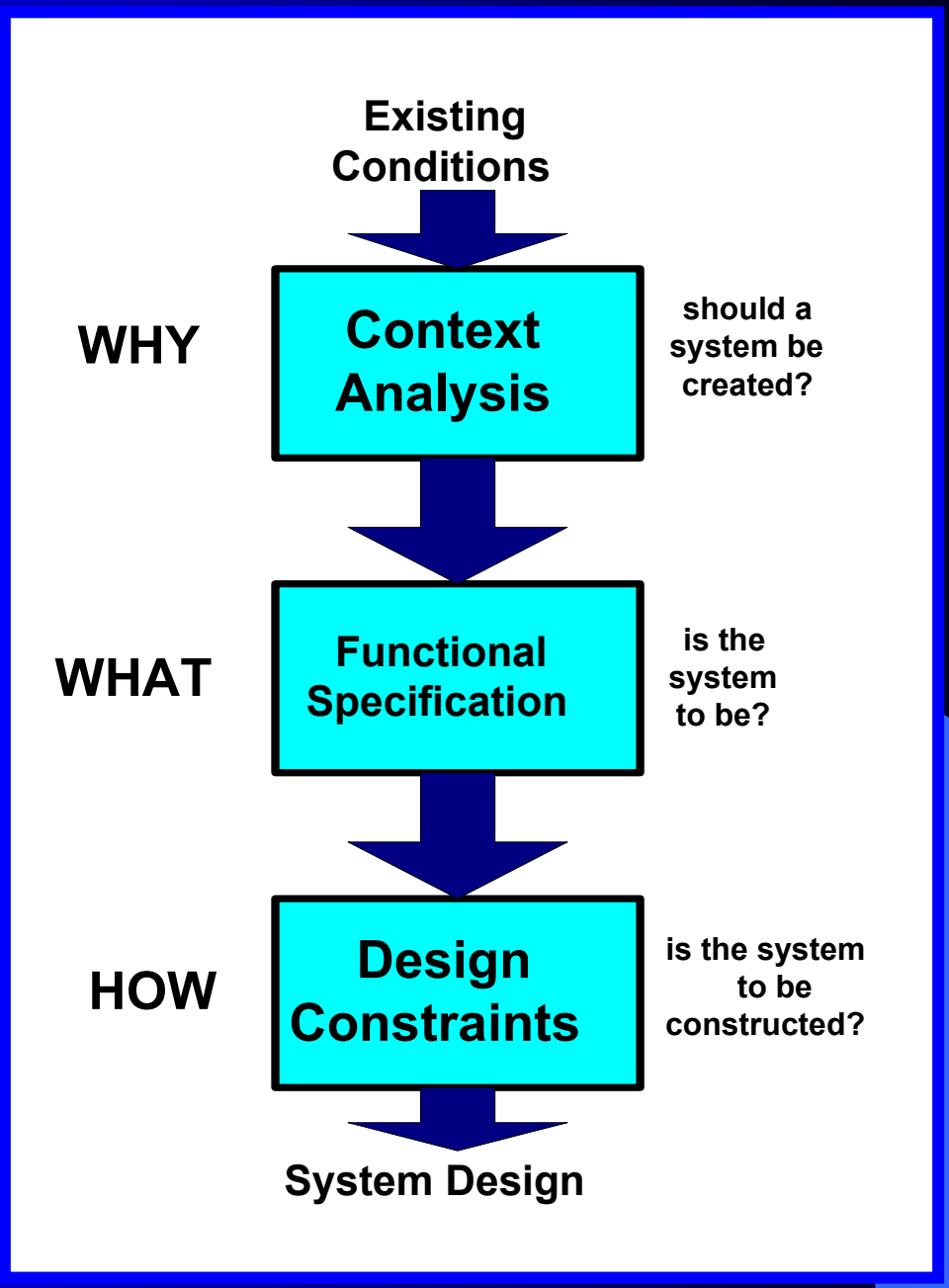
Modeling & Simulation Activities:



This Q is answered when we have defined the system.

How we represent the Information? Static or Dynamic structure?

This Q is relative to the simulation activity as a relation between computer and model.



What Computers can do?

Philosophers have been trying to understand & resolve **TWO** questions:

Q1: How does a human mind work?

Q2: Can non-humans have minds?

What does the word "INTELLIGENCE" mean?

- It is the ability to understand and learn things.
- It is the ability to think and understand instead of doing things automatically.

What THINKING means?

It is the activity of using your brain to consider a problem or to create an idea.

What AI is?

AI is an area of computing that attempts to create machines that will perform in the same way as humans (experts).

What Machine Learning is?

It is the process by which s/w or h/w can:

1. Discover patterns in data (data are useful in modeling & simulation).
2. Use patterns it has learned for; classification, prediction, decision making, modeling & simulation, control, ……

What dose Data Mining means?

It is the process of discovering the patterns from data. It involves;

1. Collect data containing examples relevant to the problem.
2. Analyze data using a m/c learning technique. A m/c learning algorithm produces a representation used to advise.
3. Test this representation against other data. If it works, you have a model.

What do we mean by Soft-Computing?

- Traditional or hard computing uses **GRISP** values.
- Soft-computing deals with **SOFT** values (Fuzzy sets).
- SC is capable of operating with uncertain, imprecise, and incomplete information in a manner that reflucts human thinking.

What is the difference between SC and AI?

Conventional AI attempts to express human knowledge in symbolic terms. (Symbolic manipulation and its exact reasoning mechanisms including forward and backward chaining).

Ex: Expert System is good only if explicit knowledge is acquired and represented in the knowledge base.

Recently, AI has expanded rapidly to include ANN, GA, and FL.

This makes the boundaries between modern AI and SC vague!!

Comparison:

Characteristic	ES	FL	NN	GA
• Knowledge Representation	R good	Good	bad	V bad
• Uncertainty tolerance	R good	Good	Good	Good
• Imprecision tolerance	Bad	Good	Good	Good
• Adaptability	Bad	R bad	Good	Good
• Learning ability	Bad	Bad	Good	Good
• Explanation ability	Good	Good	Bad	R bad
• K discovery & data mining	Bad	R bad	Good	R good
• Maintainability	bad	Bad	Good	R good

- The term **Soft Computing** was proposed by Lotfi Zadeh in 1994;

" Soft Computing is a collection of methodologies that aim to exploit the tolerance for impressions & uncertainty to achieve tractability, robustness, and low solution cost. Its principle constituents are;

- **Fuzzy logic,**
- **Neuro-computing, and**
- **Probabilistic reasoning.**

" The role model for soft computing is the **human mind**. *"*

"A good hybrid would be: British Police, German Mechanics, French Cuisine, Swiss Banking and Italian Love".

- FL is concerned with imprecision.
- NN is concerned with learning.
- PR is concerned with uncertainty.

- In general, FL, NN, and PR are complementary rather than competitive.
- It is clear that in many cases it is advantageous to employ FL, NN, and PR in combination rather than exclusively.
- So our goal is to select the right components for building a good hybrid system for modeling and simulation.
- In particular, the combination of FL and NN leads to:

NEROFUZZY SYSTEMS.

Neuro-Fuzzy Systems:

- **NN**s are low-level computational structures that perform well when dealing with raw data.
- **FL** deals with reasoning on a higher level using linguistic information acquired from domain experts.
- FL systems lack the ability to learn and can not adjust themselves to a new environment.
- NNs can learn, but they are opaque to the user.
- The merger of a NN with a FL system into one integrated system combines the parallel computation and learning abilities of NNs with the human-like knowledge representation and explanation abilities of FL systems.
- A N-F system is a multi-layer NN equivalent to a F inference model.
- It can be trained to develop IF-THEN fuzzy rules and determine membership functions for input and output variables of the system.
- Expert knowledge can be easily incorporated into the structure of the N-F system.

- Today, FL, NN, and GP have been applied to many real world applications.
- Although, these methodologies seem to be different, they have many common features;

- the use of basis functions;

  FL has membership functions, NNs have activation functions, GAs use probability density functions.

- the aim to estimate functions from sample data or heuristics.
- Good results have been achieved by combining different SC methods.

- Soft Computing can also be seen as a foundation for the growing field of COMPUTATIONAL INTELLIGENCE (CI).
- The difference between traditional AI and CI is that AI is based on hard computing while CI is based on soft computing.

Fuzzy Models:

- In the analysis of complex systems, the principle of incompatibility established by Zadeh (1973) help us in modeling:

"*The closer one looks at a* **REAL-WORD** *problem, the* **FUZZIER** *becomes its solution*"

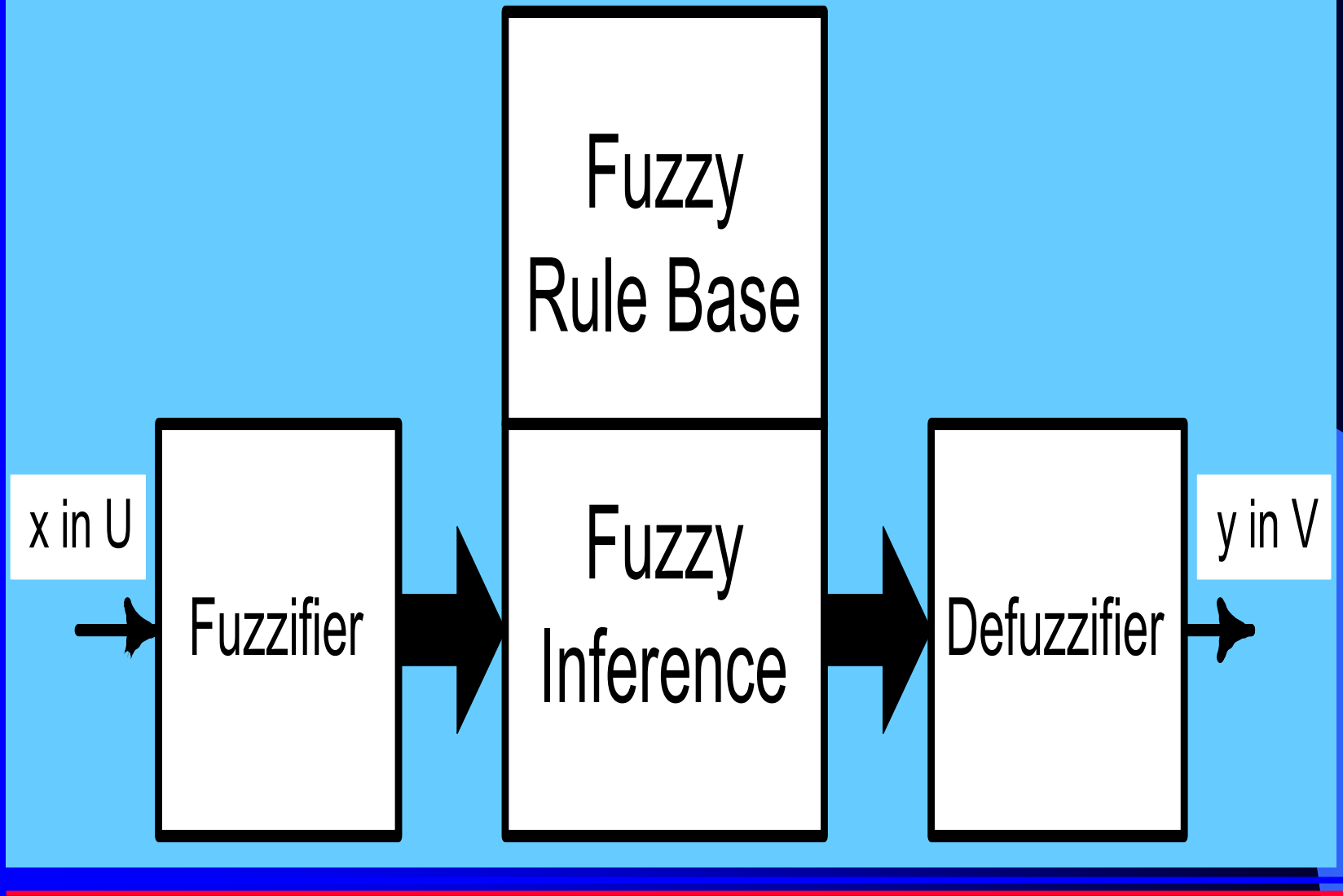
- As the complexity of a system increases, our ability to obtain precise model becomes difficult.

Fuzzy Models:

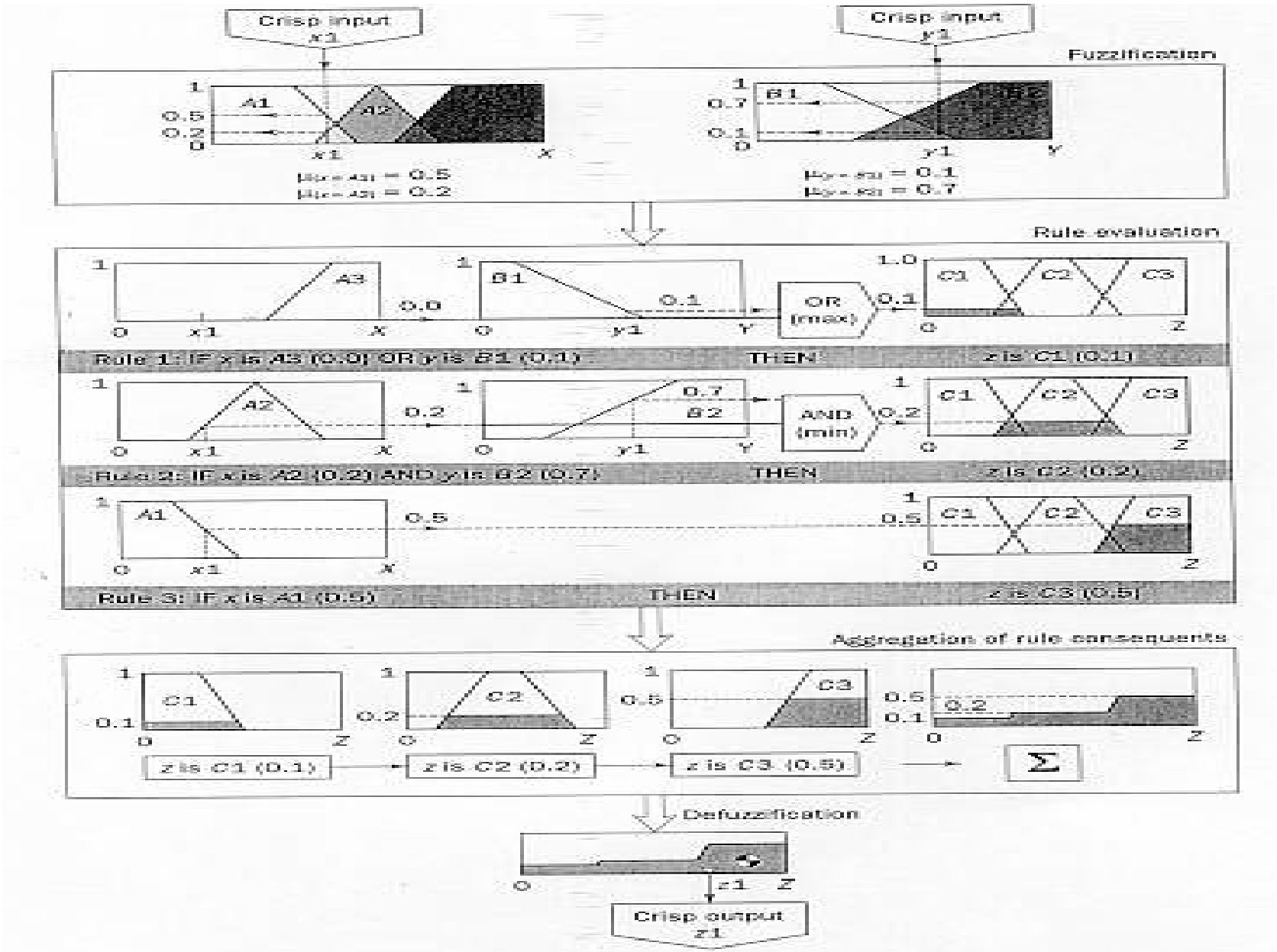
- Fuzzy models are appropriate where goals & constraints as well as physical parameters are not clearly defined.
- A fuzzy model does not require a deep information.
- Identification has THREE steps:

1. Determination of the model structure.
2. Model parameters estimation.
3. Model validation.

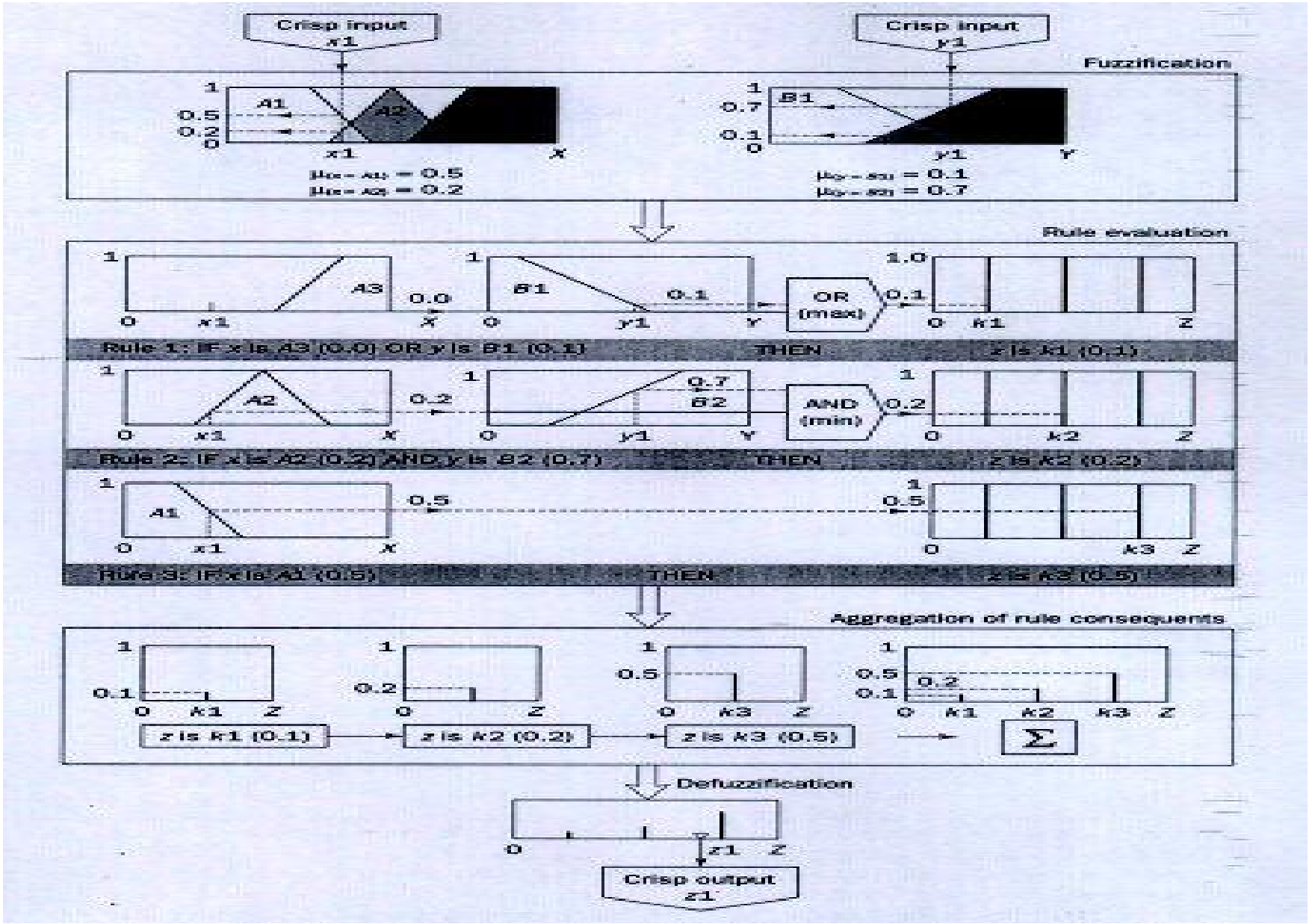
Basic Fuzzy System:



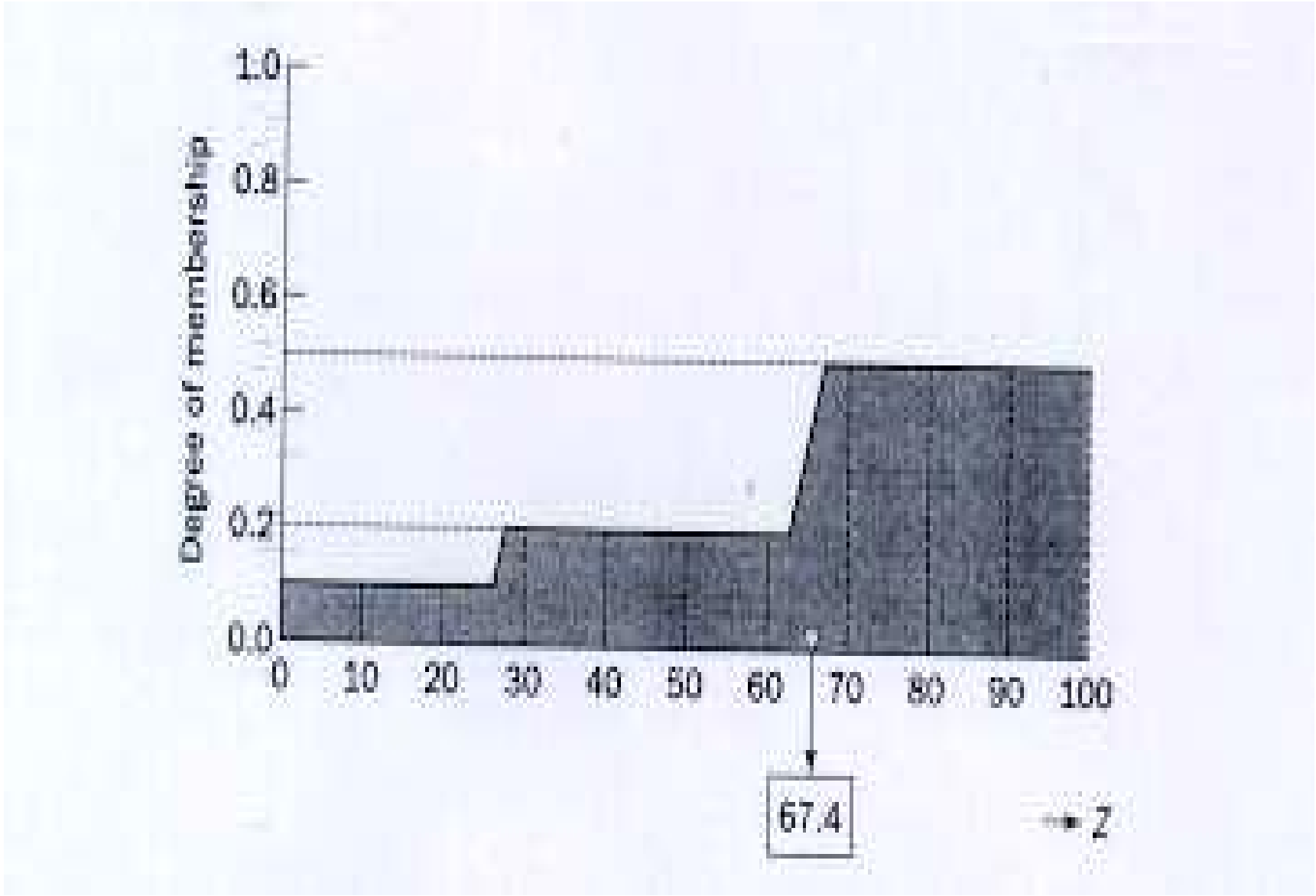
Fuzzy Inference: (Mamdani Style)



Fuzzy Inference: (Sugeno Style)



Fuzzy Set Defuzzifying:



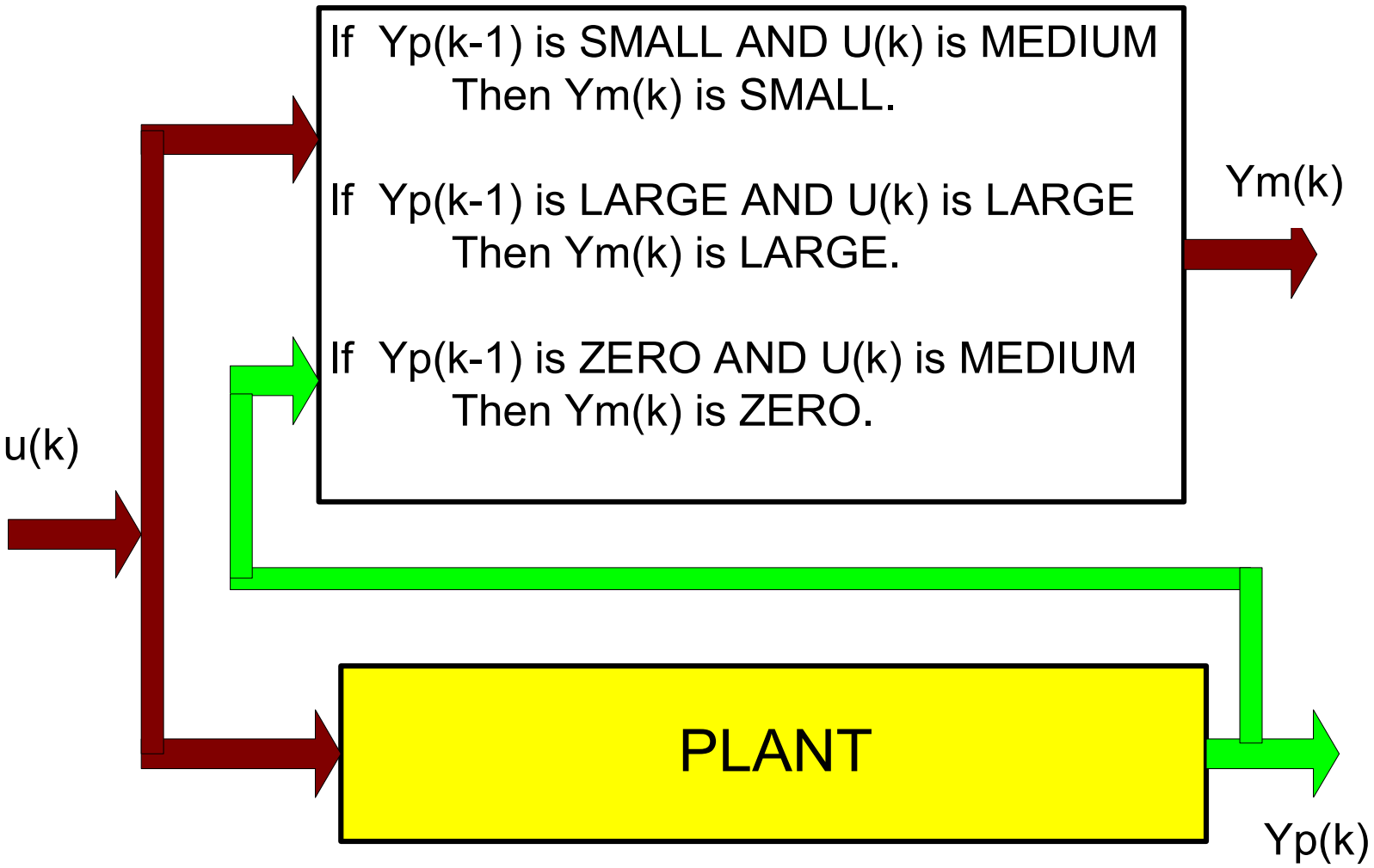
Fuzzy Systems & Neural Networks:

- Approaches to apply NNs in fuzzy systems;

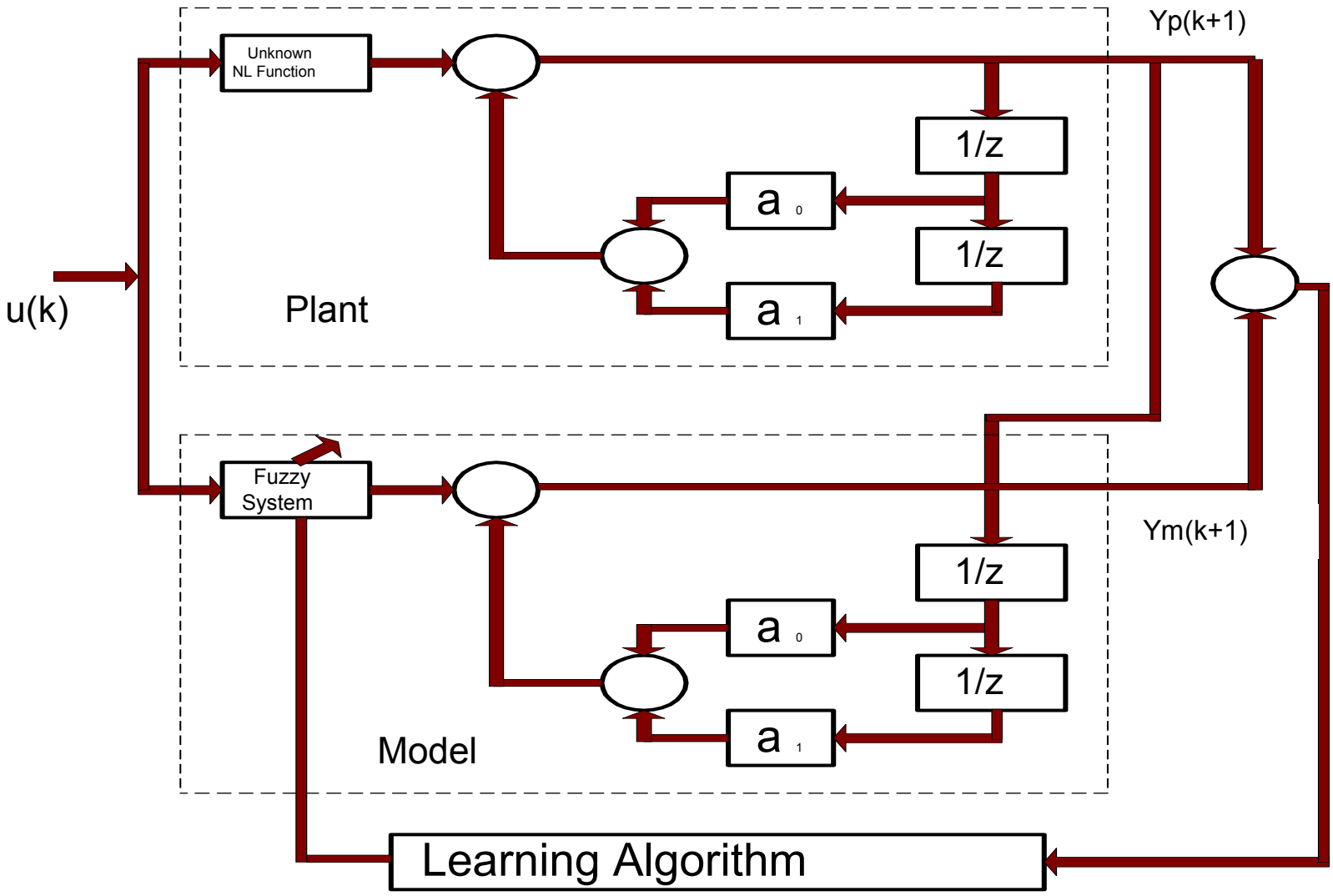
1. FS where NN learn the shape of the membership functions, the rules & o/p membership values.
2. FS that are expressed in the form of NN and are designed using a learning capability of NN.
3. FS with NN which are used to tune the system parameters as a design tool.

In this research the fuzzy system was represented as a NN. Based on the BB training, a supervised learning algorithm for system's parameters adjustment was developed.

Identification Model:



Identification Model:



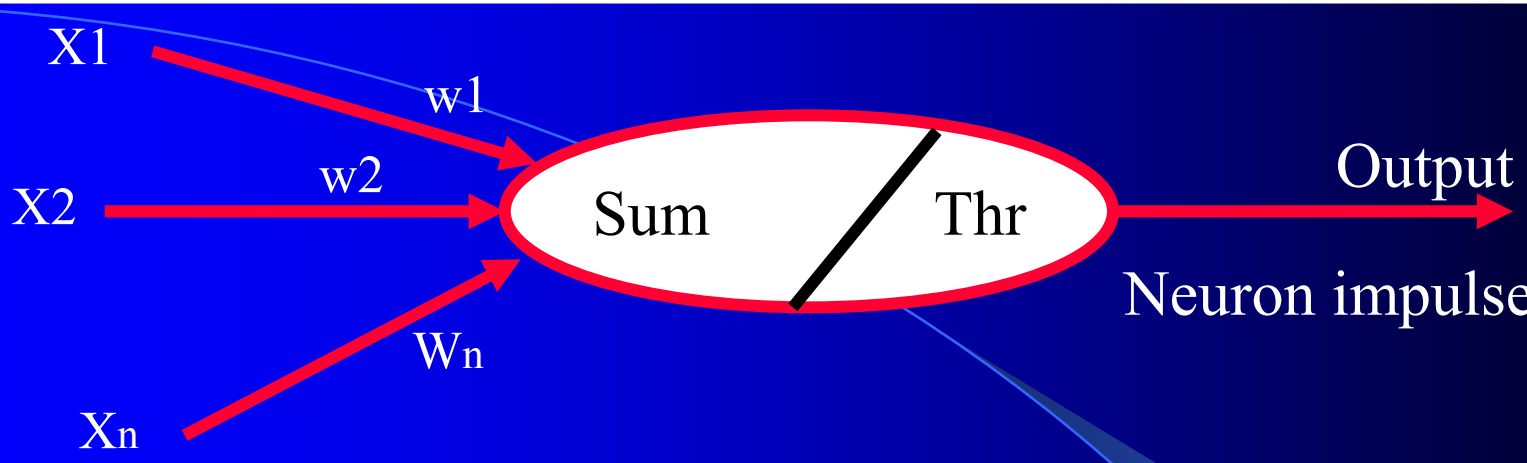
ARTIFICIAL NEURAL NETWORKS

What is a Neural Network?

- A new form of computing, inspired by biological models.
- A mathematical model, composed of a large number of processing elements (PEs) organized into layers.
- A computing system, make up of a number of simple, highly interconnected PEs, which processes information by its dynamic state response to external inputs.

ANN Structure:

- It evaluates the I/p signals, determining the strength of each one.
- It calculates a total for the combined I/p signals & compares the total against some threshold level.
- Depending on the result, it determines what the output should be.



$$Y = w1 * X1 + w2 * X2 + \ldots\ldots + wn * Xn$$

- This is a linear function. You may have another function, not a sum but a product or a logical function.
- To create a nonlinear network, compare the mapping result with the threshold. A special impulse (an excitation signal) is generated if the weighted sum of the inputs is higher than the threshold value (Neuron fired).
- Threshold may be; hard limiter, ramping functions, or sigmoid.

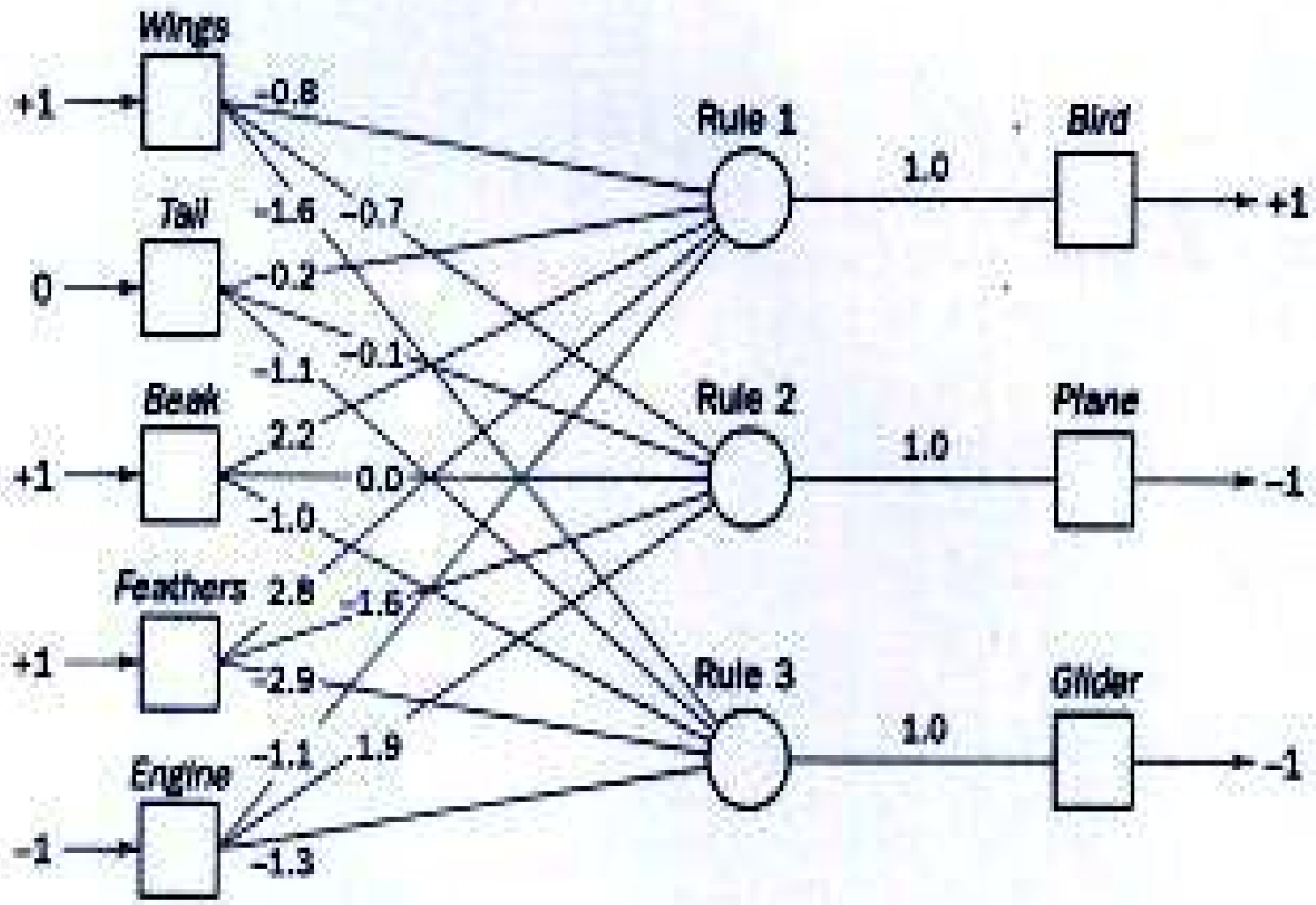
Advantages of Neural Networks:

- They do not need to be programmed, they can learn from examples.
- They can generalize from their training data to other data.
- They are fault tolerant: they can produce correct outputs from noisy and incomplete data, whereas conventional computers usually require correct data.
- They are fast: their interconnected PEs work in parallel.
- They are relatively inexpensive to build and to train.

Disadvantages of Neural Networks:

- Neural networks have no model of the universe in which they work.
- Whereas neural networks work well for inputs reasonably similar to their training data, they may give completely unpredictable outputs outside this region.
- Although they require no programming, a considerable effort may go into the pre-processing and post-processing subsystems for a neural network.
- Much of the knowledge about neural networks is empirical.

The Neural Knowledge Base:



•Set each I/P of I/P layer to: +1= True, -1= False, 0= Unknown

•If the object has Wings(+1), Beak(+1) & Feathers(+1), but does not have Engine(-1), then:

$$Xrule1 = 1(-0.8)+0(-0.2)+1(2.2)+1(2.8)+(-1)(-1.1) = 5.3 > 0$$

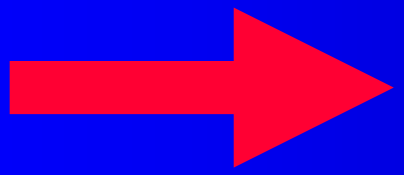
$$Yrule1 = Ybird = +1$$

$$Xrule2 = 1(-0.7)+0(-0.1)+1(0)+1(-1.6)+(-1)(1.9) = -4.2 < 0$$

$$Yrule2 = Yplane = -1$$

$$Xrule3 = 1(-0.6)+0(-1.1)+1(-1)+1(-2.9)+(-1)(-1.3) = -4.2 < 0$$

$$Yrule3 = Yglider = -1$$



Then this object is Bird

The Heuristic applied in this case is:

*An inference can be made if the **KNOWN** net weighted input to a neuron is **greater** than the sum of the **absolute values** of the weights of the **UNKNOWN** inputs.*

For the input feather= +1

KNOWN= 1 (2.8)= 2.8

UNKNOWN= [-0.8]+[-0.2]+[2.2]+[-1.1]= 4.3

Then: KNOWN < UNKNOWN ????? Inference cannot be made yet, ……give a value for the next input **BEAK**

For the input Beak= +1

KNOWN= 1 (2.8)+ 1(2.2)= 5.0

UNKNOWN= [-0.8]+[-0.2]+[-1.1]= 2.1

Then: KNOWN > UNKNOWN

The following inference can be made:

CONCLUDE: BIRD IS TRUE

Rules:

IF Feather is True THEN Bird is True

IF Feather is True AND Beak is True Then Bird is True
If Engine is False AND Feathers is True THEN Plane is False
If Feathers is True AND Wings is True Then Glider is False

- **In this Ex. We assume that the NES has a properly trained neural knowledge base. In real world, the training data is not adequate!**
- **Can we determine an initial structure of the neural knowledge base by using domain knowledge, train it with a given set of training data, and then interpret the trained neural network as a set of IF-THEN rules.**
- **These rules can be mapped into a multi-layer NN.**

Example: Multi-layer KB:

Rule 1:
IF *a1* AND *a3* THEN *b1* (0.8)

Rule 2:
IF *a1* AND *a4* THEN *b1* (0.2)

Rule 3:
IF *a2* AND *a5* THEN *b2* (–0.1)

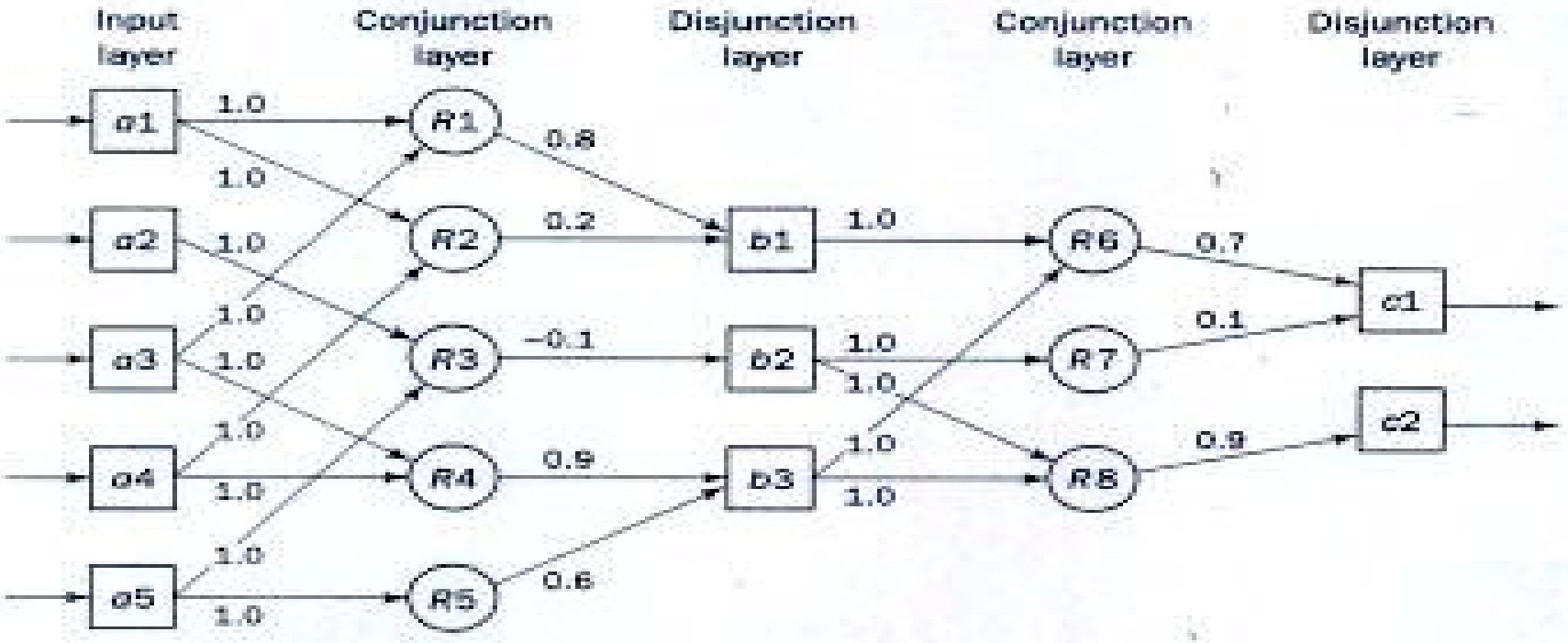
Rule 4:
IF *a3* AND *a4* THEN *b3* (0.9)

Rule 5:
IF *a5* THEN *b3* (0.6)

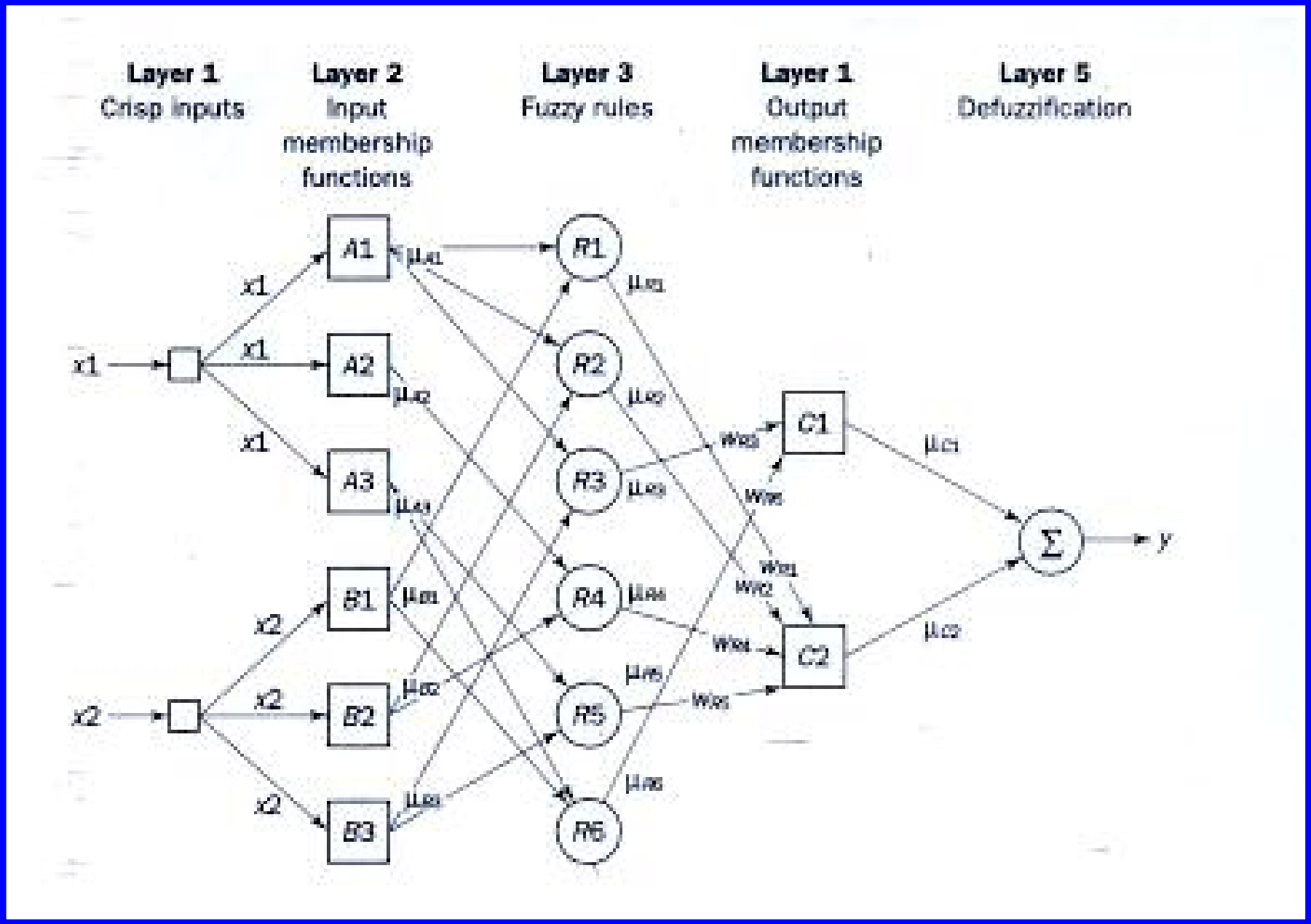
Rule 6:
IF *a1* AND *b3* THEN *c1* (0.7)

Rule 7:
IF *b2* THEN *c1* (0.1)

Rule 8:
IF *b2* AND *b3* THEN *c2* (0.9)



Nero-Fuzzy Systems:



Genetic Algorithms:

- Genetic algorithms were invented by John Holland and developed by him and his colleagues. Holland's Book "Application in Natural & Artificial Systems" 1975.
- In 1992 John Koza has used GA to evolve programs to perform certain tasks. He called his method "GENETIC PROGRAMMING"
- GA is a model of machine learning which derives its behavior from the processes of evolution in nature. This is done by the creation within a machine of a population of individuals represented by chromosomes. The individuals in the population then go through process of evolution.

For more information:
www.cs.telk.cvut.cz/~xobitko/ga/main.html

Evolutionary NNs

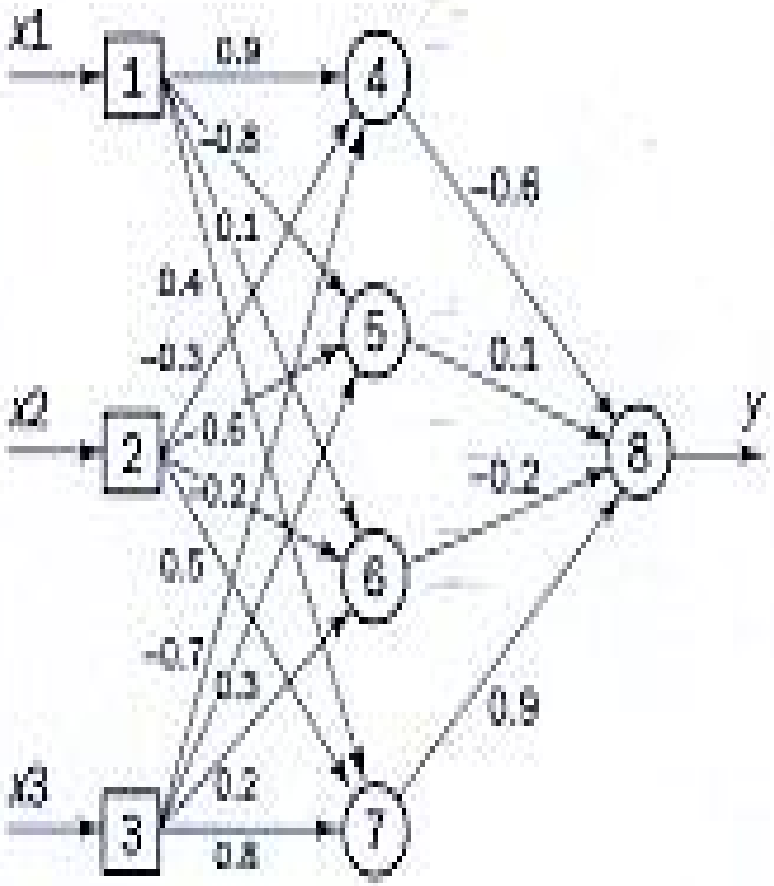
Evolution: is a series of genetic changes by which a living organism acquires c/cs that distinguish it from other organisms.

Evolution Strategies: are numerical optimization procedures similar to a focused Monte Carlo search. Unlike GA, they use only a mutation operator, and don't require a problem to be represented in a coded form. They are used for solving technical optimization problems when no analytical function is available and no conventional optimization method exists.

Evolution Computation: are computational models used for simulating evolution on a computer. It includes GA, Evolution strategies and GP.

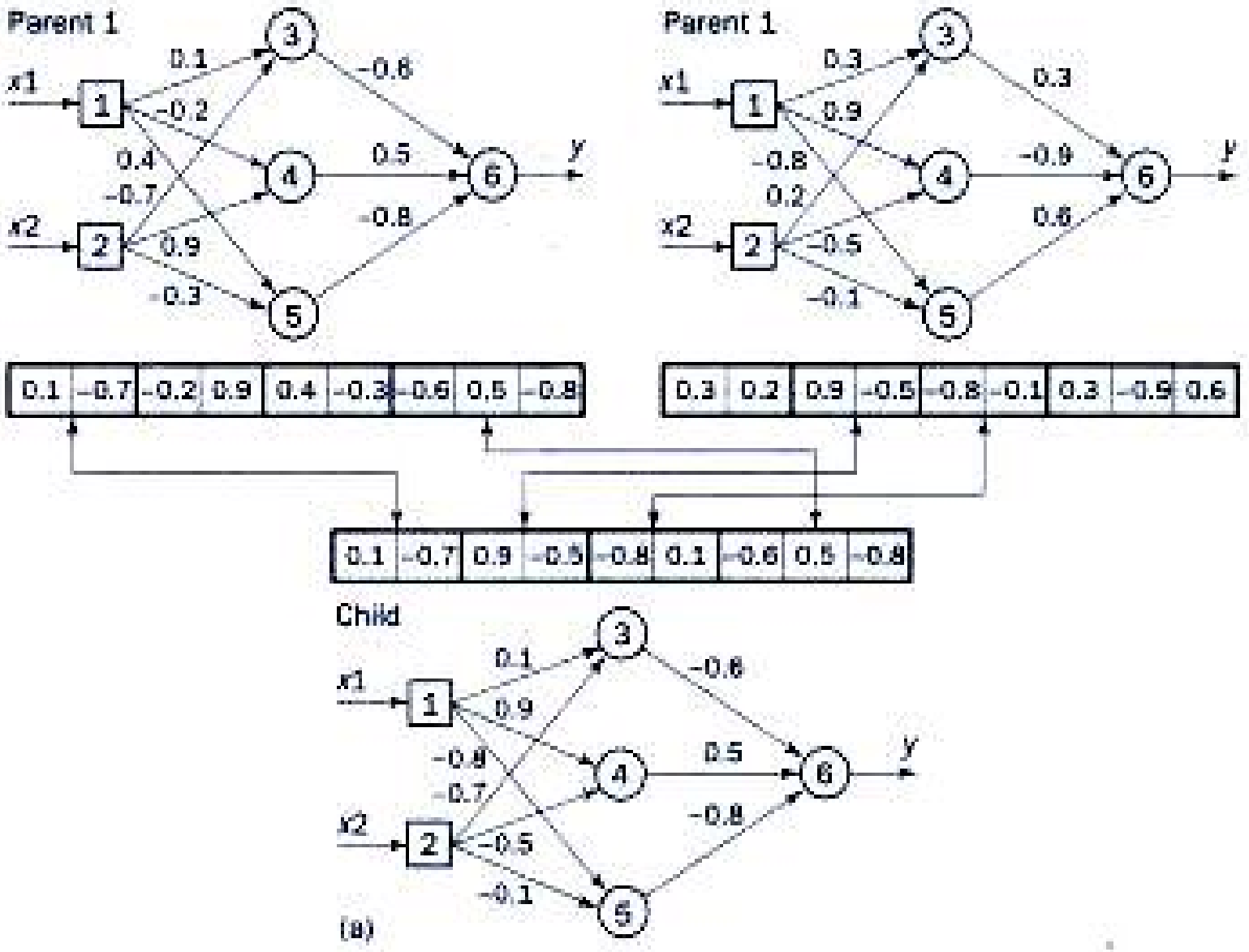
Encoding a set of weights in a chromosome:

From neuron:	1	2	3	4	5	6	7	8
To neuron: 1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0.9	-0.3	-0.7	0	0	0	0	0
5	-0.8	0.6	0.3	0	0	0	0	0
6	0.1	-0.2	0.2	0	0	0	0	0
7	0.4	0.5	0.8	0	0	0	0	0
8	0	0	0	-0.6	0.1	-0.2	0.9	0

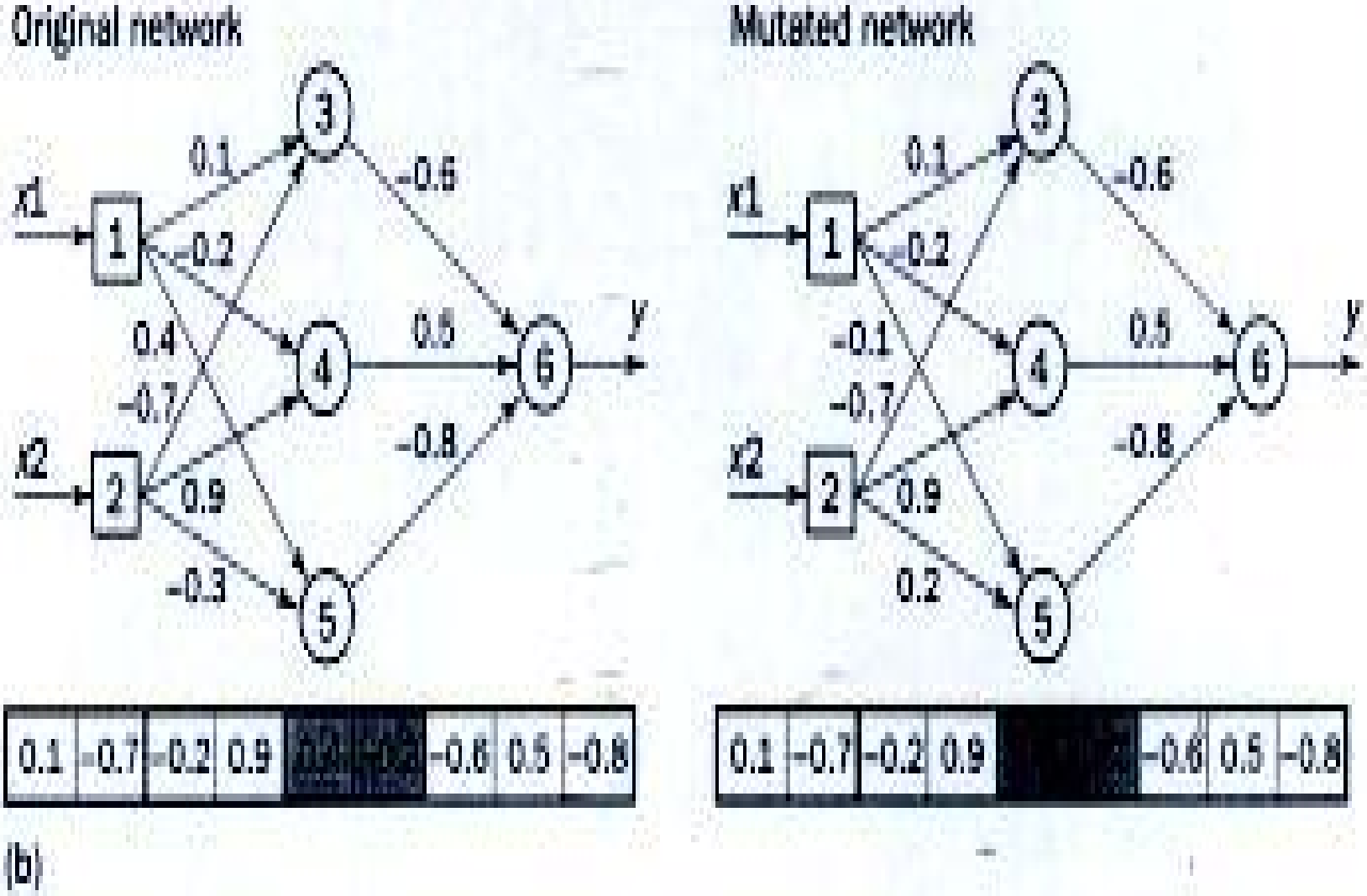


Chromosome:	0.9	-0.3	-0.7	-0.8	0.6	0.3	0.1	-0.2	0.2	0.4	0.5	0.8	-0.6	0.1	-0.2	0.9

Genetic operations in NNs/ crossover:



Genetic operations in NNs/ mutation:



CONCLUSSIONS:

- Probabilistic reasoning, FS, NNs and EC form the core of soft-computing, an emerging approach to building intelligent systems for modeling, simulation and decision making.
- Systems based on soft-computing combine at least two intelligent technologies.
- An ES can not learn, but can explain its reasoning, while NN can learn, but acts as black-box. These make them together with FS good candidates for building a hybrid intelligent systems.
- G.As are effective for optimizing weights and selecting the topology of a NN.
- EC can also be used for selecting a set of Fuzzy rules for solving a problem. While a complete set of fuzzy rules is generated from numerical data. GA is used to select a small number of fuzzy rules with high classification power.


The
End