FUZZY EXPERT SYSTEMS

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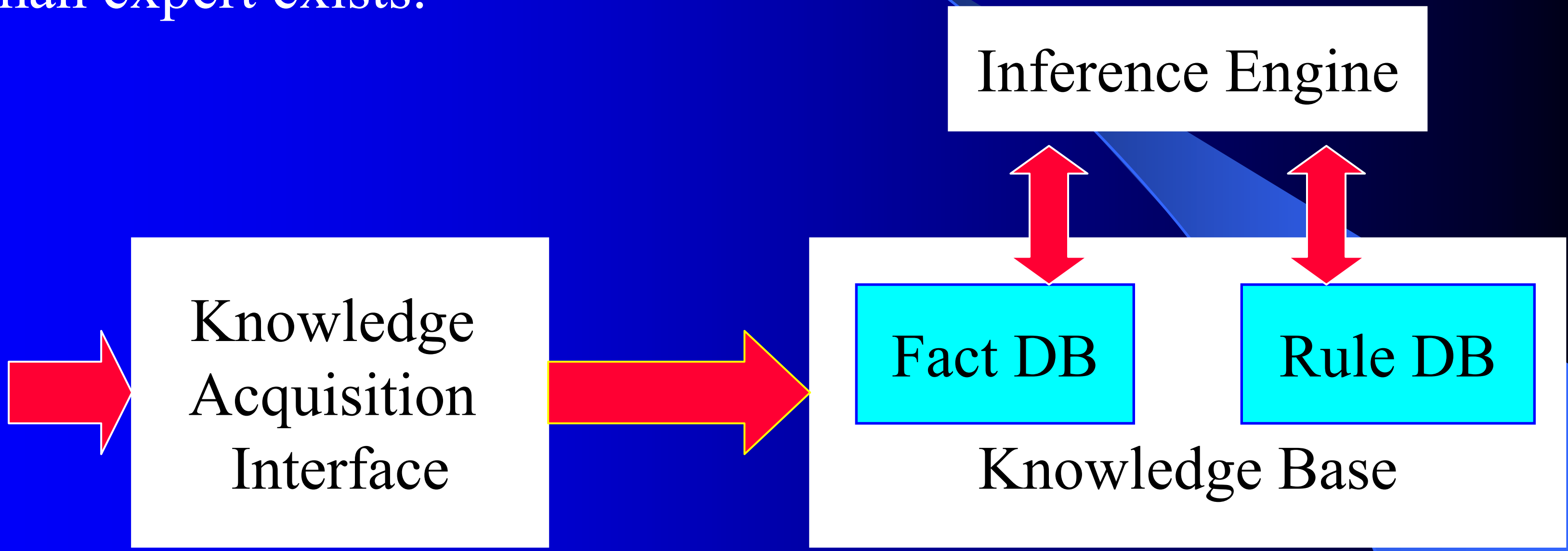
What is Expert Systems?

ES are computer programs that emulate the reasoning process of a human expert or perform in an expert manner in a domain for which no human expert exists.



The KB consists of FACTs and RULES.

<u>FACTS:</u> are the elementary components of knowledge that guide the reasoning of the ES.

<u>RULES:</u> are used to relate facts together to enable reasoning and derive new facts. Rules can be expressed as:

IF <Condition> THEN <Conclusion>

<u>Example:</u>

IF (**Temp HOT**) THEN (**Heating OFF**)

Temp HOT= TRUE if Temp> 40

Temp HOT= FALSE if Temp <= 40

Heating OFF= TRUE if the heating is switched to OFF.

Heating OFF= FALSE if the heating is switched to ON.

Inference Engine (IE):

It is a software module programmed to process the knowledge in the KB to solve problems.

The IE combines facts and rules to arrive at conclusions.

Consider this simple rule:

IF A THEN B

This means;

If A is TRUE, then B is TRUE

Methods of Search:

1. Forward Chaining.
2. Backward Chaining.

Uncertain FACTS:

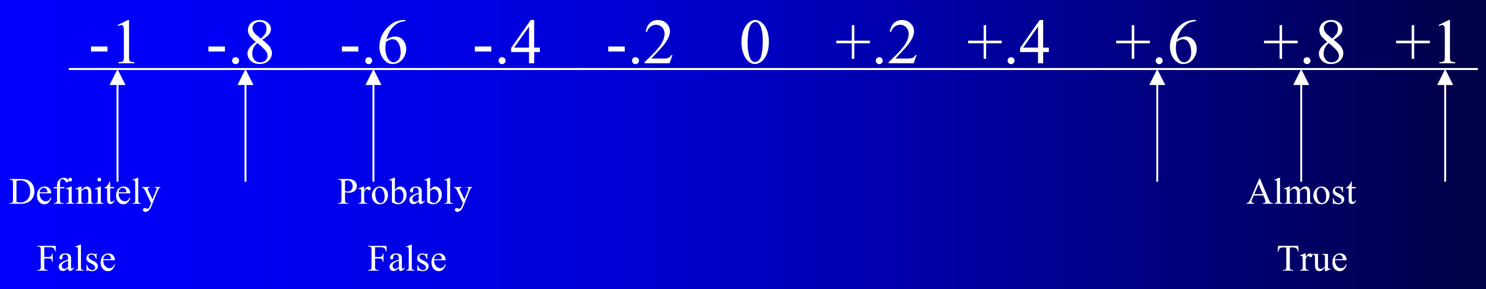
Our world is not BLACK & WHITE. We have some "degree of belief" in the event. For example:

IT PROBABLY RAIN TODAY

Certainty Factor (CF):

It is a conventional method used in ES for managing uncertain information. It is a numeric value assigned to a statement that represents the degree of belief in the statement.

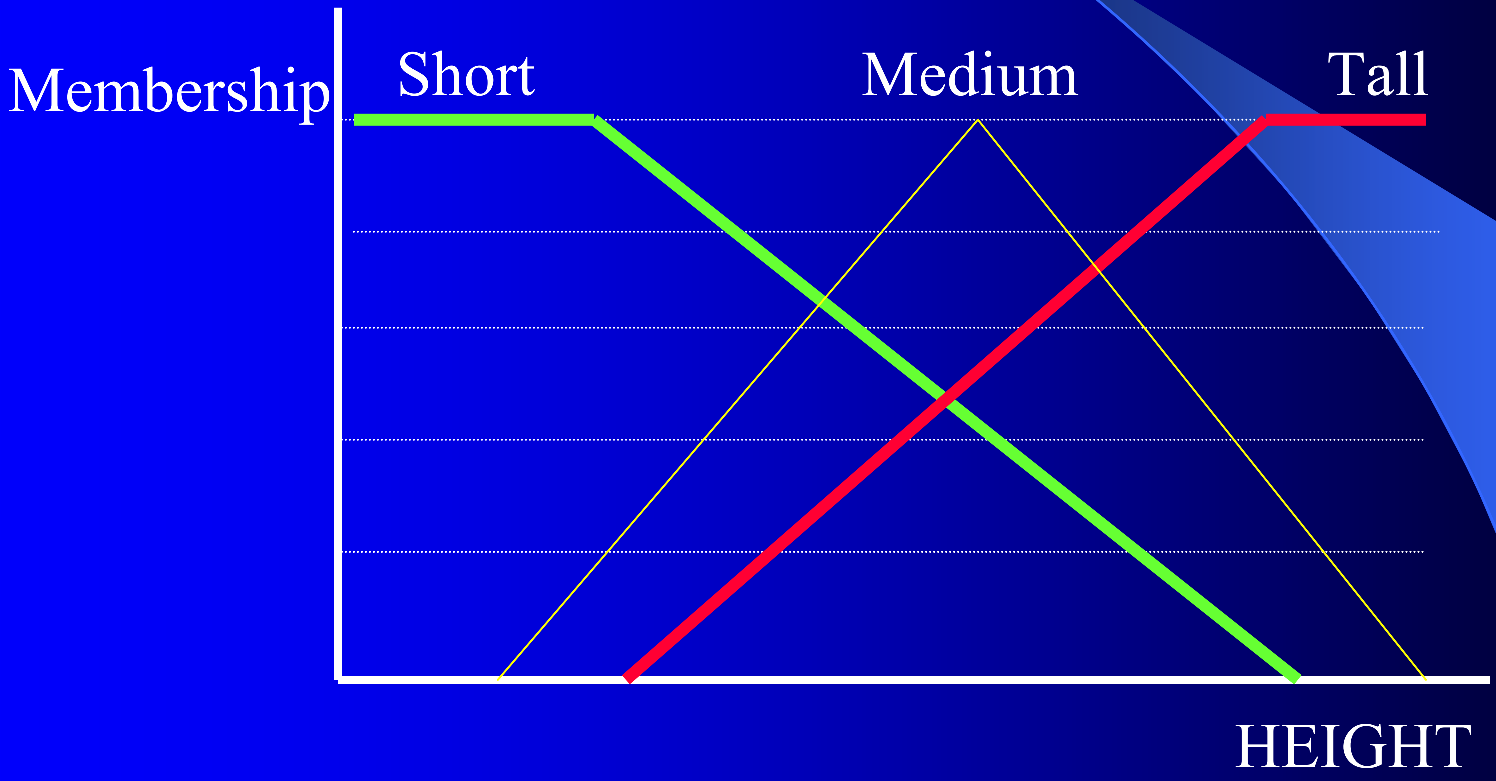
Example: MYCIN



FUZZY FACTS:

Fuzzy logic provides methods for both representing and reasoning with ambiguous terms. For example;

Omer is TALL



- THREE fuzzy sets mapping the domain of height into a number called “Membership value or Grade (u= 0 to 1.0)”.

For Example:

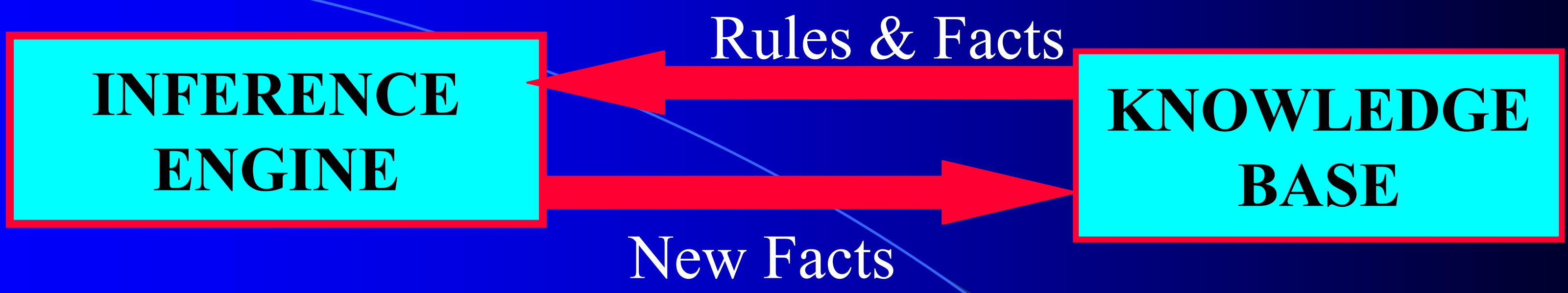
A height of 150 cm would be said to a member of “MEDIUM” with u=1.0, and at the same time a member of “SHORT” and “TALL” with u=0.4

- In addition to creating fuzzy sets, fuzzy logic permits you to write fuzzy rules.

A fuzzy rule contains fuzzy sets in both its **IF** and **THEN** parts. For example;

IF Omer’s Height is **TALL** **THEN** Omer’s weight is **HEAVY**

TALL & HEAVY are fuzzy sets.



- The rules & facts are analyzed by the IE. Inferencing begins with an examination of the KB for any rule conditions that matches existing facts.

- When all of the condition clauses in a rule have a corresponding fact in the KB, the IE can assert the conclusion of the corresponding rule into the KB as a new fact.

- Rules and facts represent **WHAT** the knowledge is.
- IE determines **HOW** the knowledge should be analyzed.

Rule-Based Fuzzy System Operation:

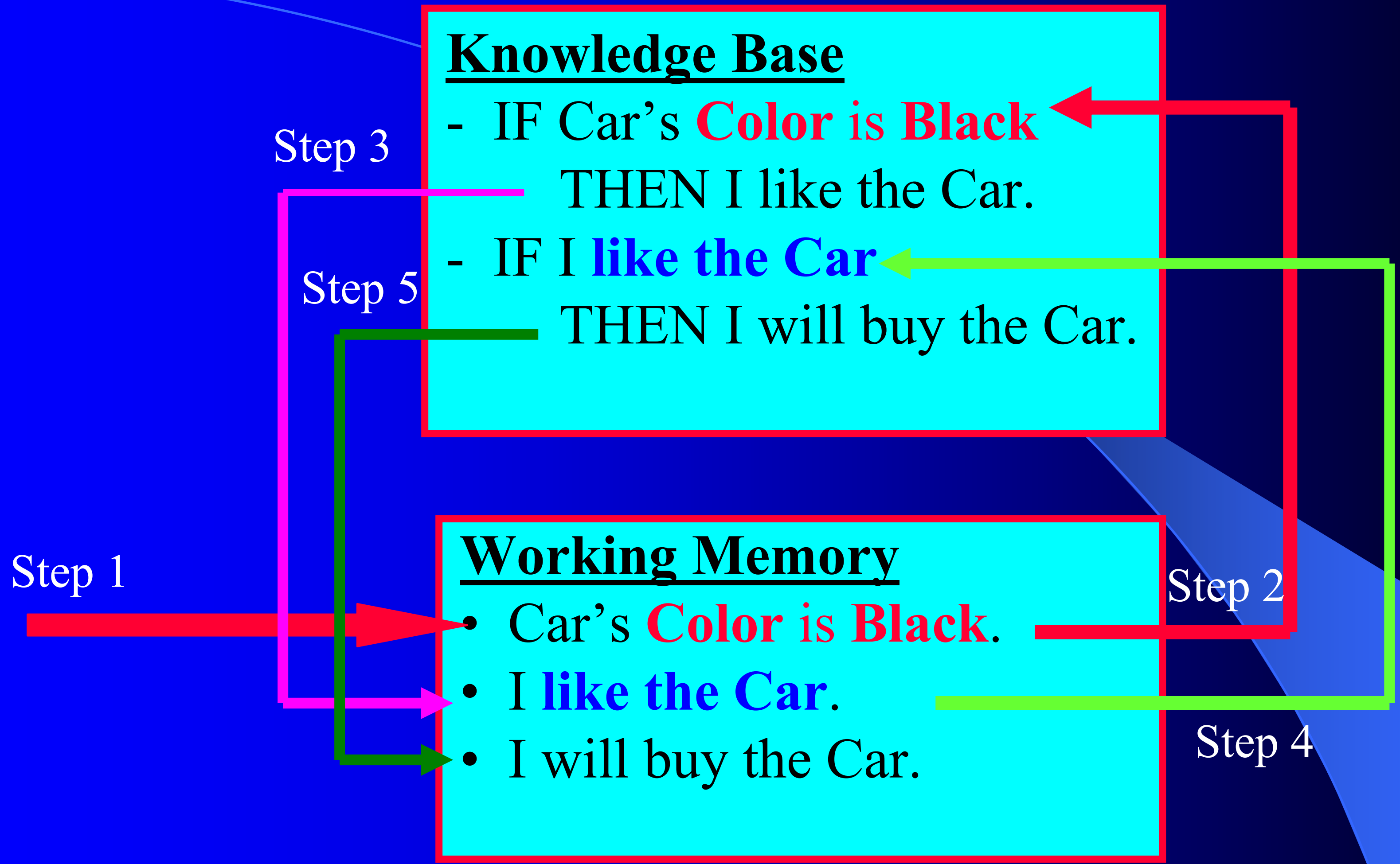
- When the **IF** part of a rule matches the information contained in the WM, the system performs the action specified in the **THEN** part. When this occurs, the rule **FIRES** and its **THEN** statements are added to the WM.

- The new information added to the WM can also cause other rules to fire.

  - Consider this example:

R1: IF car's color is Black THEN I like the car.

R2: IF I like the car THEN I will buy the car.



Q: Car’s color?

Answer: Black.

Expert Systems & Conventional Programs:

- In an ES, all the knowledge is kept separate from control structure of the programs.

  In a conventional programs, the two would be intermixed.

- In an ES , new knowledge can be added or unwanted knowledge taken away relatively easily.

  In a conventional program, if some new knowledge became available, the program would have to be rewritten.

- ES has mechanisms to explain its conclusions and lines of reasoning.

ES= Knowledge + Inference

Program= Algorithm + Data

Traditional Program	Expert System
• Handles data.	• Handles knowledge.
• Uses algorithms.	• Uses rules or heuristics.
• Goes through repetitive processes.	• Goes through inferential process.
• Based on large DBs.	• Based on KBs.

FCS & ES:

- FL has been successfully incorporated in several FCSs and Ess.
- First FES was a rule-based fuzzy control system developed in 1974 by Mamdani & Assilian.
- FCSs & Ess have one thing in common: both want to model human experience, human decision making behavior.
- Fuzzy expert systems are strongly tied to knowledge-based techniques for gathering and processing information.
- Knowledge representation is in the form of rules garnered through consultation with human experts.

- NNs encode knowledge implicitly, adjusting internal weights so that their I/O relations remain consistent with observed training data

- Coupling the methods of approximate reasoning with knowledge-based techniques yields systems which model human decision making.

- ESs provide a ready mechanism for explanation why certain decisions are made.

- A major disadvantage of KBSs is their reliance upon consultation with human experts for new information.

Hybrid Systems:

- Every ES has particular computational properties that make them suited for particular problems and not for others. These properties include;

  - ability to learn.
  - explanation of decisions

- NNs are good at recognizing patterns, they are not good at explaining how they reach their decisions.

- FLSs can reason with imprecise information, they are good at explaining their decisions, but they cannot automatically acuire the rules they use to make those decisions.

- Due to these limitations, two or more techniques are combined in a manner that overcomes these limitations.

- Hybrid systems are important when considering the varied nature of application domains. Many complex domains have many different component problems, each of which may require different types of processing.

- NNs are used to tune membership functions of FSs that are used as decision-making systems.

- FL can encode expert knowledge directly using rules with linguistic labels, it usually takes a lot of time to design and tune the membership functions which quantitatively define these linguistic labels.

- NN learning techniques can automate this process and then reduce development time and cost while improving performance.

- For NNs, knowledge is automatically acquired by the backpropagation algorithm, but the learning process is relatively slow and analysis of the trained network is difficult (black box).

- FSs are more favorable in that their behavior can be explained based on fuzzy rules and thus their performance can be adjusted by tuning the rules.

- In general, knowledge acquisition is difficult and also the universe of discourse of each I/p variable need to be divided into several intervals, applications of fuzzy systems are restricted to the fields where expert knowledge is available and the number of I/p variables is small.

- To overcome the problem of knowledge acquisition, NNs are extended to automatically extract fuzzy rules from numerical data.

NN Applications in FES Design:

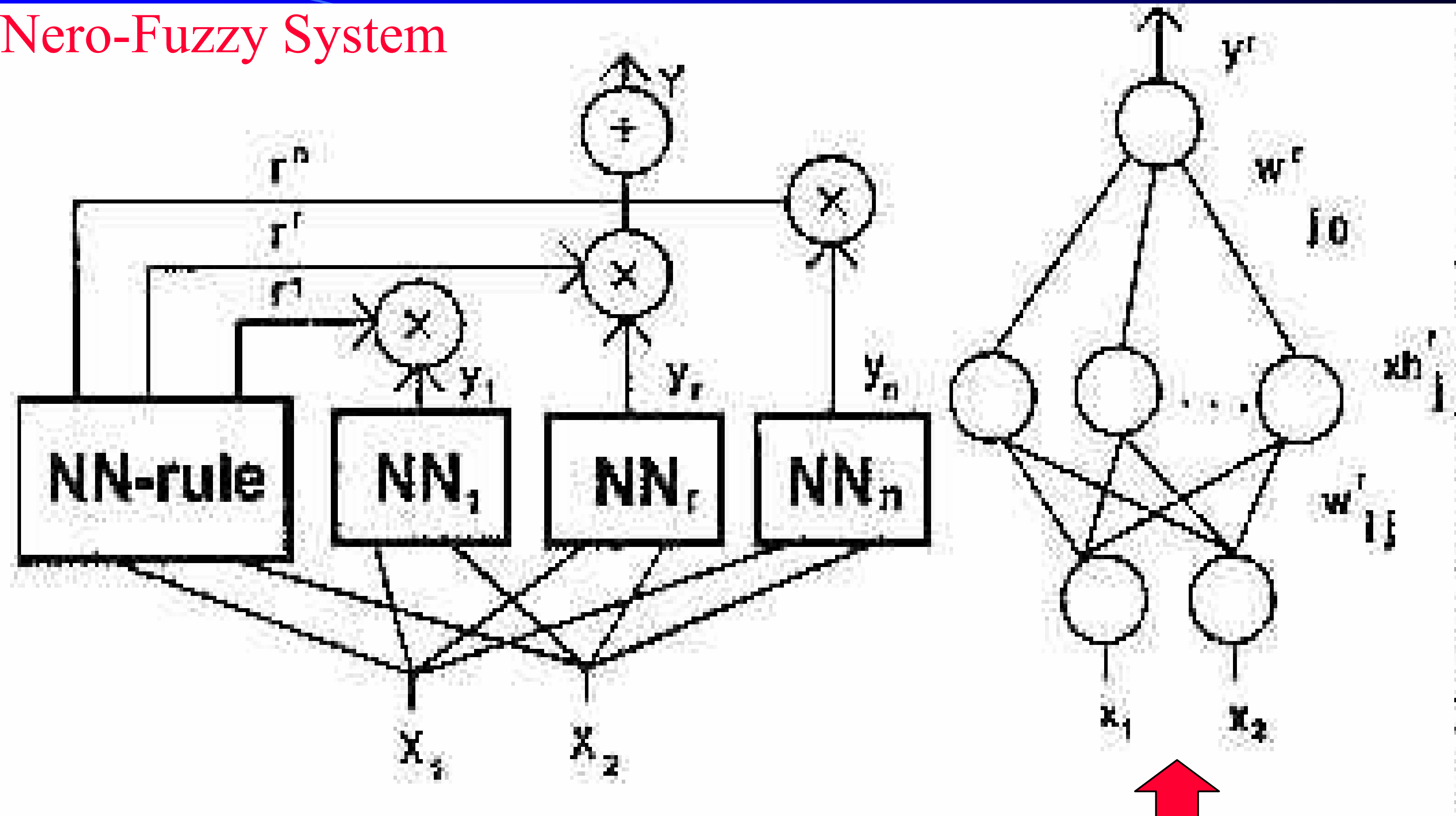
There are three main approaches;

- FSs where NN learn the shape of the surface of membership functions, the rules and output membership values. A NN is applied directly to design nonlinear multidimensional membership functions.

- FSs that are expressed in the form of NN and are designed using a learning capability of the NN. NN become a component of the whole nero-fuzzy ES.

- FSs with NN which are used to tune the parameters of fuzzy controller as a design tool but not as a component of the final FS.

Nero-Fuzzy System



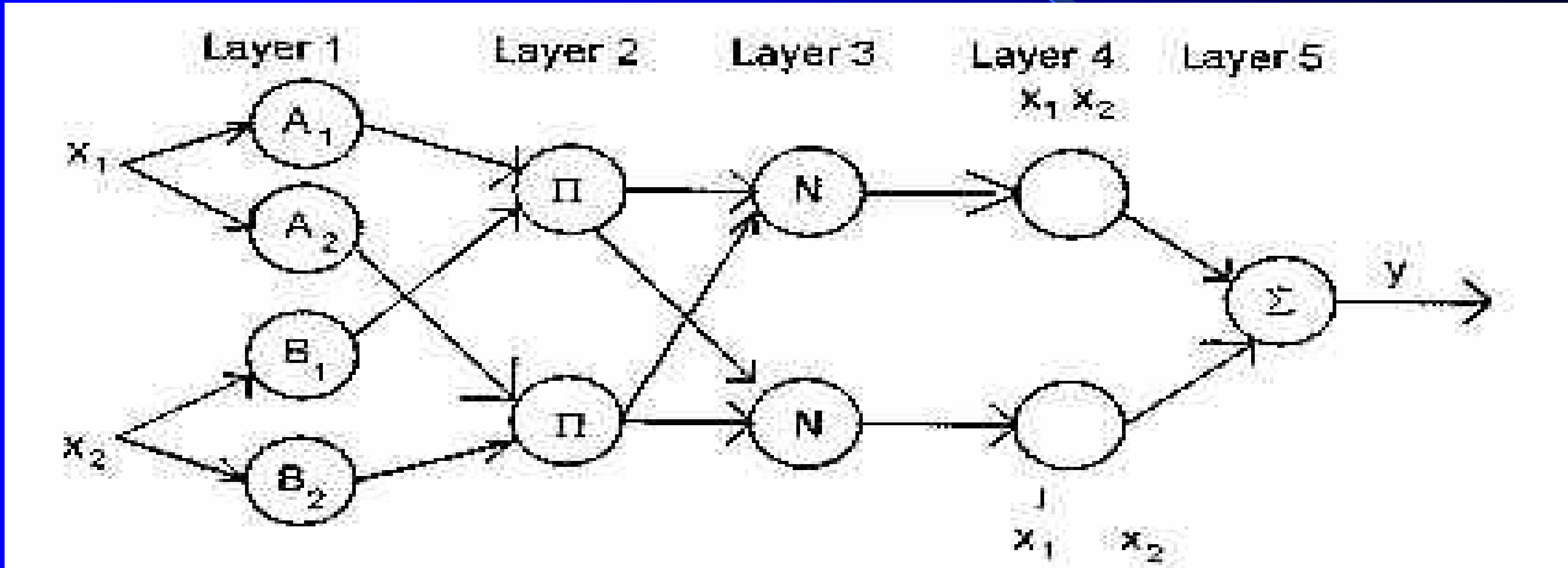
One rule implementation

Example: Sugeno Model

The NN is used to realise Fuzzy processing of typical fuzzy rules like;

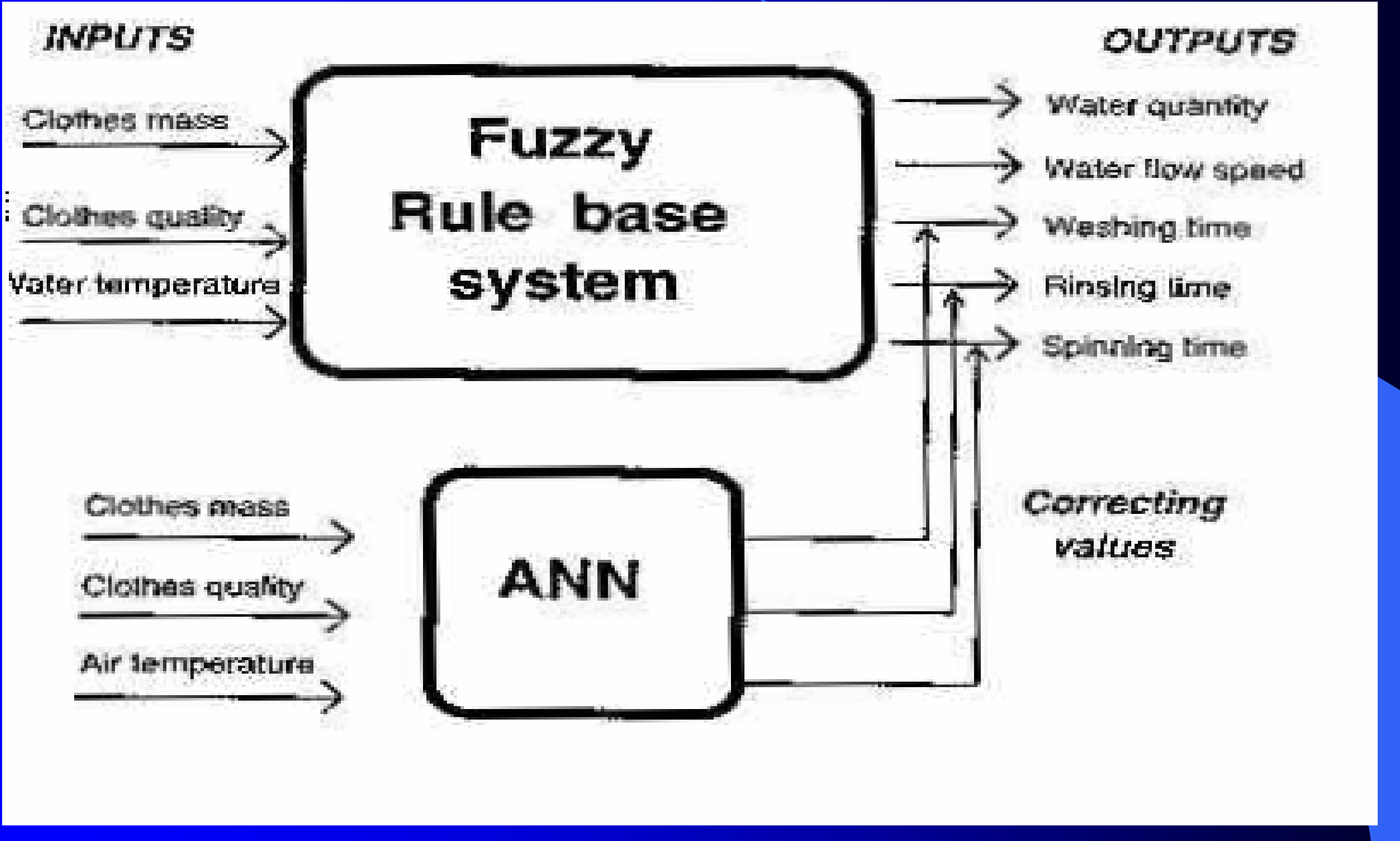
IF X1 is A1 **AND** X2 is A2 **THEN** y1=w1*x1 + w2*x2 +r1

IF X1 is B1 **AND** X2 is B2 **THEN** y2=v1*x1 + v2*x2 +r2



Layer 5; (output layer); it calculates the output of the NN.

Example: Nero-Fuzzy ES for Washing Machine. *(Hitachi, Japan)*



HARDWARE IMPLEMENTATION OF FES:

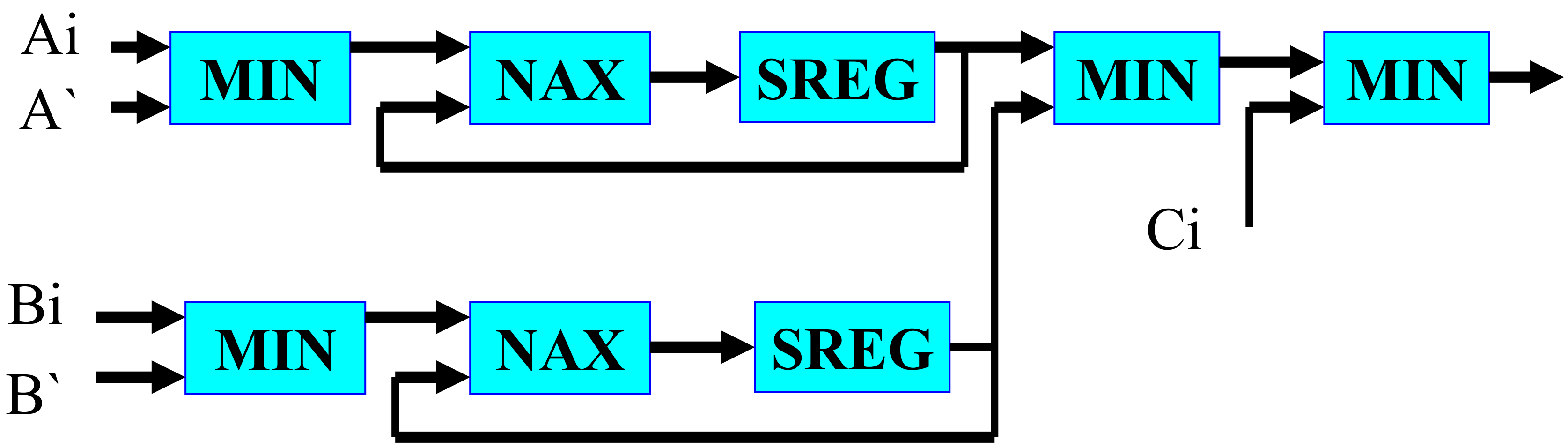
The IE consists of three major components;

- Rule set memory (RAM or ROM).
- Inference processor.
- Controller (counters).

All rules are executed in parallel, each rule is processed serially.

➢Because of the very high rate of communication between the rule set storage unit and the inference processing unit, these rules are stored on a chip.

➢In this case the control unit of the IE is simple since we do not need to load a rule set from off-chip.



Rule 1: IF X is A1, Y is B1 THEN Z is C2

Rule 2: IF X is A2, Y is B2 THEN Z is C2

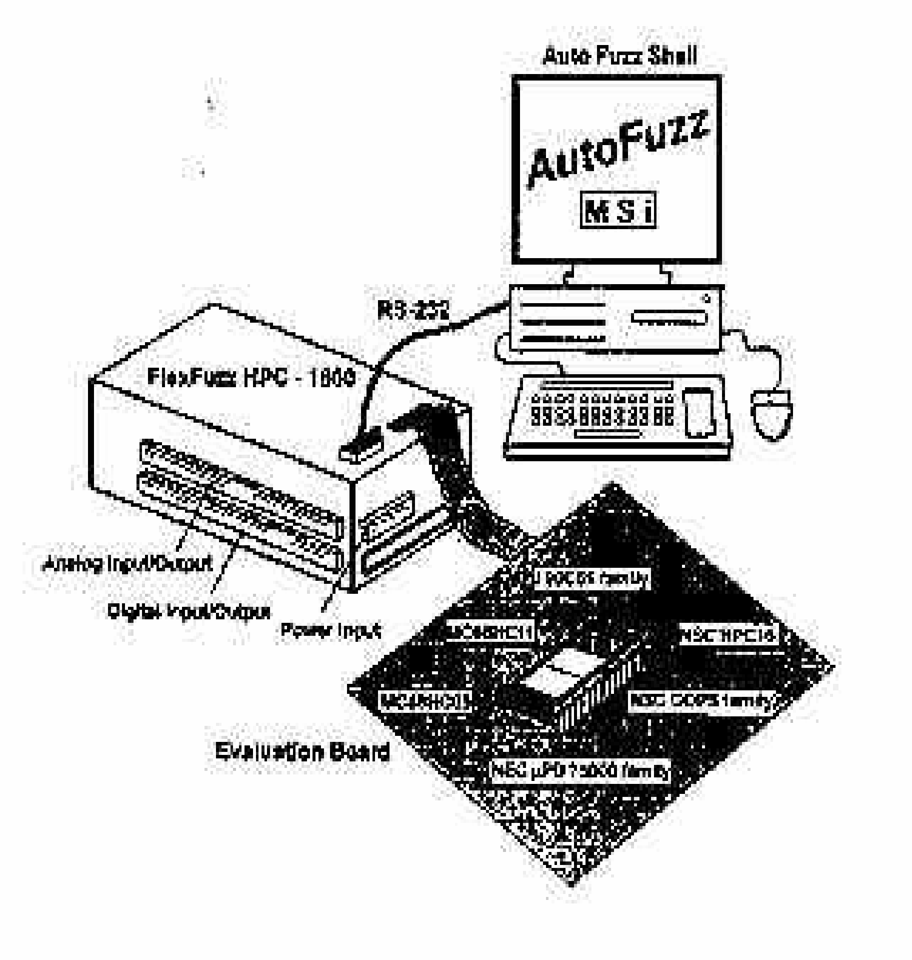
Examples:

- The 1st implementation of this technology was demonstrated at AT&T Bell Laboratories.
- It stores 16 rules, 31 elements with 16 levels of membership. 4-bit resolution of membership function. 124 bits per rule, a single inference process takes 256 clock cycles.
- The IE begins to produce the result on the 133rd cycle after the reset signal. Frequency: 20.8 MHz (48 ns cycle)
- Chip size: 2.99 mm * 3.84 mm. 68-pin package

The automated FC design station includes FES for generation and optimization of automatic fuzzy rules and membership functions.

It includes;

1. The FlexFuzz HPC1600 block for control modeling.
2. Special evaluation board for chip development.



FC110 DIGITAL FUZZY PROCESSOR:

The 1st specialized processor from Togai InfraLogic.

It is a single chip small enough for sensitive embedded applications.

Its architecture suppose high communication possibilities for working together with a host computer.

Variable data are stored in a 256 byte on-chip RAM. At least the low 64 bytes are shared between the host and the device.

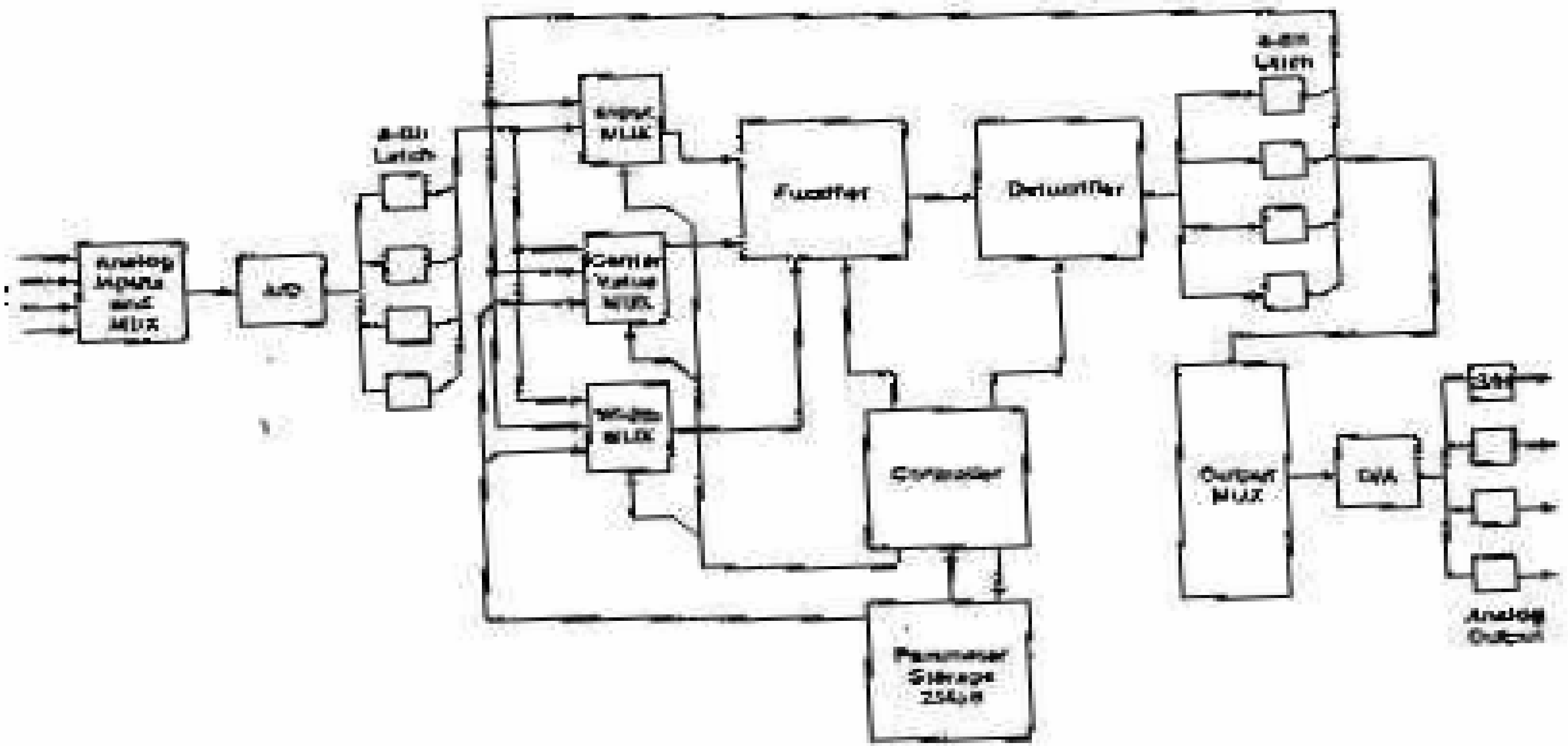
FP-3000 DIGITAL FUZZY PROCESSOR:

It is a high speed fuzzy processor applied in different Omron product.

WARP FUZZY PROCESSOR:

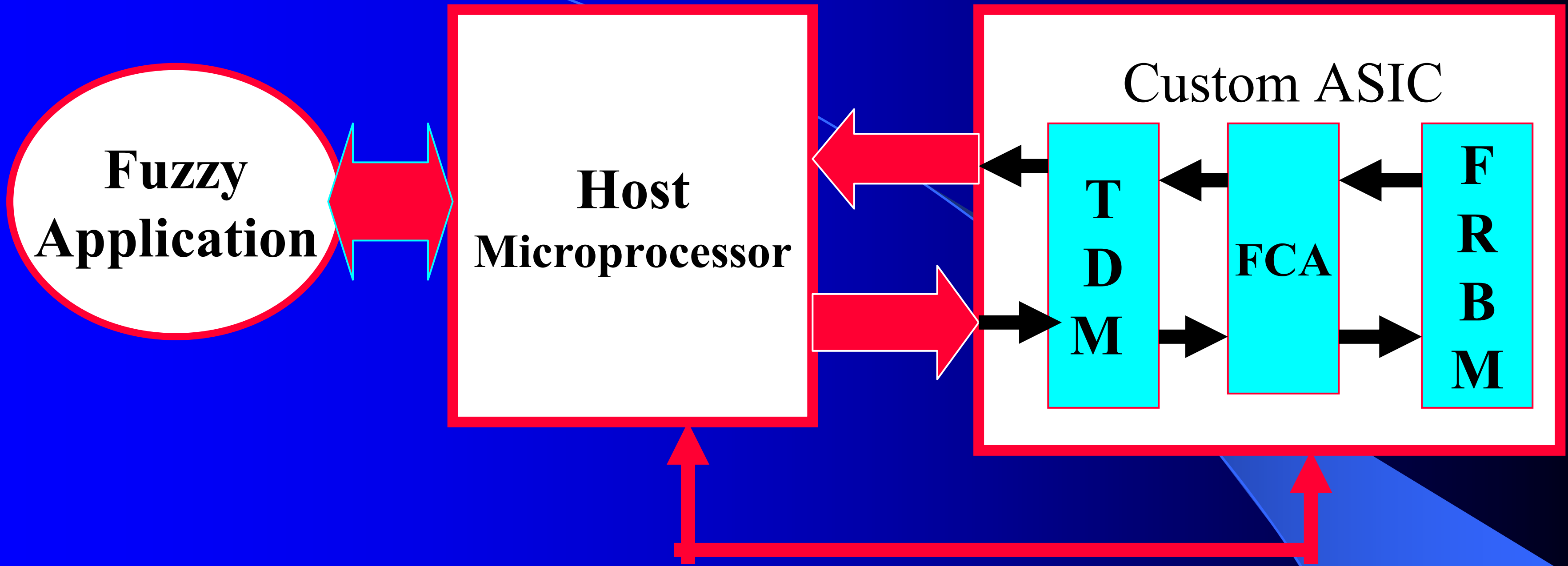
Weight Associative Rule Processor from SGS-Thomson. It is a high speed fuzzy processor.

AL220 MICROCONTROLLER:



It is high performance fuzzy microcontroller. It contains 4 analog I/ps and single o/p (8-bit resolution). Its main elements are; fuzzifier, defuzzifier, and a controller

Custom ASIC Chip Used as Fuzzy Coprocessor:



It is a high performance Fuzzy coprocessor with a 12-bit FCA (Fuzzy Computational Acceleration) core, 4K*12-bit Temp. Data Memory (TDM), a Fuzzy Rule Base Shared Memory (FRBM), and a Host interface logic combined in a single chip.

A FRB is downloaded by the host. At the beginning of fuzzy computation, crisp I/p values are downloaded by the host into TDM. The Fuzzy core uses the rule base information to perform calculation and produce a crisp o/p values stored at TDM and are used by host.

H/W IMPLEMENTATION	ADVANTAGES	DISADVANTAGES
Digital General Purpose Processors	Flexibility in choice Of H/W & S/W Tools	Low performance
Digital Special Purpose Processors	Increasing Performance	Complex: it must be coupled with a Host
Analog Processors	High performance Low cost	Used for research Low accuracy

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