Introduction.

• To Implement Fuzzy Logic Systems you can either use.
  – Conventional Programming techniques
  – Dedicated fuzzy logic hardware and software tools

• Software tools include.
  – Simple Fuzzy Logic kernels.
  – CASE-like packages.

• Hardware includes
  – Fuzzy logic processors.
  – Fuzzy Logic accelerator boards which include these chips.
Fuzzy Logic Design Cycle

User

Fuzzy Logic Development Environment

Produce Programming Language Code

Produce MCU Code

Produce FLC Data

Stand ALone Code

Compile for MCU Code

Implement on Standard MCU

Implement on FLC
Fuzzy Logic Software Tools

• Fuzzy Logic systems can be developed using conventional programming techniques
• This can bog down the designer with implementation details
• Fuzzy logic design/development tools are designed to simplify the whole design cycle.
• Capitalise on the intuitive nature of fuzzy logic.
Fuzzy Logic Software Tools

- The most basic fuzzy logic tools consist of fuzzy logic inference kernels for microcontrollers
  - Perform fuzzification, rule evaluation or inference and defuzzification.
  - The user must define the system parameters
  - Kernel then produces assembly language
Design Cycle with CubiCalc

1. Enter in Initial Parameters i.e. Input/Output MF's, Rule Data Base.
2. Tune System Parameters i.e. Input/Output MF's, Rule Data Base.
3. Define a simulation
4. Run Simulation and observe the system response.
5. Compile to source C-code
Fuzzy Logic Software Tools

• A package which provides identical functions to CubiCalc is FIDE from Aptronix.

• The output from FIDE is a system description in Aptronix structured data language.

• Features built in code generators for:
  – Motorola 68HC05, 68HC11 and 68HC16 microcontrollers.
  – Motorola 68300 families.
  – Motorola 56000 DSP family.
  – Produces C-code.
Fuzzy Logic Software Tools

• Togai Infralogic produces software (TILShell) for:
  – Its own range of fuzzy logic processors (FC110 & boards)
  – Hitachi's H8\300, H8\500 and HMCS 400 microcontrollers.
  – generates C source code.

• Omron produces its own fuzzy support software (FSS)
  for its own range of fuzzy processors and computer cards.

• NeuraLogic also provides basic software for its own
  fuzzy logic processors.
Fuzzy Logic and Microcontroller

• For many applications fuzzy logic does not require special hardware.

• one of the key advantages of fuzzy logic is that it allows standard low-cost microcontrollers to solve complex control problems

• Fuzzy logic is not very demanding on computer power.
Microcontrollers v’s Dedicated Fuzzy Logic Chip

- With dedicated fuzzy logic processor the fuzzy process can be pipelined and also all the rules can be executed in parallel.
- On microcontrollers the fuzzy process must be done sequentially.
- For many consumer and other control system applications, the slower microcontroller approach is fast enough.
- 8-bit microcontroller is adequate for any application where the sampling rate is a half a second or greater.
Execution of Fuzzy Logic Algorithm on Microcontrollers

Pre-process Inputs

For each rule, find rule antecedent with MINimum truth Value

Apply MINimum truth value to rule consequence; when more than one rule affects the same fuzzy output, use the larger (MAXimum)

Defuzzification; take centre of gravity (COG) for all fuzzy outputs, for each system output.

Post-process outputs
Fuzzy Logic and Microcontrollers

- To keep speed acceptable minimise computationally intensive operations such as
  - fuzzification.
  - centre of gravity (COG) calculations in defuzzification.

- Membership function for input variables are normally triangular or trapezoidal in shape

- A typical rule with two antecedents (IF part) and one consequent (THEN part) would occupy only three bytes.
**Fuzzy Logic and Microcontrollers**

- The process of defuzzification can be alot more complicated as multiply and divide operations are required.
- Depends on the shape of the output membership functions.
- By using the singleton technique COG calculations are as follows ...

\[
\frac{\sum_{\text{rule } = 1}^{\text{rule } = n} (S_r \ast F_r)}{\sum_{\text{rule } = 1}^{\text{rule } = n} F_r}
\]
Control Application with Microcontroller

\[
m \frac{d^2 x}{dt^2} + l \sin \theta \cos \theta - m \frac{d^2 l}{dt^2} l \cos \theta \sin \theta = mg l \sin \theta
\]
Fuzzy Logic and Dedicated Hardware

• With dedicated hardware, fuzzy logic can achieve substantial speed improvements.

• Lends itself well to parallel processing in that all of the rules can be applied to the input simultaneously.

• Lends itself to pipeline processing where the three stages can be executed simultaneously.
Omron: Fuzzy Logic Hardware

- Omron has three devices on the market
  - FP1000 simple consumer products
  - FP3000 General purpose controller
  - FP5000 Image processing device

- Membership function shapes can only be defined as triangles or trapezoids.
- Crisp data entering the chip must be digitised externally
- Output membership functions are specified as singleton values with weighted average used in defuzzification.
Neuralogic also has a range of fuzzy logic chips
- NLX220/230 - single chip fuzzy logic controllers
- NLX110 - fuzzy pattern comparators
- NLX112 - fuzzy data correlators

The NLX230 uses clever method of fuzzification. Each input membership function must be a triangle and must have a slope of 1.

It is easy to calculate the degree of membership value of an input, knowing only the width and centre location.
Togai InfraLogic: Fuzzy Logic Hardware

- Togai InfraLogic produces its own FC110 general purpose controller
- And also a number of related products such as an SBus accelerator board and an AT board.
Architecture of the Neuralogic NLX230