Fuzzy Logic and Fuzzy Algorithms

CISC871/491

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Presentation Outline

- Fuzzy control system
- Fuzzy Traffic controller
- Modeling and Simulation
- Hardware Design
- Conclusion

Fuzzy Control System

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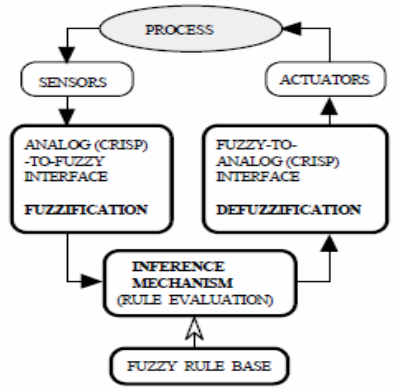
Fuzzy Control

Fuzzy control provides a formal methodology for representing, manipulating, and implementing a human's heuristic knowledge about how to control a system.



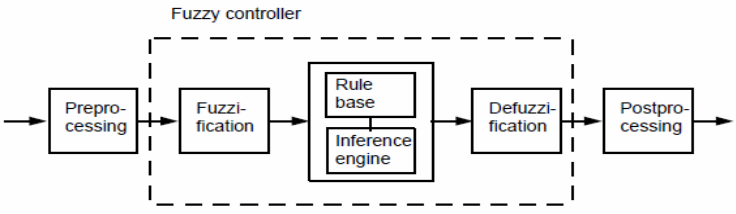


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Figure from Prof. Emil M. Petriu, University of Ottawa

Advantage

Useful cases:

- The control processes are too complex to analyze by conventional quantitative techniques.
- The available sources of information are interpreted qualitatively, inexactly, or uncertainly.
- Embedded design & control, Industrial control, Robot control etc

Advantages of FLC:

• Parallel or distributed control multiple fuzzy rules – complex nonlinear system
• Linguistic control. Linguistic terms - human knowledge
• Robust control. More than 1 control rules – a error of a rule is not fatal.

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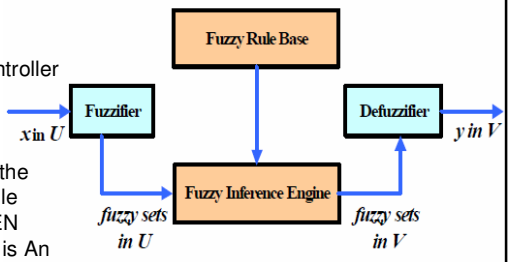
Basic Structure of Controller

FUZZIFIER
Fuzzifier takes the crisp inputs to a fuzzy controller and converts them into fuzzy inputs.

FUZZY RULE BASE (Knowledge base)
It consists of fuzzy **IF-THEN rules** that form the heart of a fuzzy inference system. A fuzzy rule base is comprised of canonical fuzzy IF-THEN rules of the form IF x1 is A1(l) and ... and xn is An (l)THEN y is B(l), where l = 1, 2, ...,M. Should have Completeness, Consistency, Continuity..

FUZZY INFERENCE ENGINE
Fuzzy Inference Engine makes use of fuzzy logic principles to combine the fuzzy IF-THEN rules. Composition based inference **(Max/Min, Max/Product)** and individual-rule based inference **(Mamdani).** Other methods like **Tsukamoto, Takagi Sugeno Kang (TSK)**



General model of a Fuzzy system.

DEFUZZIFIER – It extracts a crisp value from a fuzzy set.
· Smallest of Maximum.
· Largest of Maximum.
· **Centroid of area.**
· Bisector of Area
· Mean of maximum.

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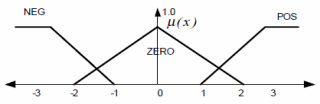
Example

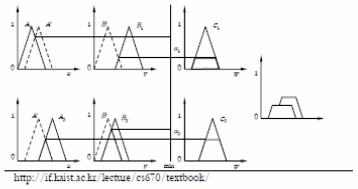
$$\mu_{pos}(x) = \begin{cases} 1 \; if & x \geq 3 \\ \dfrac{x-1}{2} & if \; 1 \geq x < 3 \\ 0 & otherwise \end{cases}$$



Membership functions of positive, zero and negative numbers.

Inference method: Mamdani

- minimum operator for a fuzzy implication
- max-min operator for the composition



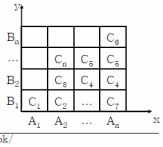
http://if.kaist.ac.kr/lecture/cs670/textbook/

Rule base design. Types of fuzzy control rules.

A set of fuzzy rules

R_i: if x is A_i, and y is B_i then z is C_i, i = 1, 2, … , n

Can be represented as a rule table



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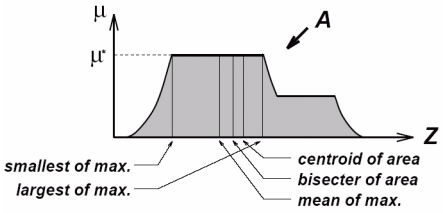

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"Fuzzy Control" Kevin M. Passino and Stephen Yurkovich
http://if.kaist.ac.kr/lecture/cs670/textbook/

Fuzzy Traffic controller

A Design Methodology for the Implementation of a Fuzzy Logic Traffic Controller Using FPGA Technology

Mandar Ambre, Bing W.Kwan and Leonard J.Tung
Department of Electrical & Computer Engineering
FAMU-FSU College of Engineering, Florida State University

THE HUNTSVILLE SIMULATION CONFERENCE HSC 2003

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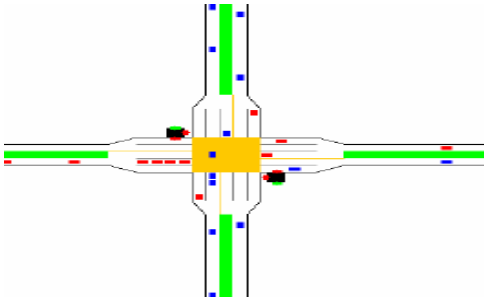
Overview



Goal
--Improving Safety
--Balanced traffic flow
--Minimizing travel time
--Increasing the capacity

Why Fuzzy traffic controller
--No obvious optimal solution
--Most traffic has fixed cycle controllers that need manual changes to adapt specific situation
--One of the desirable features of traffic controllers is to dynamically effect the change of signal phase durations
--This problem can be solved by use of fuzzy traffic controllers which are capable of signaling adaptively at an intersection.

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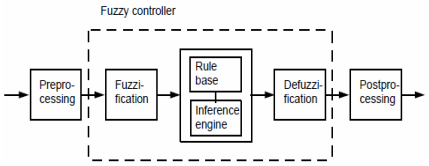
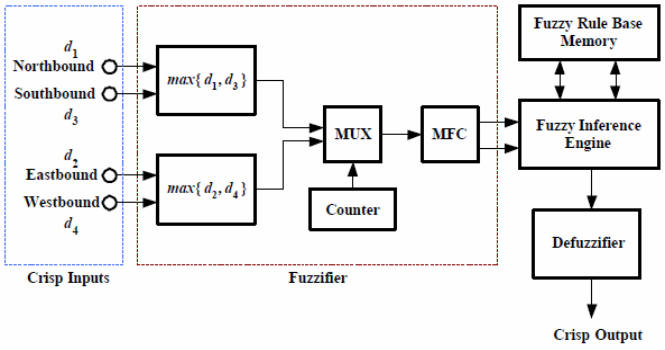
Traffic Controller Case example





Basic configuration of the fuzzy logic traffic controller

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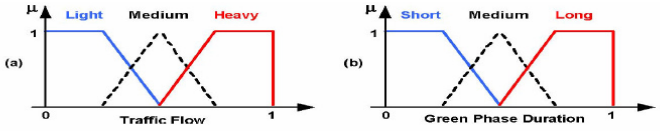
Membership functions and Fuzzy Rule Base



(a) Membership functions for the fuzzy sets, Light, Medium, and Heavy, which are induced by the traffic-queue deviations. (b) Membership functions for fuzzy sets, Short, Medium, and Long, which label the green phase duration.

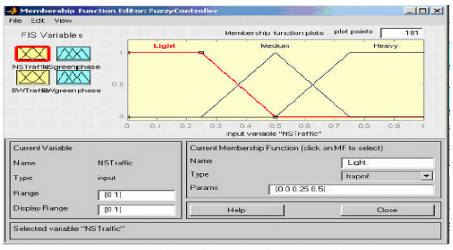
Fuzzy **IF-THEN** rules for traffic control

	Traffic Flow Condition								
NS-bound traffic	Light	Light	Light	**Med**	Med	Med	Heavy	Heavy	Heavy
EW-bound traffic	Light	Med	Heavy	**Light**	Med	Heavy	Light	Med	Heavy
NS green phase	Short	Short	Short	**Med**	Med	Med	Long	Long	Long
EW green phase	Short	Med	Long	**Short**	Med	Long	Short	Med	Long
	Duration								

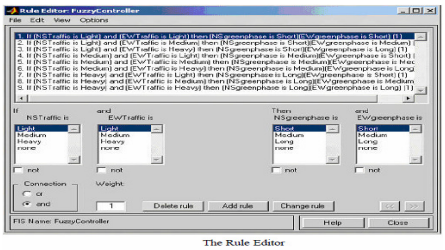
IF (*NS-bound traffic is Medium*) **THEN** (*NS green phase duration is Medium*)

IF (*EW-bound traffic is Light*) **THEN** (*EW green phase duration is Short*)

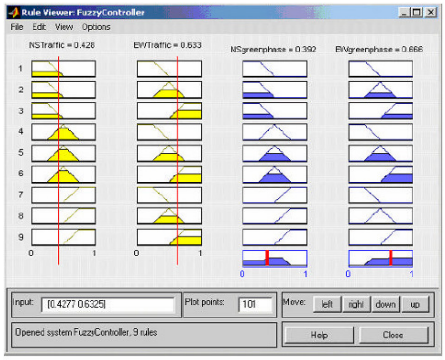
MATLAB



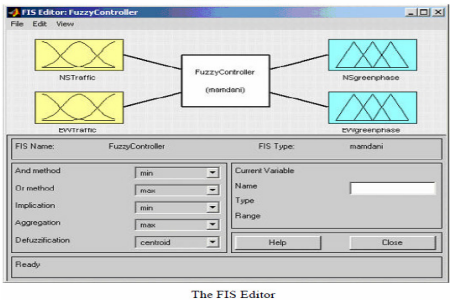
The Membership Function Editor



The Rule Editor



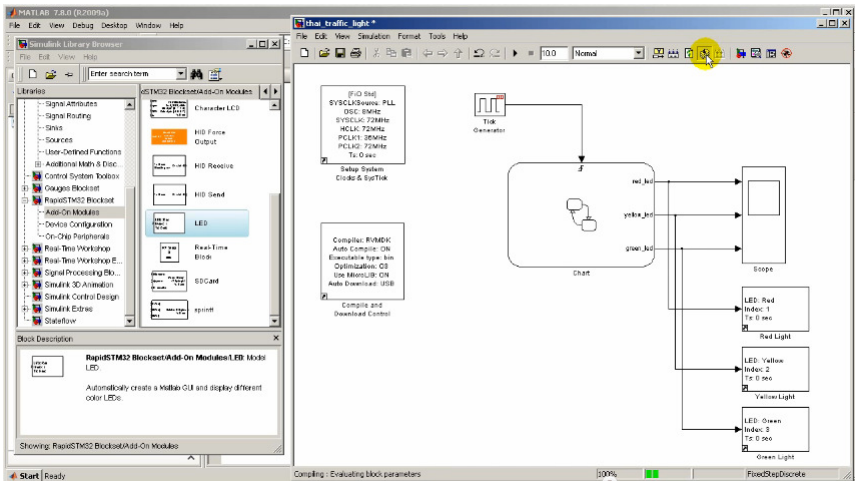
The Rule Viewer



The FIS Editor

http://www.mathworks.com/help/toolbox/fuzzy/fp243dup9.html

Modeling example (Simulink)



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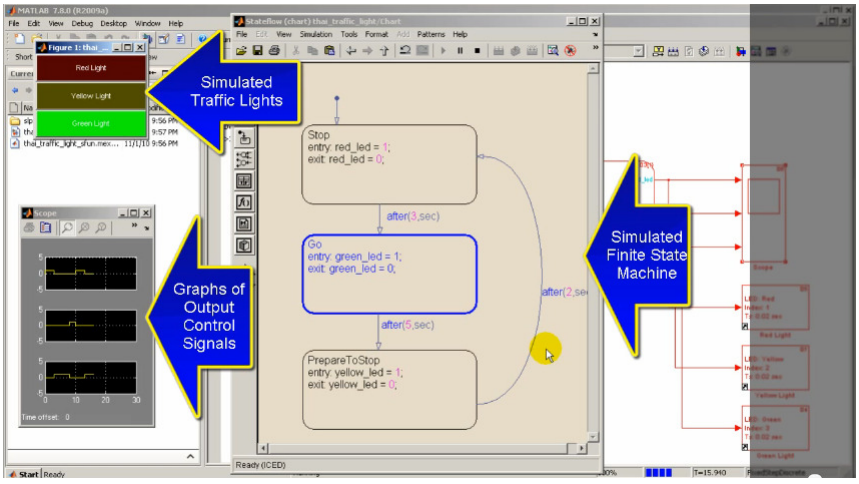
http://www.youtube.com/watch?v=hFWGToL-NHw
http://www.mathworks.com/products/simulink/demos.html

Modeling using Simulink (Cont.)



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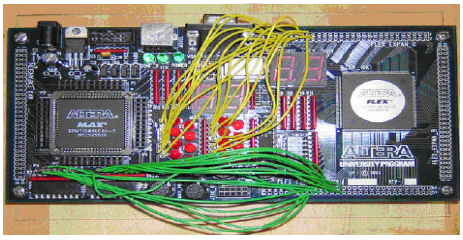
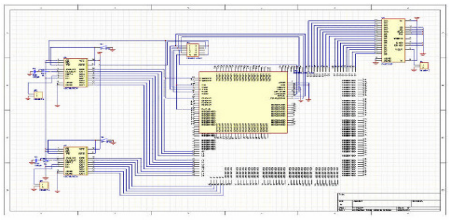
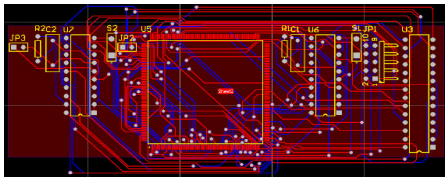
http://www.youtube.com/watch?v=hFWGToL-NHw
http://www.mathworks.com/products/simulink/demos.html

Hardware Design





Schematic Document for the circuit



Conclusion

- ✓ Overview of Fuzzy Controller basic theory
- ✓ Case Study of Fuzzy Traffic Controller Desin
- ✓ Discuss about Simulation Environment
- ✓ Hardware Implementation Issue

Further Improvement

- •Evolving Fuzzy system
- •Utilize genetic algorithm
- •Use Dynamic inputs
- •Advanced EDE tools (H/W)

Thank you!

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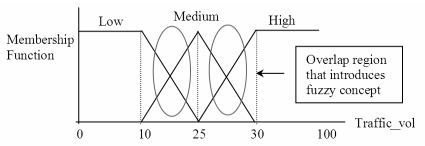
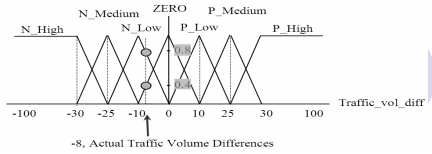
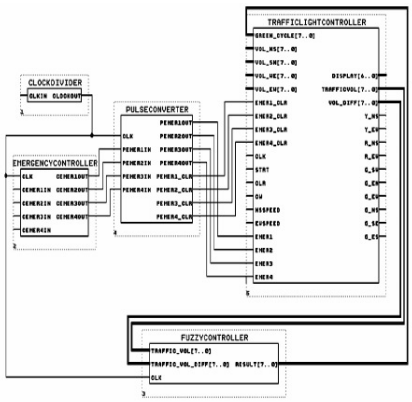




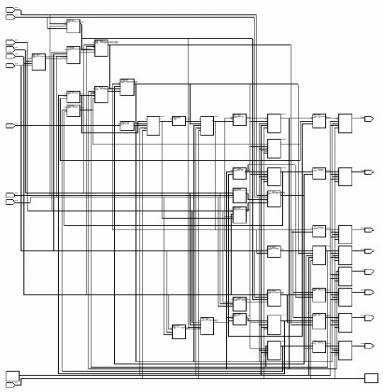
-8, Actual Traffic Volume Differences

Case Study 2 (Extra)

TRAFFIC VOLUME	TRAFFI_VOL _DIFF = ACTIVE LANE TRAFFIC – AVERAGE WAITING TRAFFIC						
	P_HIGH	P_MEDIUM	P_LOW	ZERO	N_LOW	N_MEDIUM	N_HIGH
HIGH	P_HIGH	P_MEDIUM	HIGH	HIGH	HIGH	N_MEDIUM	N_HIGH
MEDIUM	P_HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	N_HIGH
LOW	P_HIGH	LOW	LOW	LOW	LOW	LOW	N_HIGH



Fuzzy traffic controller-interconnection of the entire modules



Fuzzy traffic controller gate level