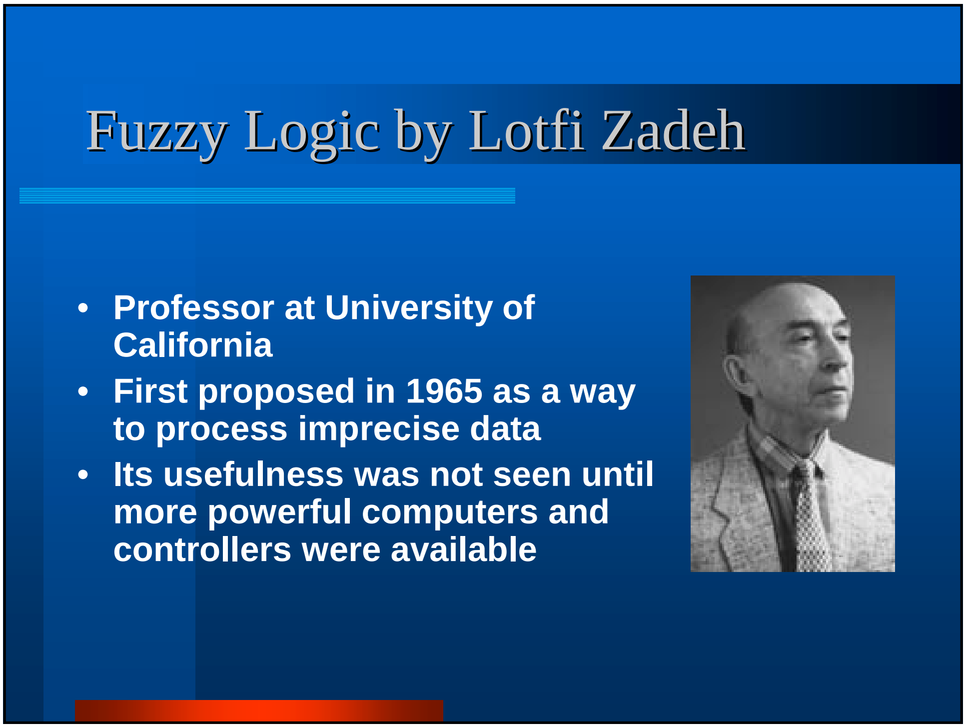
Fuzzy Logic Controllers

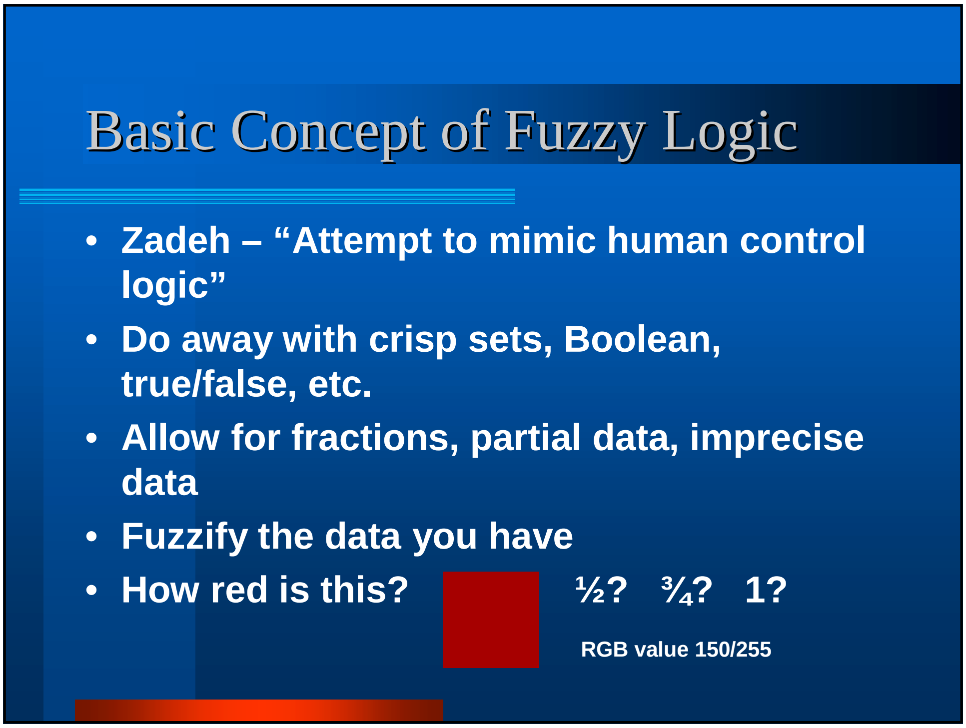
by Scott Lancaster

- Description of Fuzzy Logic
- What Fuzzy Logic Controllers Are Used for
- How Fuzzy Controllers Work
- Controller Examples



Fuzzy Logic by Lotfi Zadeh

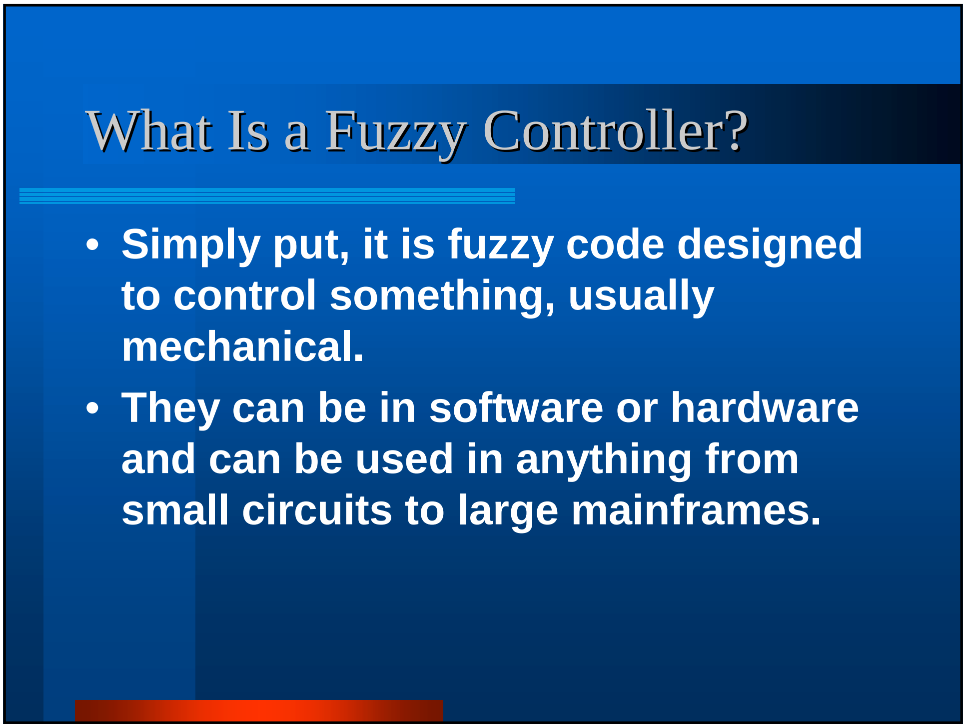
- Professor at University of California
- First proposed in 1965 as a way to process imprecise data
- Its usefulness was not seen until more powerful computers and controllers were available



Basic Concept of Fuzzy Logic

- Zadeh – “Attempt to mimic human control logic”
- Do away with crisp sets, Boolean, true/false, etc.
- Allow for fractions, partial data, imprecise data
- Fuzzify the data you have
- How red is this? 🟥 ½? ¾? 1?

RGB value 150/255



What Is a Fuzzy Controller?

- Simply put, it is fuzzy code designed to control something, usually mechanical.
- They can be in software or hardware and can be used in anything from small circuits to large mainframes.

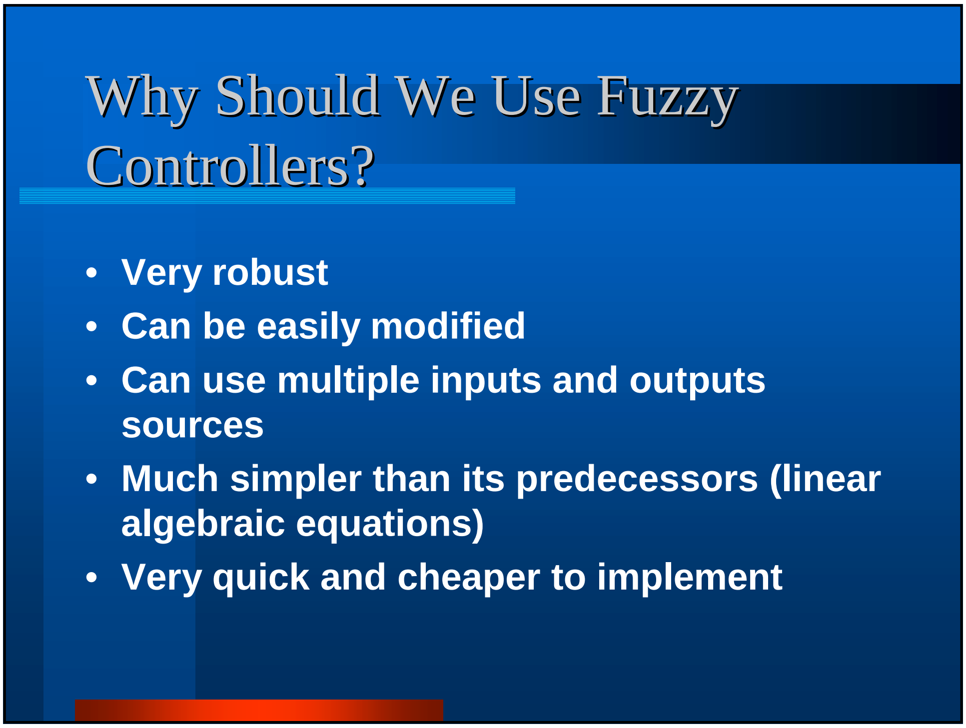
Currently Used Fuzzy Controllers

F-117 Flight Control System

Camcorder - Stabilization

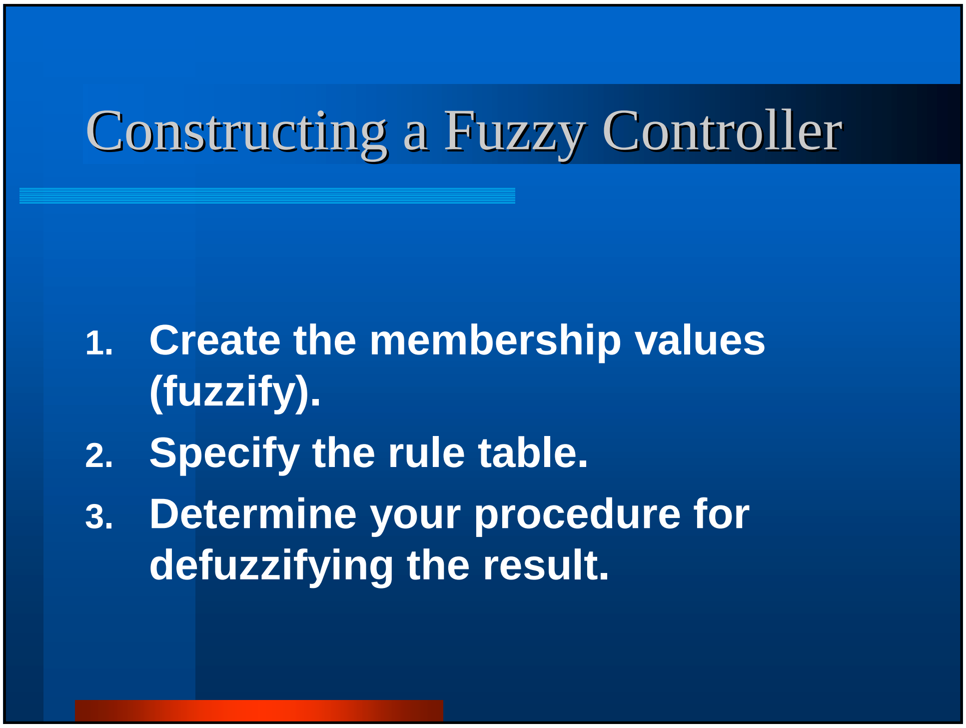
Lifting Bodies

http://iridia.ulb.ac.be/~famimo/



Why Should We Use Fuzzy Controllers?

- Very robust
- Can be easily modified
- Can use multiple inputs and outputs sources
- Much simpler than its predecessors (linear algebraic equations)
- Very quick and cheaper to implement



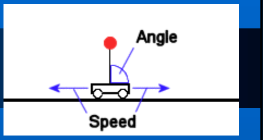
Constructing a Fuzzy Controller

1. Create the membership values (fuzzify).
2. Specify the rule table.
3. Determine your procedure for defuzzifying the result.

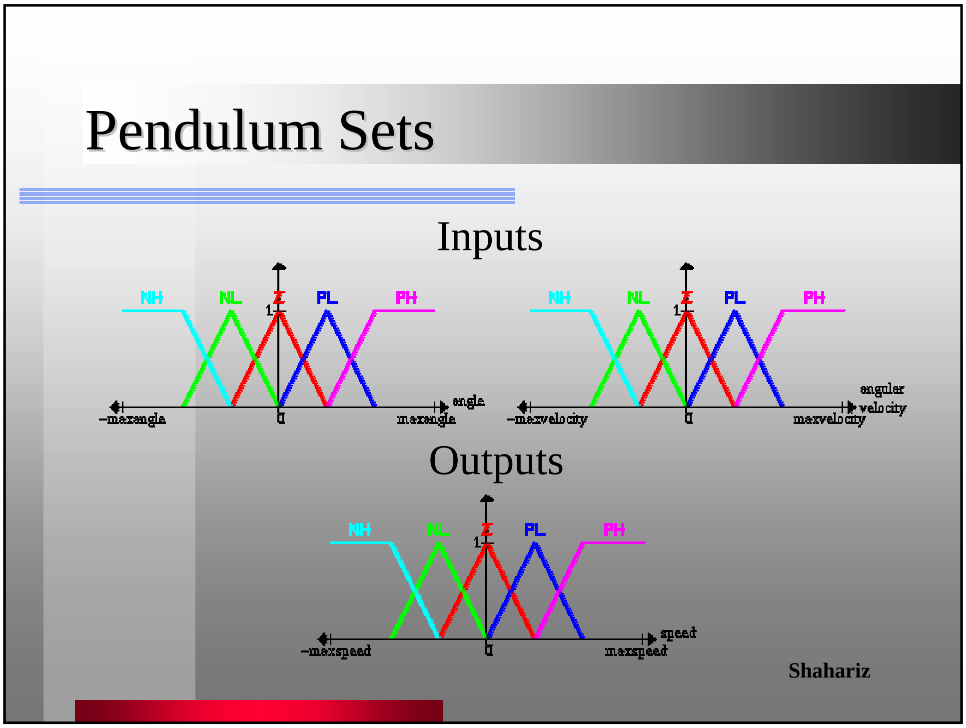
Create the Membership Value

- First we have to fuzzify the data or create membership values for the data and put them into fuzzy sets.
- Put simply, we have to divide each set of data into ranges.
- The Y value will always be on a range of 0 to 1 (theoretically 0 to 100%).
- The X will be an arbitrary range that we determine

Membership for Inverted Pendulum



- Typically a fuzzy controller has at least 2 inputs and one output.
- For the inverted pendulum experiment, we will have angle and angular velocity as our inputs and speed as our output (the activity we want to control).
- The ranges you determine for each set of data can drastically determine how well the controller works.



Pendulum Sets

Inputs

Outputs

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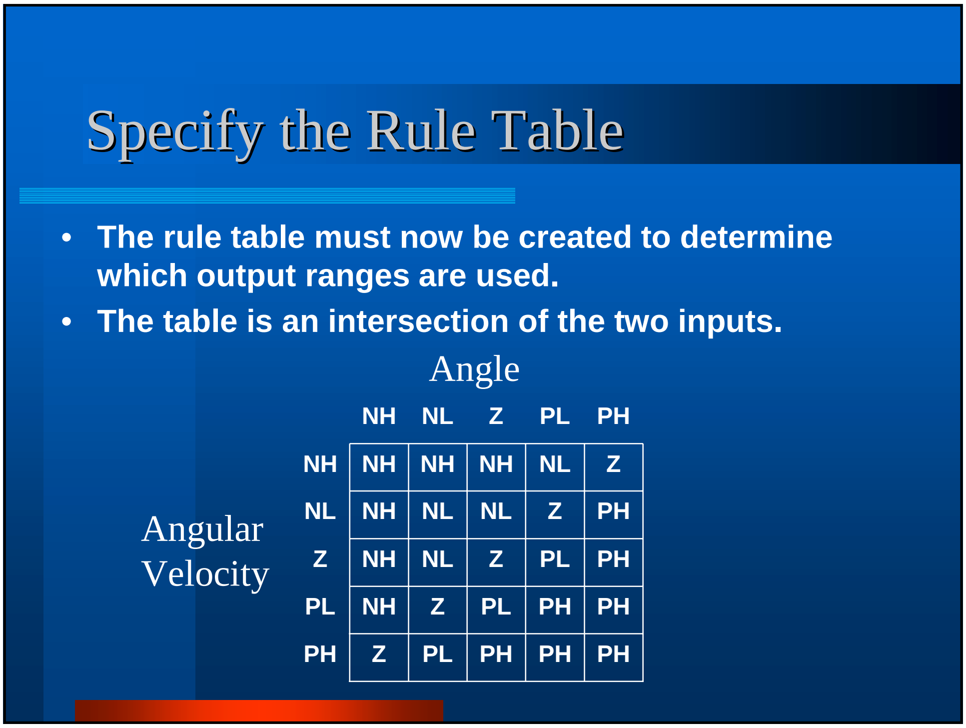
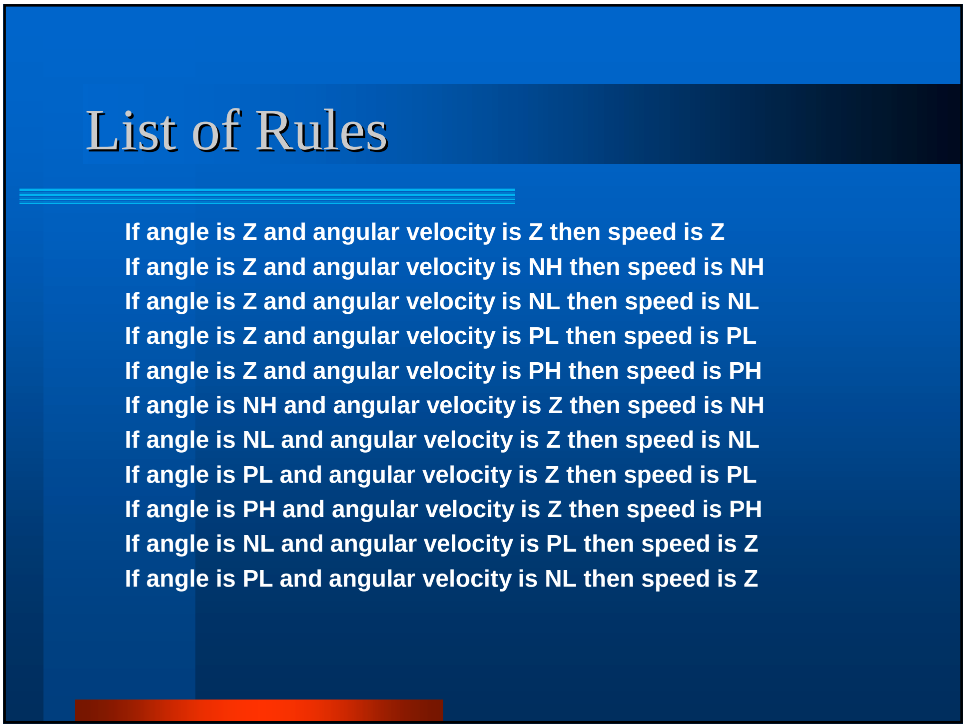


Specify the Rule Table

- The rule table must now be created to determine which output ranges are used.
- The table is an intersection of the two inputs.

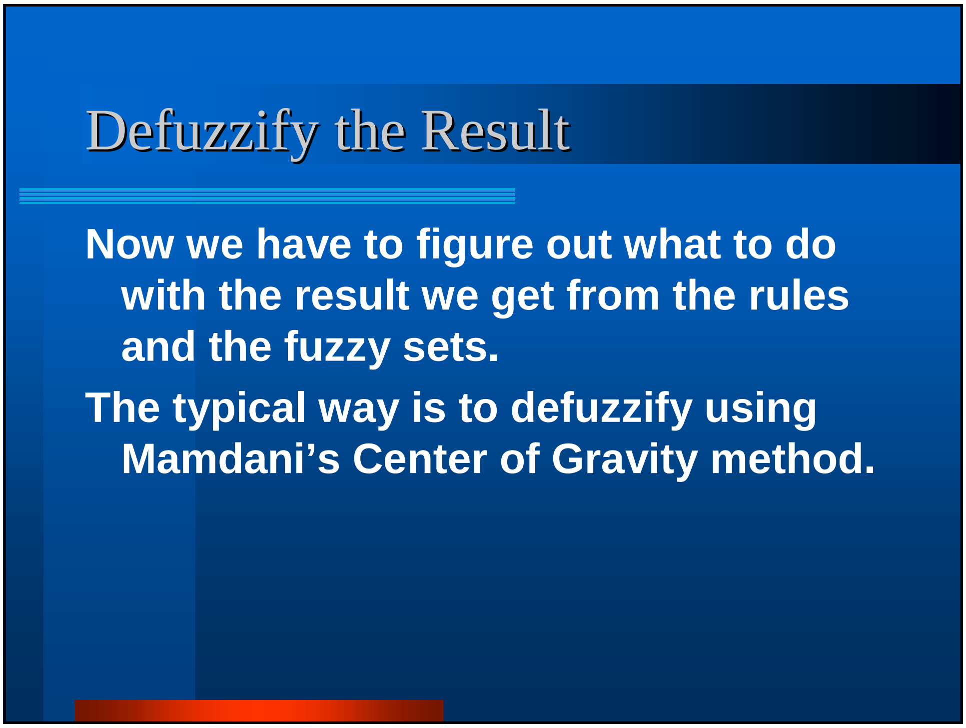
Angle

Angular Velocity	NH	NL	Z	PL	PH
NH	NH	NH	NH	NL	Z
NL	NH	NL	NL	Z	PH
Z	NH	NL	Z	PL	PH
PL	NH	Z	PL	PH	PH
PH	Z	PL	PH	PH	PH



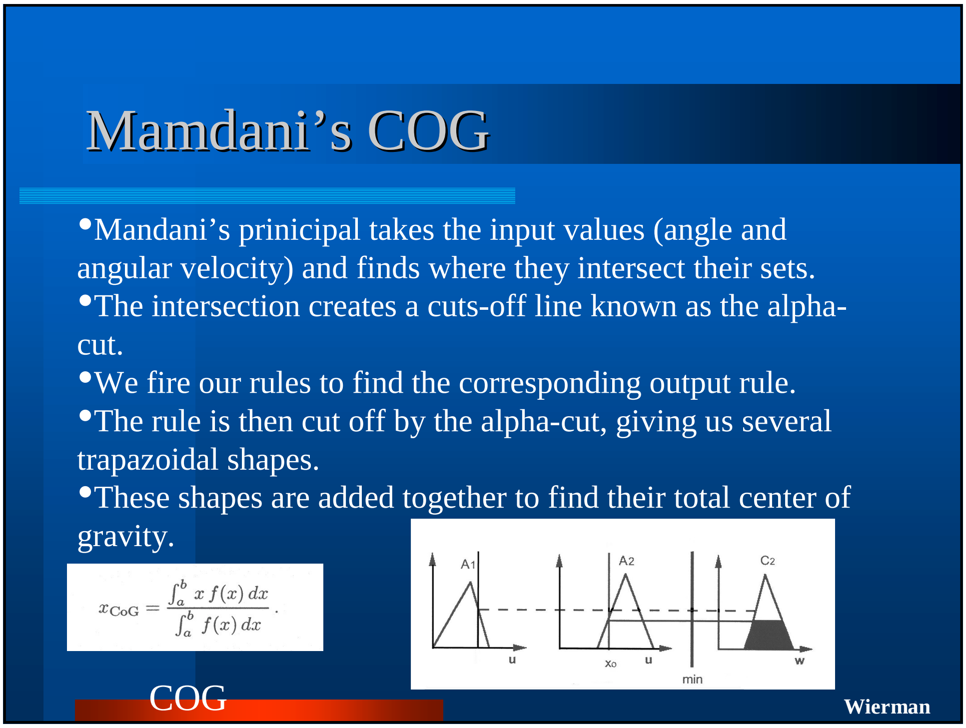
List of Rules

If angle is Z and angular velocity is Z then speed is Z
If angle is Z and angular velocity is NH then speed is NH
If angle is Z and angular velocity is NL then speed is NL
If angle is Z and angular velocity is PL then speed is PL
If angle is Z and angular velocity is PH then speed is PH
If angle is NH and angular velocity is Z then speed is NH
If angle is NL and angular velocity is Z then speed is NL
If angle is PL and angular velocity is Z then speed is PL
If angle is PH and angular velocity is Z then speed is PH
If angle is NL and angular velocity is PL then speed is Z
If angle is PL and angular velocity is NL then speed is Z



Defuzzify the Result

- Now we have to figure out what to do with the result we get from the rules and the fuzzy sets.
- The typical way is to defuzzify using Mamdani’s Center of Gravity method.



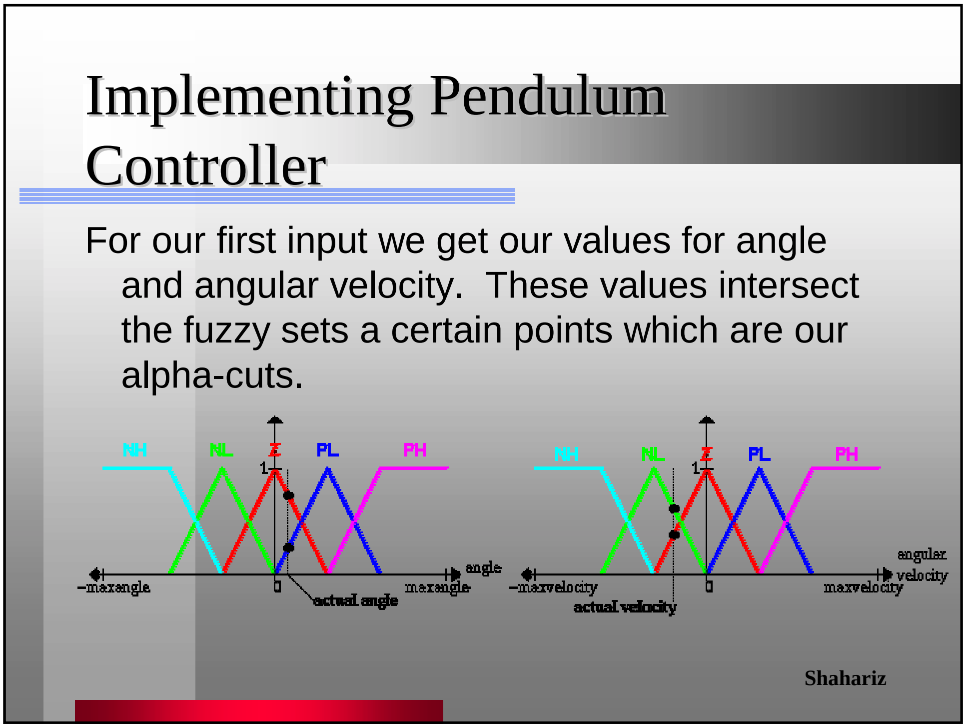
Mamdani's COG

- Mandani's prinicipal takes the input values (angle and angular velocity) and finds where they intersect their sets.
- The intersection creates a cuts-off line known as the alpha-cut.
- We fire our rules to find the corresponding output rule.
- The rule is then cut off by the alpha-cut, giving us several trapazoidal shapes.
- These shapes are added together to find their total center of gravity.

$$x_{\text{CoG}} = \frac{\int_a^b x\, f(x)\, dx}{\int_a^b f(x)\, dx}.$$

COG

Wierman



Implementing Pendulum Controller

For our first input we get our values for angle and angular velocity. These values intersect the fuzzy sets a certain points which are our alpha-cuts.

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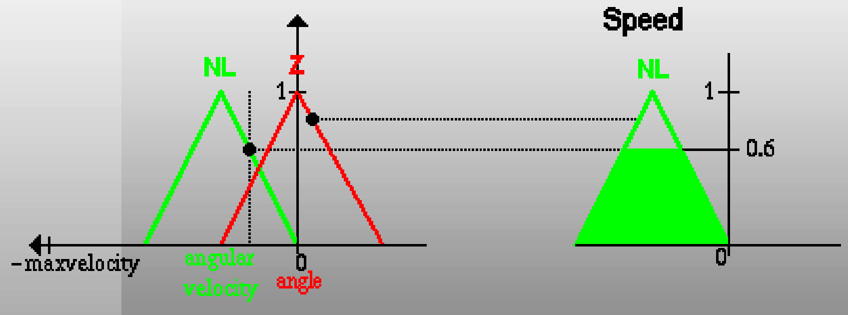
Fire Rules

Now we have to fire our rules to see which ones we will use.

- If angle is Z and angular velocity is Z then speed is Z
- If angle is Z and angular velocity is NL then speed is NL
- If angle is PL and angular velocity is Z then speed is PL
- If angle is PL and angular velocity is NL then speed is Z

	NH	NL	Z	PL	PH
NH	NH	NH	NH	NL	Z
NL	NH	NL	NL	Z	PH
Z	NH	NL	Z	PL	PH
PL	NH	Z	PL	PH	PH
PH	Z	PL	PH	PH	PH

Combine Alpha-cut and Rule



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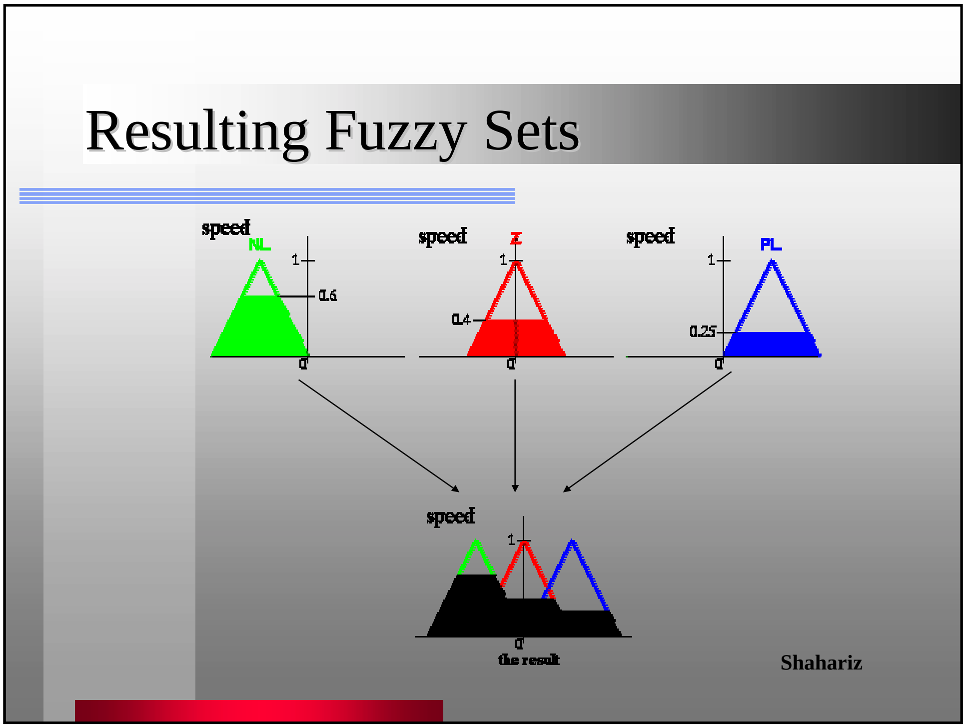

Resulting Fuzzy Sets

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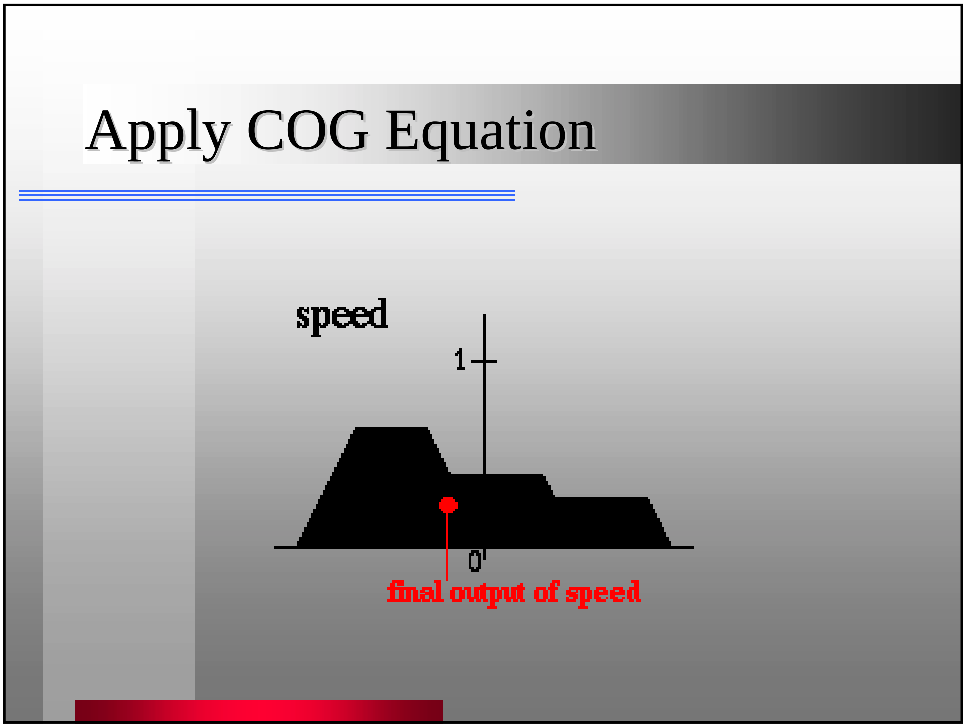
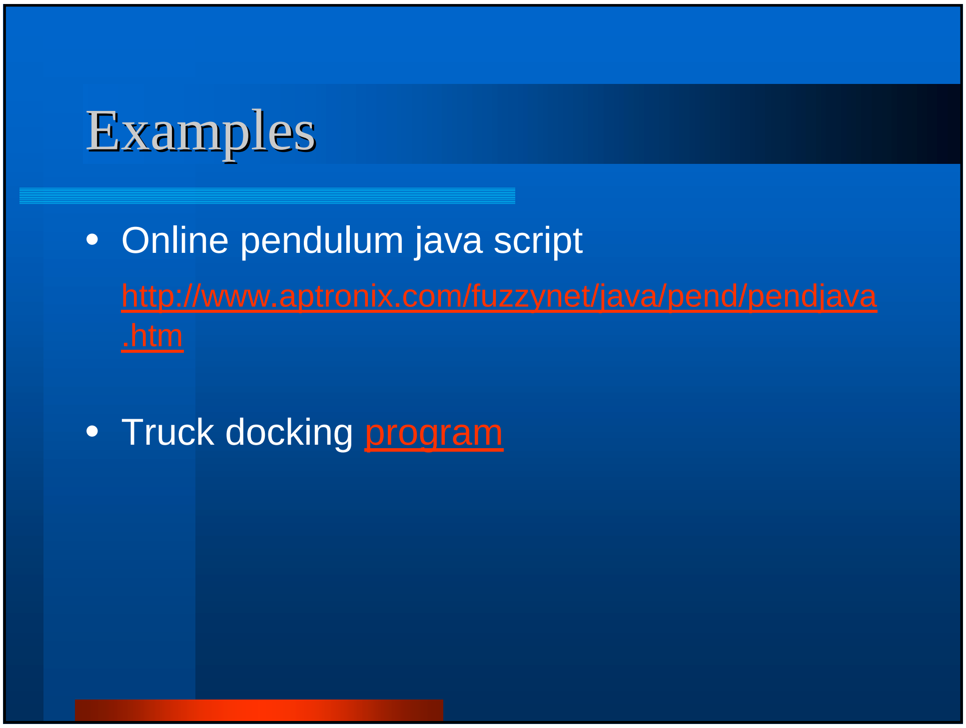


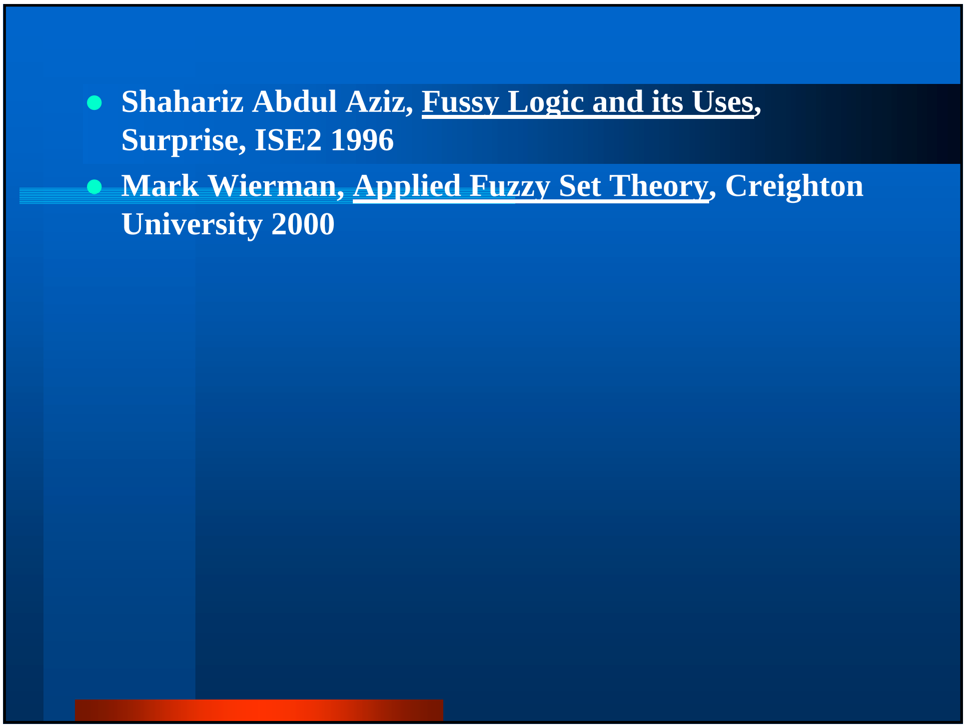
Apply COG Equation



Examples

- Online pendulum java script
  http://www.aptronix.com/fuzzynet/java/pend/pendjava.htm
- Truck docking program

The End



- Shahariz Abdul Aziz, Fussy Logic and its Uses, Surprise, ISE2 1996
- Mark Wierman, Applied Fuzzy Set Theory, Creighton University 2000