CONTROLLER AND ITS APPLICATIONS

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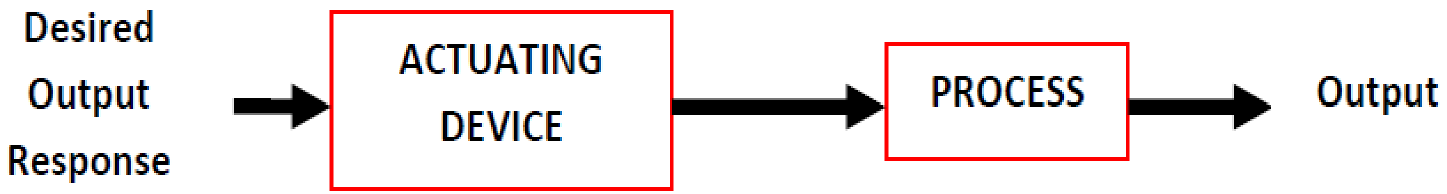
(Under section 3 of UGC Act 1956)

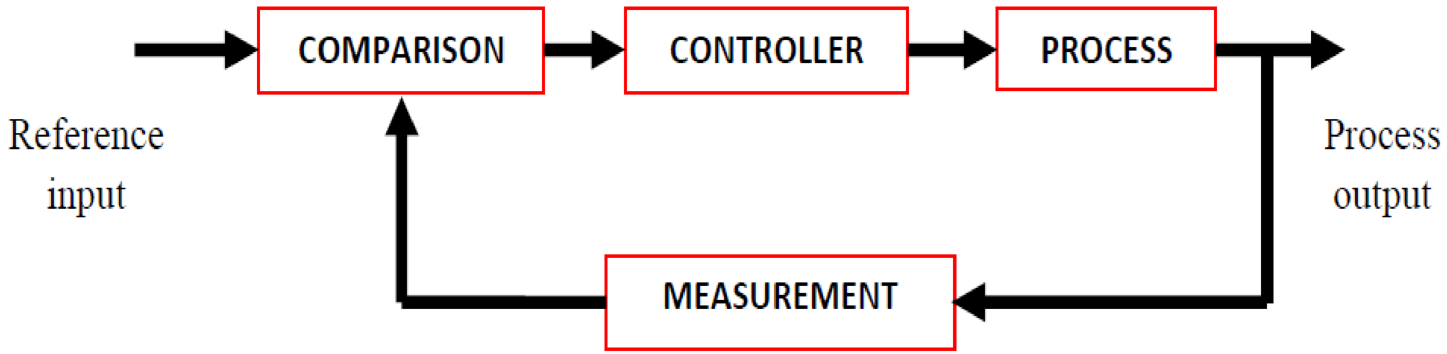
OUTLINE

- Control Systems
- PID Controller
  - Introduction
  - Implementation
  - Application
  - Ball Beam Balance Exp
- Fuzzy Logic Controller
  - Introduction
  - Implementation
  - Mobile Robot Application
  - Analysis
- Conclusion

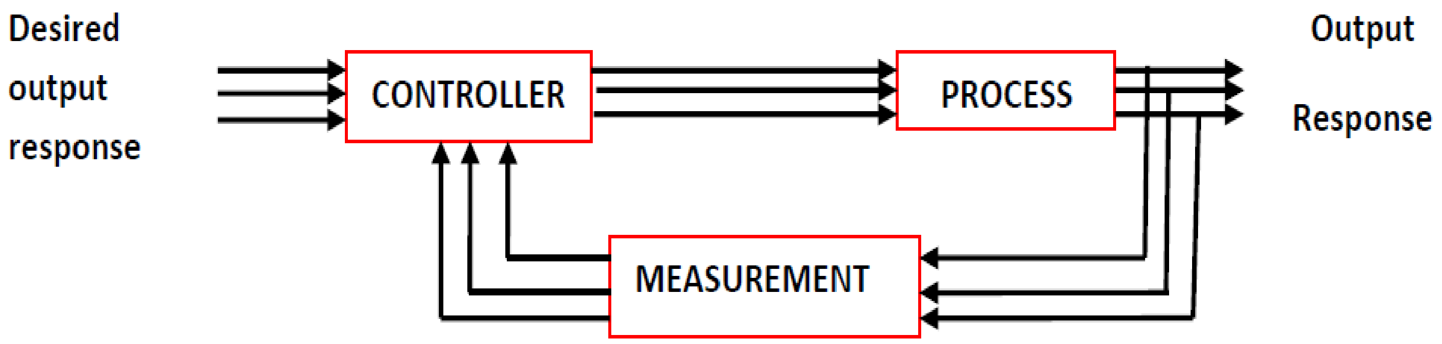
Open-loop control systems



Closed-loop control systems



Multivariable control systems



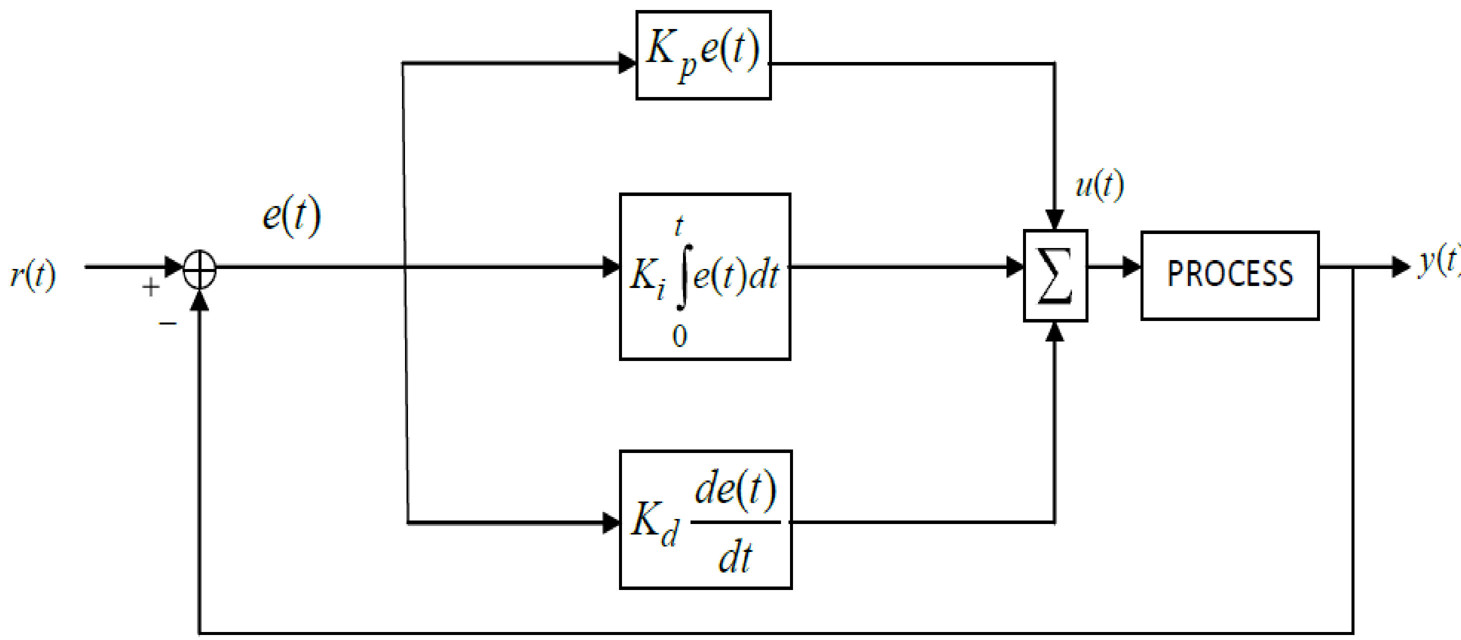
PID Control

- A closed loop (feedback) control system, generally with Single Input-Single Output (SISO)
- A portion of the signal being fed back is:
  - Proportional to the signal (**P**)
  - Proportional to integral of the signal (**I**)
  - Proportional to the derivative of the signal (**D**)

Why PID?

- PID control handles step changes to the Set Point especially well:
  - Fast Rise Times
  - Little or No Overshoot
  - Fast settling Times
  - Zero Steady State Error
- PID controllers are often fine tuned on-site, using established guidelines

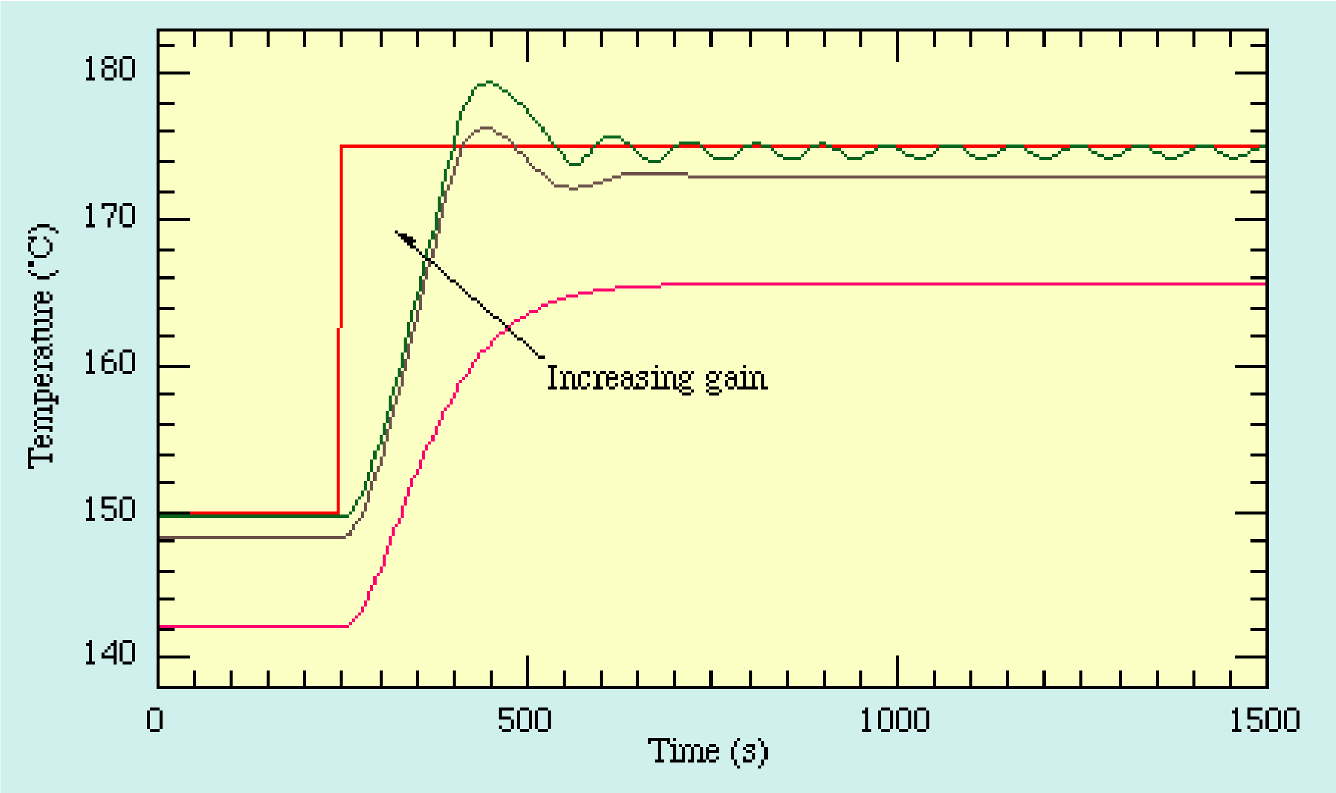
P-I-D



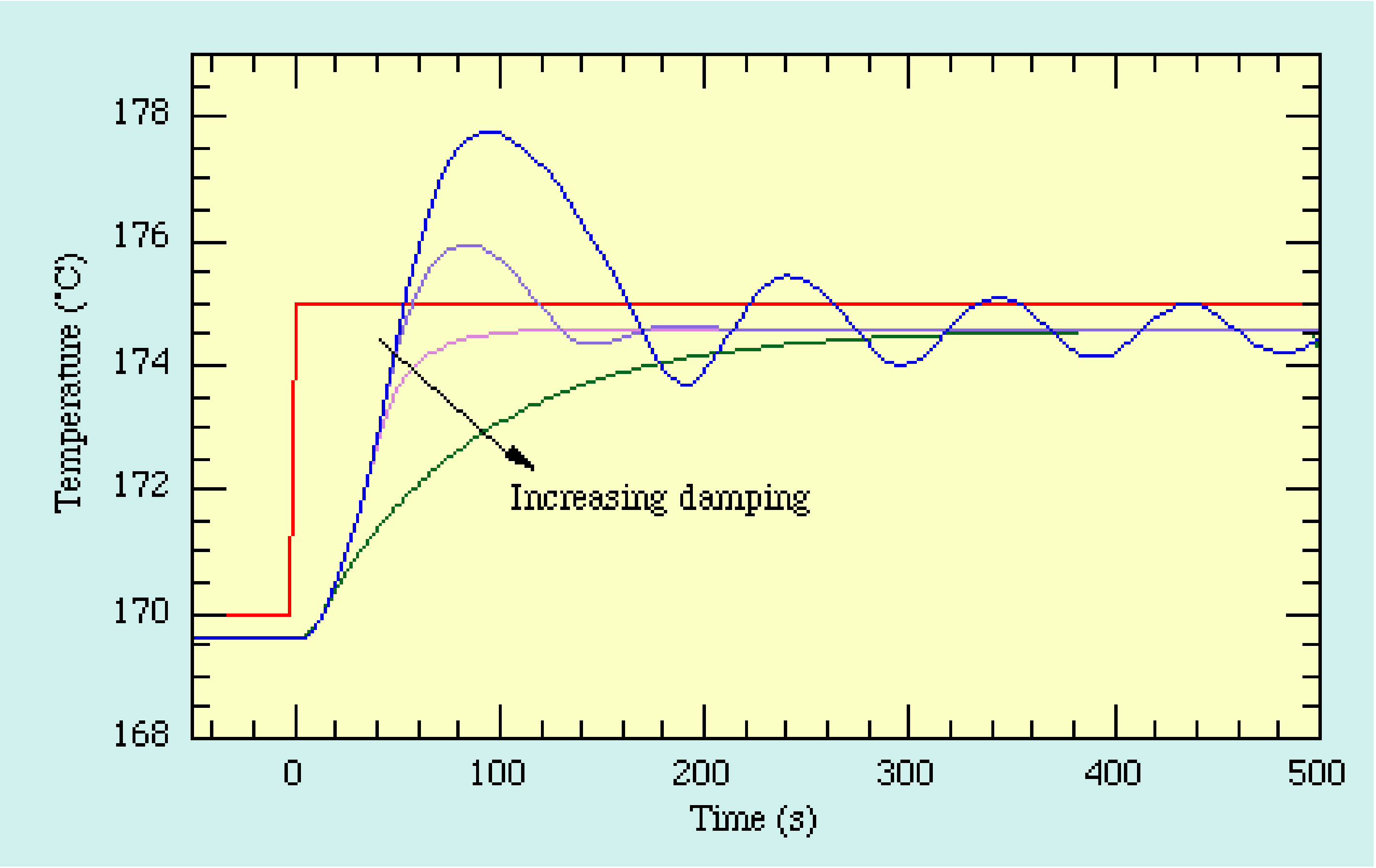
$$u(t) = K\left(e(t) + \frac{1}{T_i}\int_0^t e(\tau)d\tau + T_d\frac{de(t)}{dt}\right)$$

Proportional Control

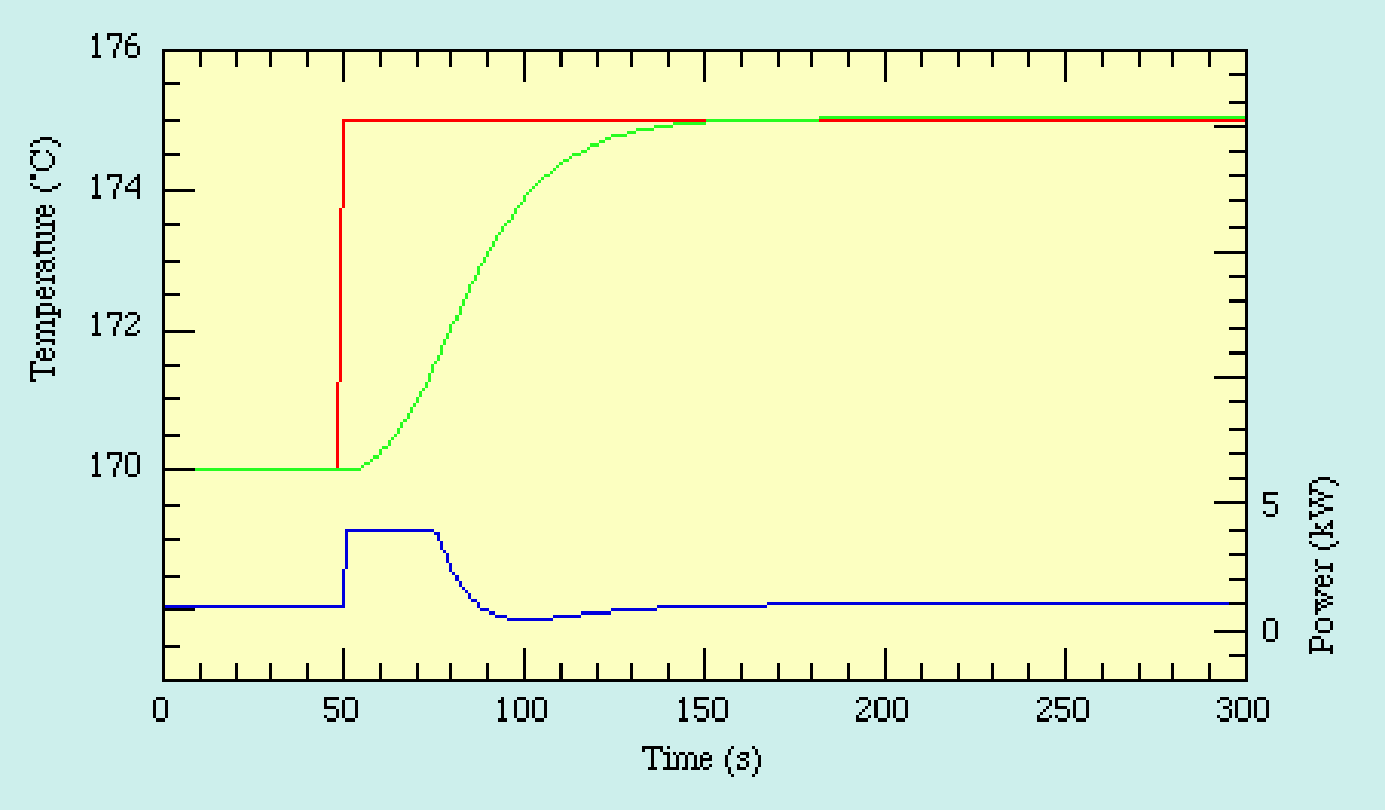
- Output= Kp * Input



Proportional, Derivative Control



Proportional+Integral+Derivative Control



The Characteristics of P, I, and D controllers

CL RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	S-S ERROR
Kp	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small Change	Decrease	Decrease	Small Change

Tips for Designing a PID Controller

1. Obtain an open-loop response and determine what needs to be improved
2. Add a proportional control to improve the rise time
3. Add a derivative control to improve the overshoot
4. Add an integral control to eliminate the steady-state error
5. Adjust each of Kp, Ki, and Kd until you obtain a desired overall response.

Application

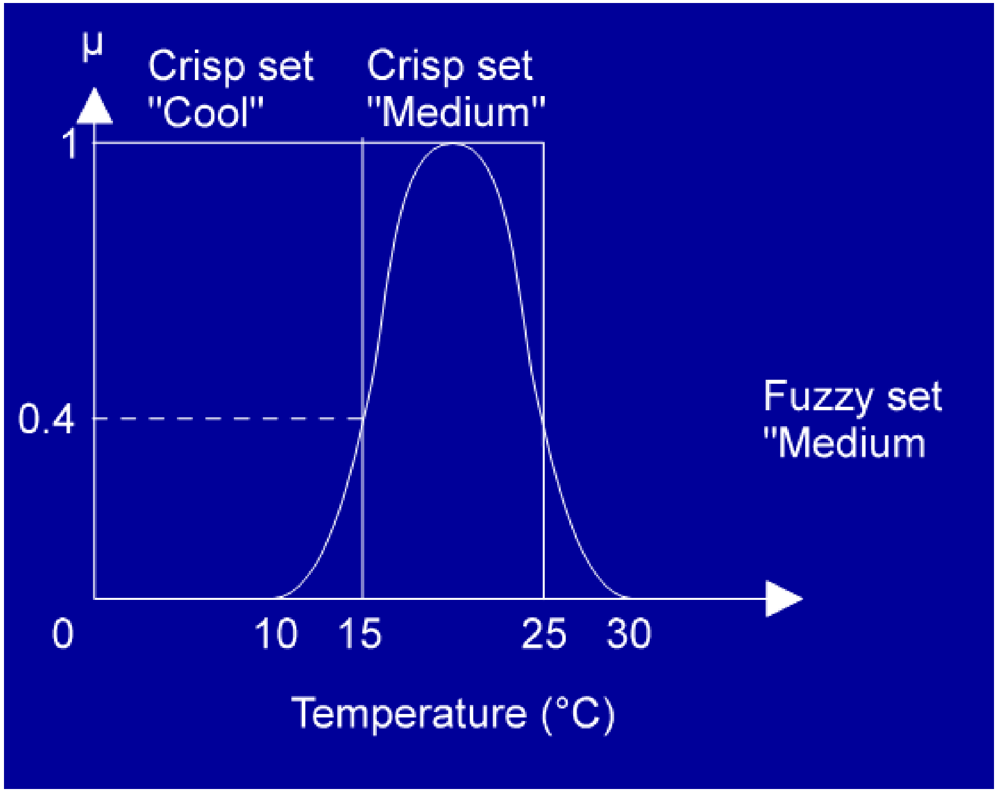
- Ball beam balance experiment.

FUZZY??

- To devise a concise theory of logic, and later mathematics, Aristotle posited the so-called ”Laws of Thought”.
- It was specifically designed to mathematically represent uncertainty and vagueness and to provide formalized tools for dealing with the imprecision intrinsic to many problems.
- Plato who laid the foundation for what would become fuzzy logic, indicating that there was a third region (beyond T and F) where these opposites ”tumbled about.”
- The notion of an infinite-valued logic was introduced in Zadeh’s seminal work ”Fuzzy Sets” where he described the mathematics of fuzzy set theory, and by extension fuzzy logic.

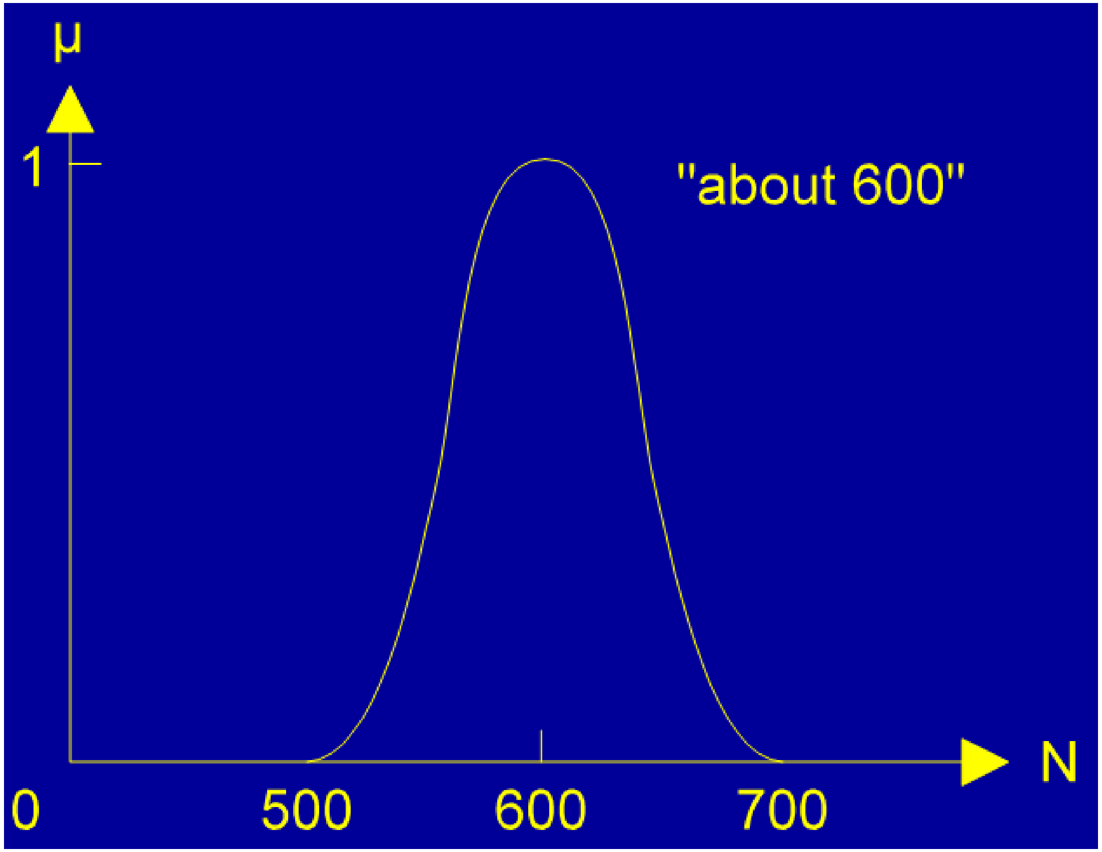
Fuzzy Sets...

- Representing crisp and fuzzy sets as subsets of a domain (universe) U".



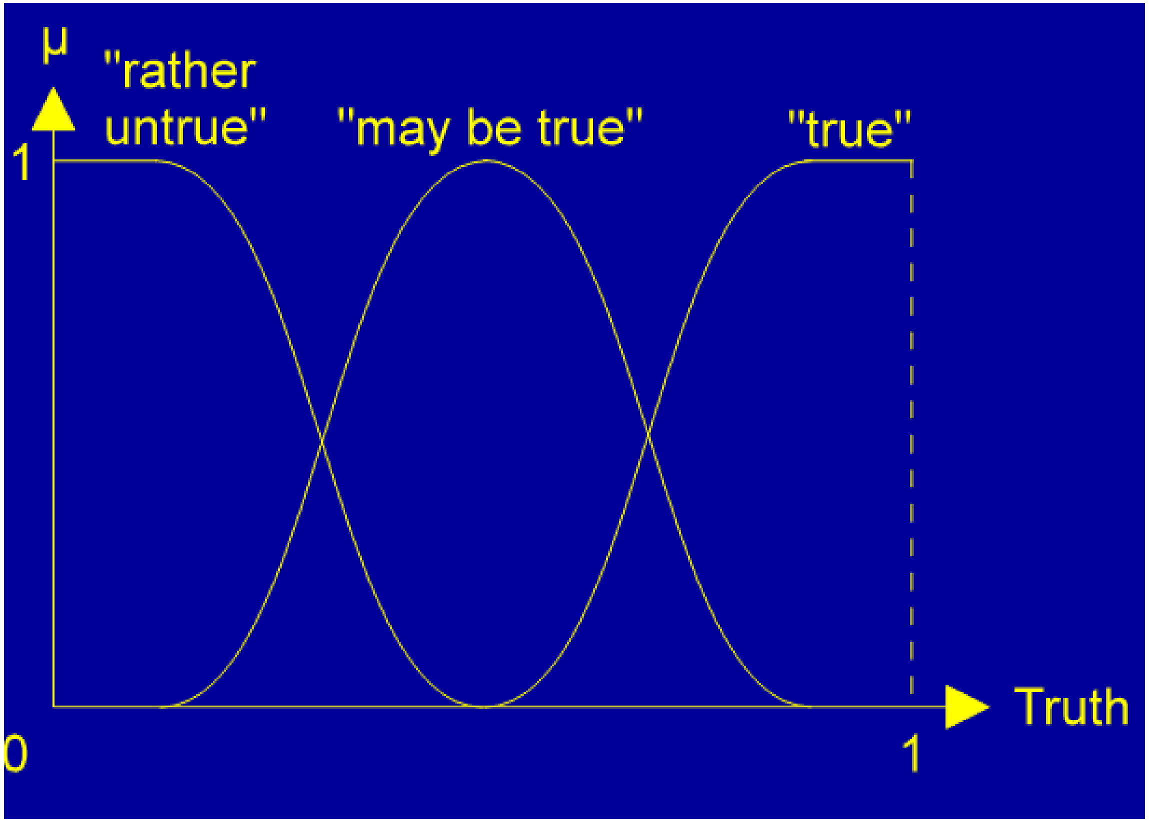
Conceptualizing in fuzzy terms...

- One representation for the fuzzy number "about 600".

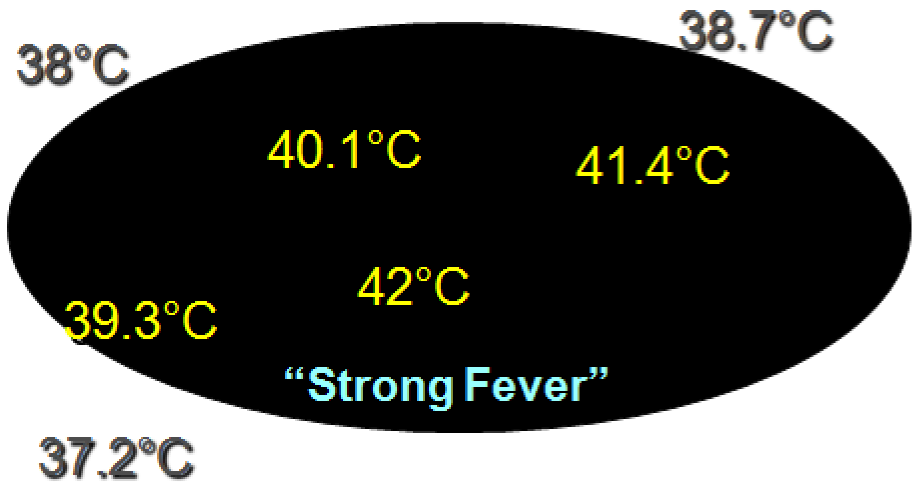


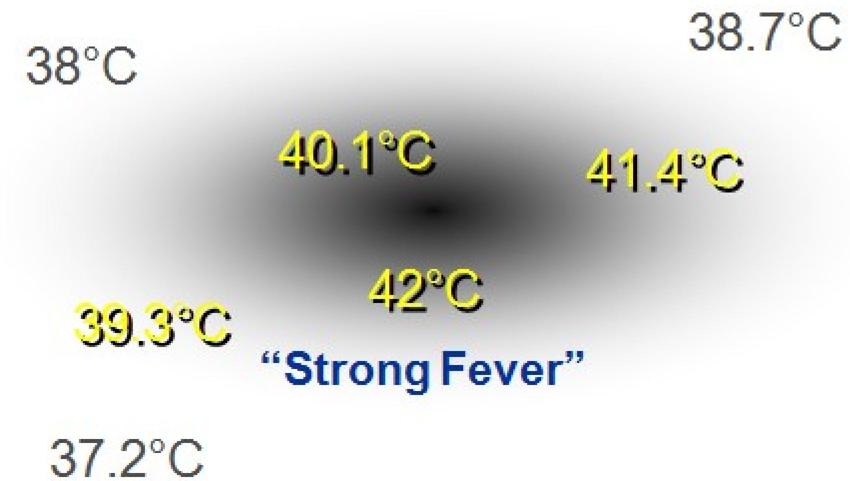
Conceptualizing in fuzzy terms...

- Representing truthfulness (certainty) of events as fuzzy sets over the [0,1] domain.



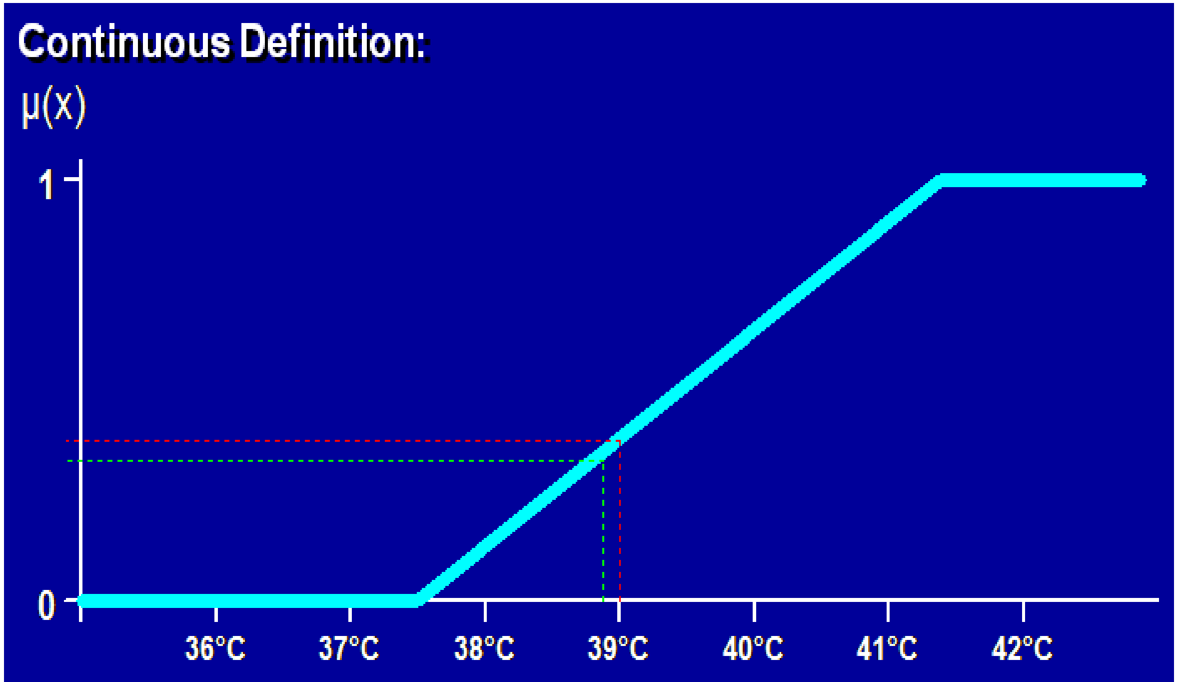
Strong Fever example





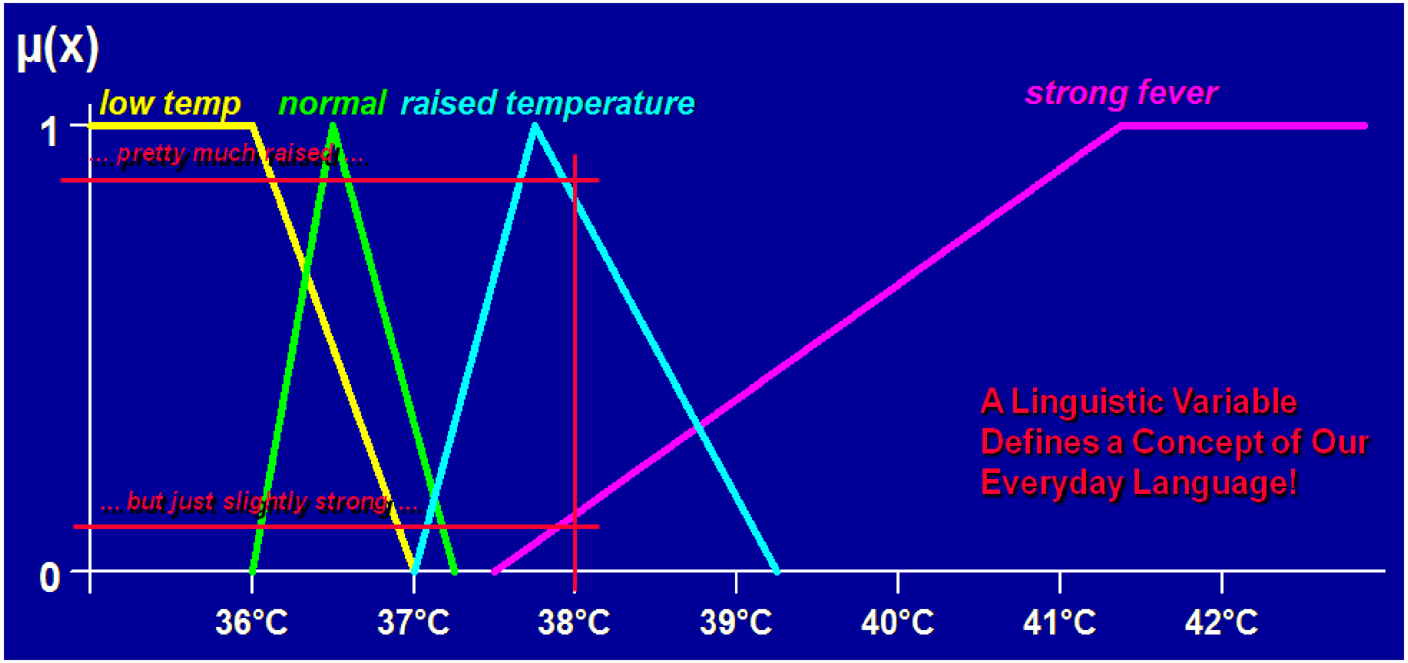
Fuzzy Set Definitions

- **Discrete Definition:**
- $\mu_{SF}(35°C) = 0$ $\mu_{SF}(38°C) = 0.1$ $\mu_{SF}(41°C) = 0.9$
- $\mu_{SF}(36°C) = 0$ $\mu_{SF}(39°C) = 0.35$ $\mu_{SF}(42°C) = 1$
- $\mu_{SF}(37°C) = 0$ $\mu_{SF}(40°C) = 0.65$ $\mu_{SF}(43°C) = 1$



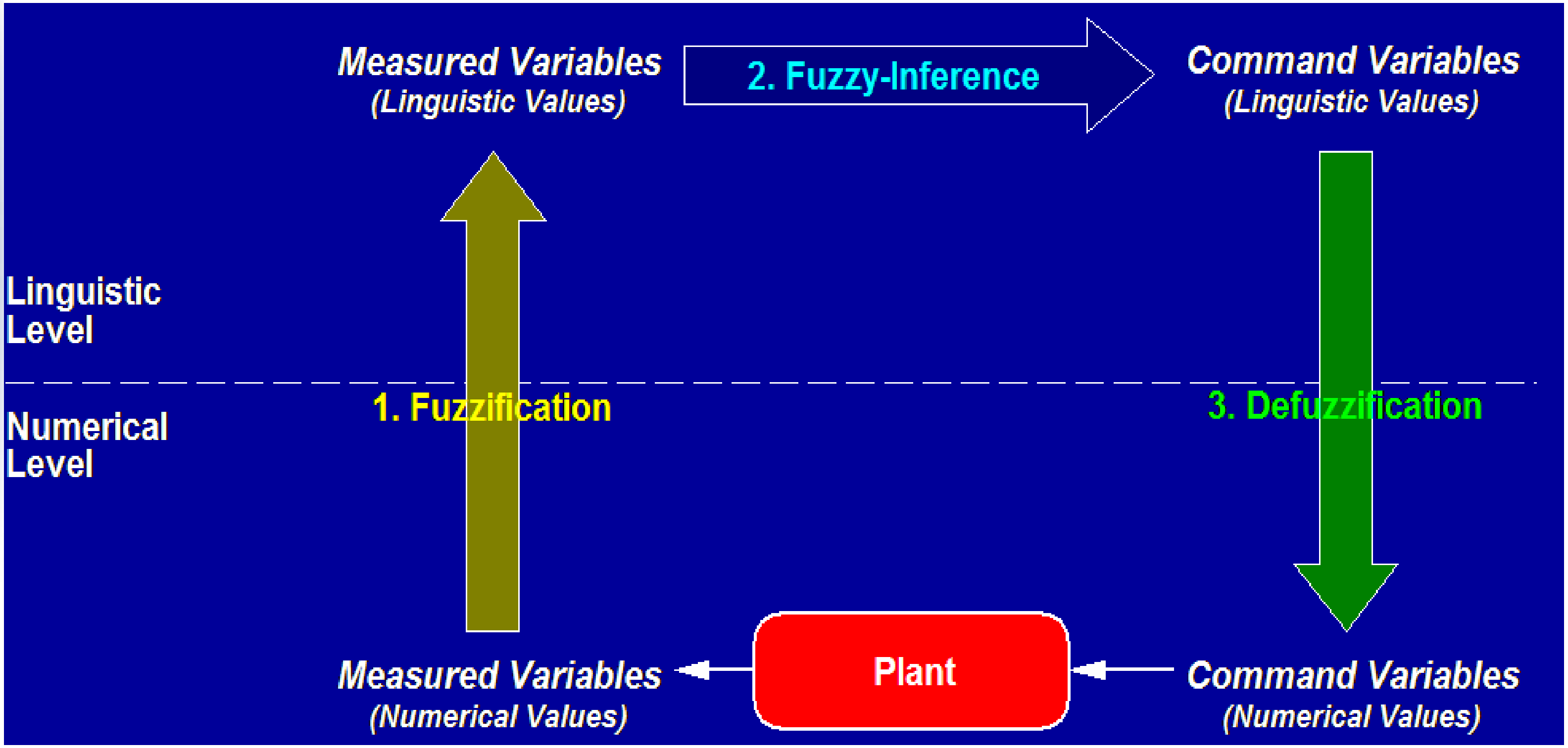
Linguistic Variable

- ...Terms, Degree of Membership, Membership Function, Base Variable...



Basic Elements of a Fuzzy Logic System

- **Fuzzification, Fuzzy Inference, Defuzzification:**

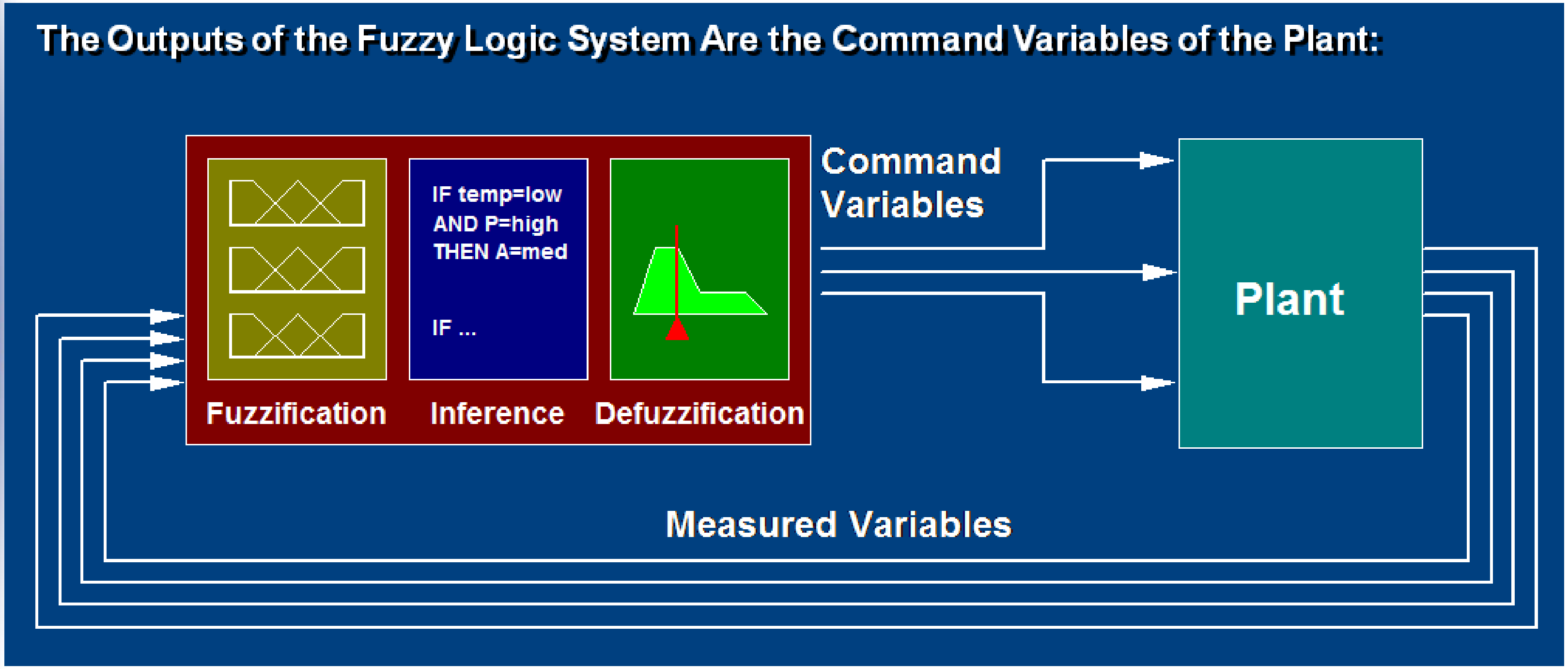


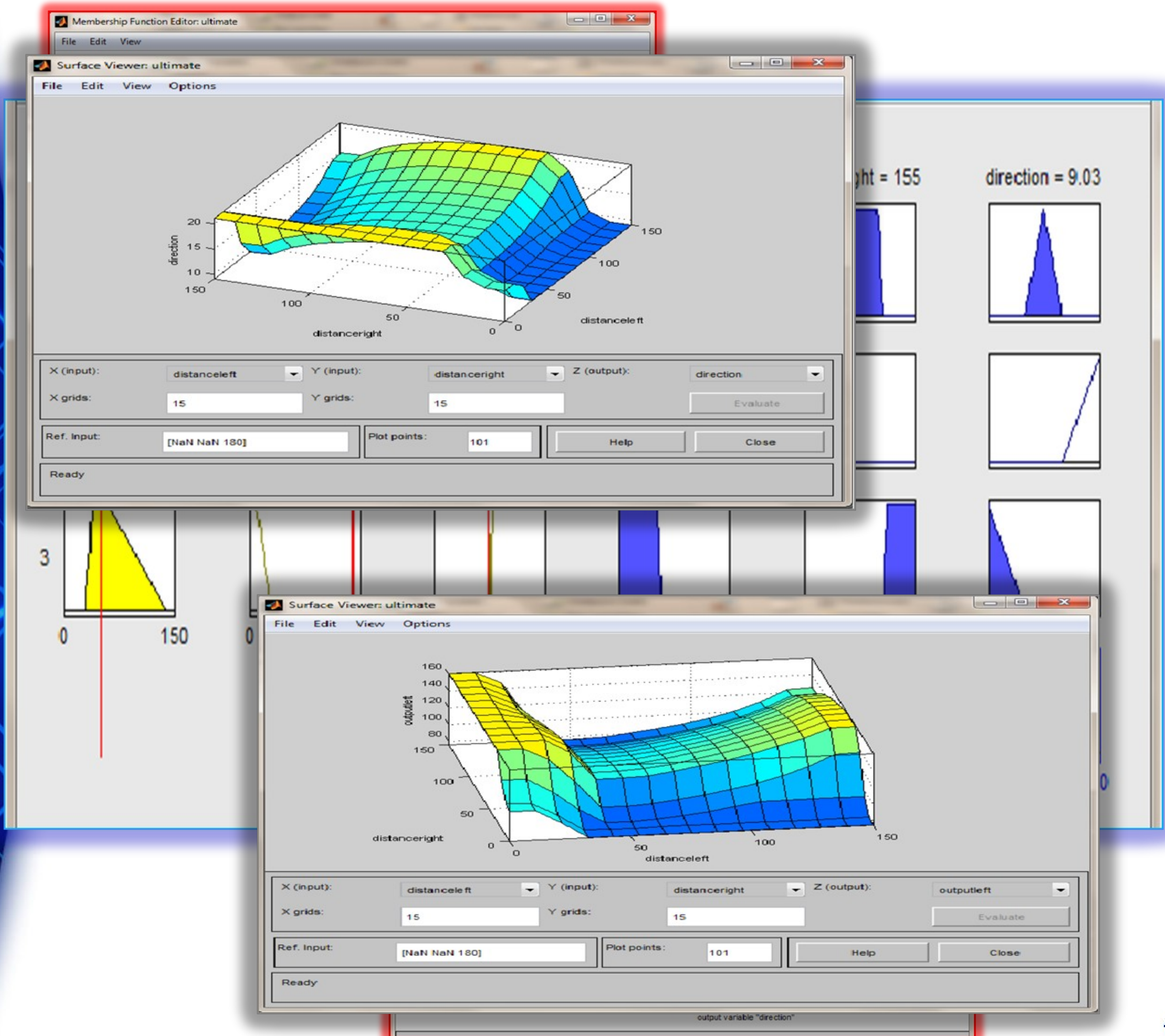
FUZZY LOGIC APPROACH

- Fuzzy Logic
- Fuzzy Inference System
  - Fuzzification
  - Rule Evaluation
    - AND: $\mu A \cap B(x) = \min [\mu A(x), \mu B(x)]$
    - OR: $\mu A \cup B(x) = \max [\mu A(x), \mu B(x)]$
  - Aggregation of the rule outputs
  - Defuzzification

$$COG = \frac{\int_a^b \mu_A(x) x \, dx}{\int_a^b \mu_A(x) \, dx}$$

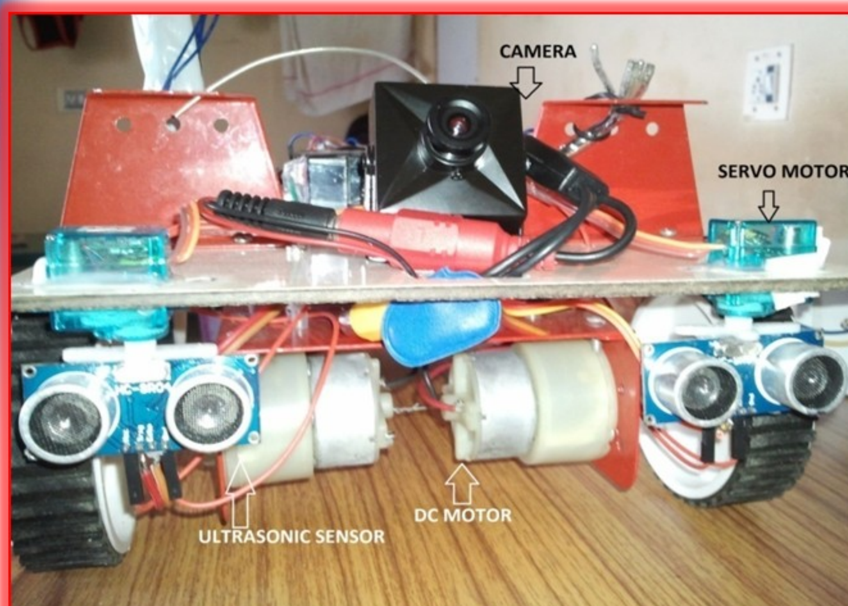
Types of Fuzzy Controllers:
- Direct Controller -

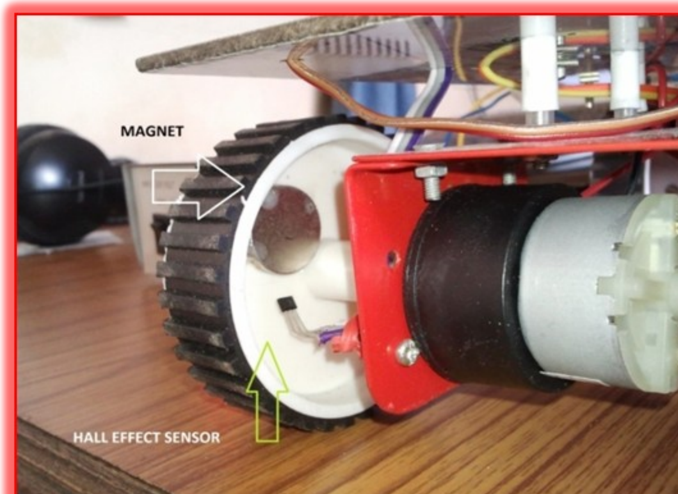



Membership Function Editor: ultimate
File Edit View
Surface Viewer: ultimate
File Edit View Options
direction
distanceright
distanceleft
X (input): distanceleft
Y (input): distanceright
Z (output): direction
X grids: 15
Y grids: 15
Evaluate
Ref. Input: [NaN NaN 180]
Plot points: 101
Help
Close
Ready
direction = 9.03
Surface Viewer: ultimate
File Edit View Options
outputleft
distanceright
distanceleft
X (input): distanceleft
Y (input): distanceright
Z (output): outputleft
X grids: 15
Y grids: 15
Evaluate
Ref. Input: [NaN NaN 180]
Plot points: 101
Help
Close
Ready
output variable "direction"

MOBILE ROBOT APPLICATION

- In this project, a fuzzy logic-based model is presented for navigation of mobile robots in indoor environments. The inputs of the fuzzy controller are the outputs from the sensor system, including the obstacle distances obtained from the left and right ultrasonic sensor groups, the target direction, and the current robot speed.

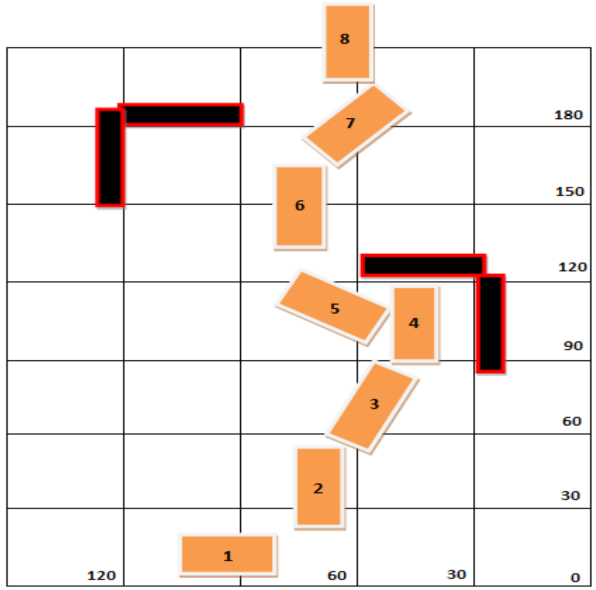




ERROR ANALYSIS

Matlab			Controller			(%) Error		
simulated left	simulated right	simulated direction	controller left	controller right	controller direction	Left	Right	Direction
111	112	15	113.58	110.94	15.88	2.271	-0.955	5.541
124	102	15.7	126.03	100.9	17.44	1.610	-1.090	9.977
161	76.7	21	160.51	77.53	21.28	-0.305	1.070	1.315
76	155	9.03	76.72	145.8	9.55	0.938	-6.310	5.445
152	81.8	19.5	153.19	82.02	20.52	0.776	0.268	4.970
137	99.8	17.9	137.11	98.82	17.93	0.080	-0.991	0.167
114	126	13.3	114.78	115.99	13.97	0.679	-8.630	4.795
76	155	9.03	76.72	145.8	9.55	0.938	-6.310	5.445
161	76.7	21	160.51	77.53	21.28	-0.305	1.070	1.315
125	120	15	125	110.29	15	0	-8.804	0
106	108	15	109.86	106.42	16.25	3.513	-1.484	7.692
196	37	26.8	190.32	42.65	26.12	-2.984	13.247	-2.603
161	76.7	21	161.18	76.74	21.39	0.111	0.052	1.823
106	108	15	109.86	106.42	16.25	3.513	-1.484	7.692
106	108	15	109.86	106.42	16.25	3.513	-1.484	7.692
111	112	15	113.5	110.81	15.89	2.203	-1.073	5.607
42	196	3.23	42.65	195.29	4.59	1.524	-0.363	29.629
76	155	9.03	76.19	146.36	9.48	0.249	-5.903	4.745
					Min (%) Error	-2.984	-8.804	-2.603
					Max (%)			

NAVIGATION TEST RESULT

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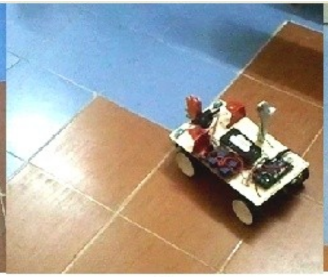
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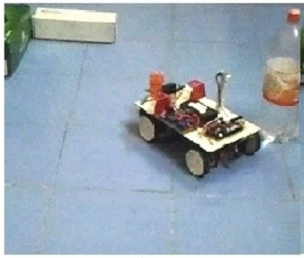
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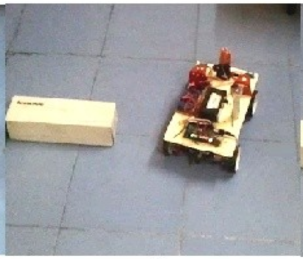
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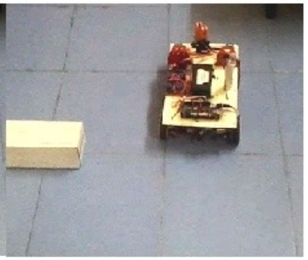
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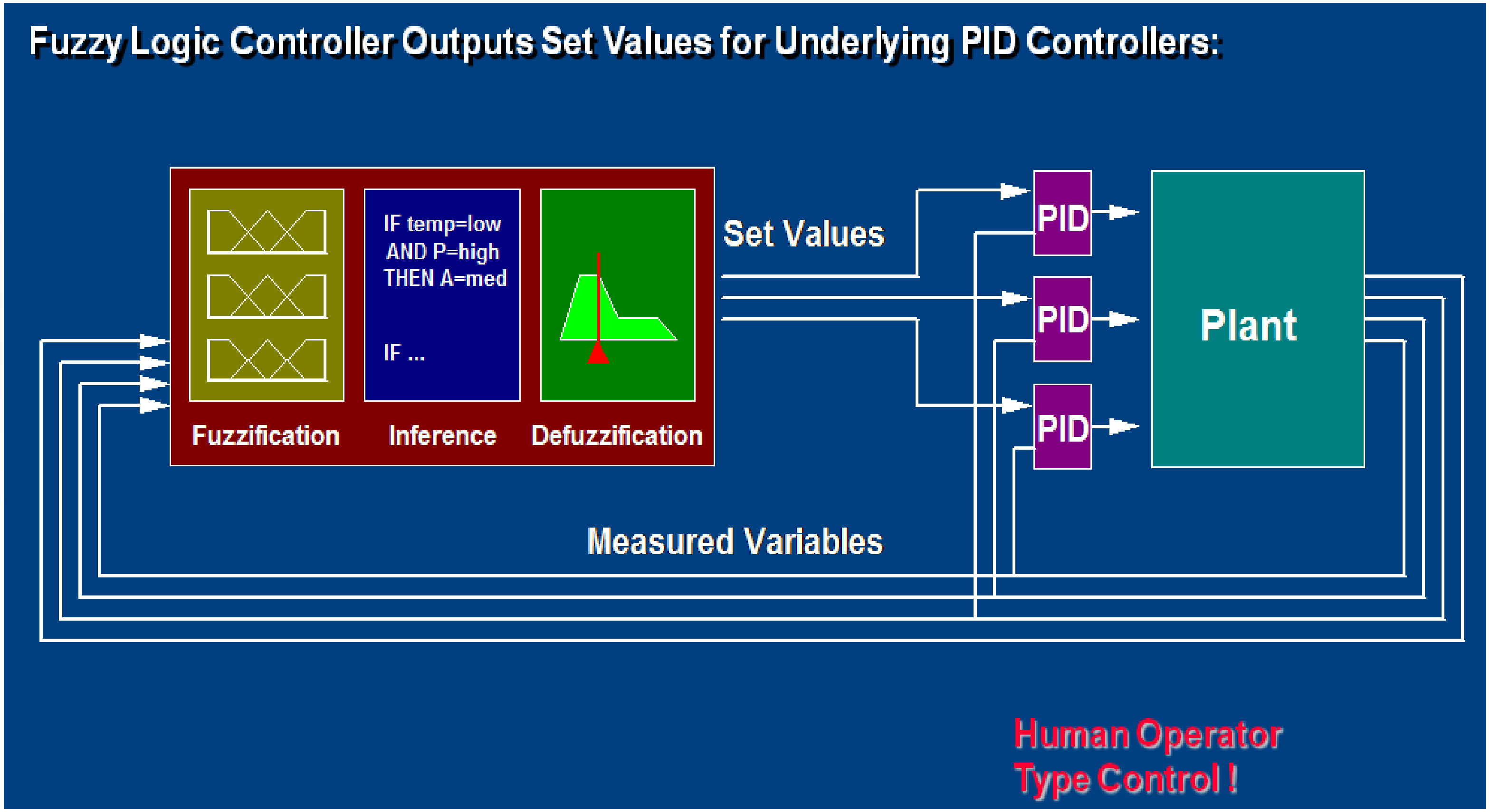
CONCLUSION

- Most of the industrial controllers are P-I-D in nature. The major reasons behind the popularity of P-I-D controller are its simplicity in structure and the applicability to variety of processes.
- Moreover the controller can be tuned for a process, even without detailed mathematical model of the process. However, proper tuning of the controller parameters requires extensive experimentation.
- PID and FUZZY LOGIC CONTROLLERs can be implemented for day to day, projects and industries applications easily and effective manner.

Application



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THANK YOU!