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ECE/CE 3720: Embedded System Design

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Lecture 25: Fuzzy Logic Control

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Fuzzy Logic Control

- Simpler than PID controllers and can be more robust.
- *Physical plant* has *real state variables*.
- DAS monitors them and creates *estimated state variables*.
- *Preprocessor* calculates *crisp inputs*.
- *Fuzzification* converts into *input fuzzy membership sets*.
- The *fuzzy rules* calculate *output fuzzy membership sets*.
- *Defuzzification* converts them into *crsip outputs*.
- *Postprocessor* modifies them into more convenient format.
- *Actuator system* affects physical plant based on outputs.

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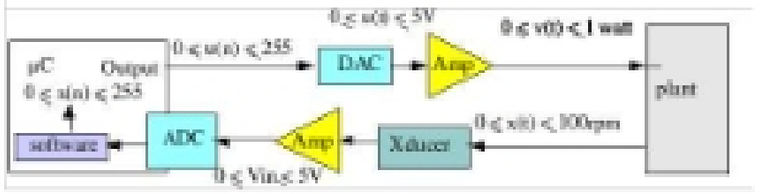
Interface of a Motor Controlled with Fuzzy Logic



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DAC, ADC Fuzzy Controller

- Two control inputs:
  - S^* : desired motor speed, rpm
  - S' : current estimated motor speed, rpm
- One control output:
  - N : digital value that we write to the DAC
- To use 8-bit math, change units to $1000/256 = 3.9$ rpm
  - $T^* = (256 \cdot S^*)/1000$: desired motor speed, 3.9 rpm
  - $T' = (256 \cdot S')/1000$: current motor speed, 3.9 rpm
- Two crisp inputs:
  - $E = T^* - T'$: error in motor speed, 3.9 rpm
  - $D = T'(n) - T'(n-1)$: change in speed, 3.9 rpm

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Subtraction with Overflow/Underflow Checking

```
char Subtract(unsigned char N, unsigned char M){
/* returns N-M */
unsigned int N16,M16;
int Result16;
     N16=N;         /* Promote N,M */
     M16=M;
     Result16=N16-M16;    /* -255Result16+255 */
     if(Result16<-128) Result16 = -128;
     if(Result16>127)  Result16 = 127;
     return(Result16);}
```

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Crisp Inputs

```
unsigned char Ts;  /* Desired Speed */
unsigned char T;   /* Current Speed */
unsigned char Told;/* Previous Speed */
char D;            /* Change in Speed */
char E;            /* Error in Speed */

void CrispInput(void){
     E=Subtract(Ts,T);
     D=Subtract(T,Told);
     Told=T;}      /* Set up Told for next time */
```


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Fuzzy Membership Sets

- Input fuzzy membership sets:
  - Slow - True if motor is spinning too slow
  - OK - True if motor is spinning at proper speed
  - Fast - True if moter is spinning too fast
  - Up - True if moter speed is getting larger
  - Constant - True if motor speed is remaining the same
  - Down - True if motor speed is getting smaller
- Output fuzzy membership sets:
  - Decrease - True if motor speed should be decreased
  - Same - True if motor speed should remain the same
  - Increase - True if motor speed should be increased

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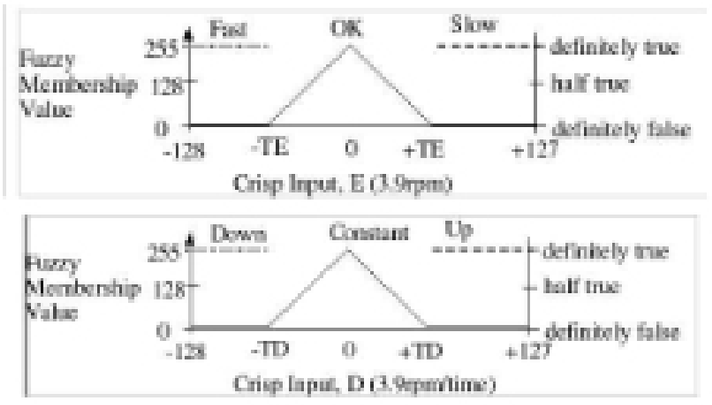
Fuzzification



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Calculation of the Fuzzy Membership Variables

```
#define TE 20
unsigned char Fast, OK, Slow, Down, Constant, Up;
#define TD 20
unsigned char Increase,Same,Decrease;
#define TN 20
void InputMembership(void){
  if(E <= -TE) { /* E <= -TE */
    Fast=255; OK=0; Slow=0;
  } else if (E < 0) { /* -TE<E<0   */
    Fast=(255*(-E))/TE; OK=255-Fast; Slow=0;
  } else if (E < TE) { /*  0<E<TE   */
    Fast=0; Slow=(255*E)/TE; OK=255-Slow;
  } else { /* +TE <= E */
    Fast=0; OK=0; Slow=255; }
```

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Calculation of the Fuzzy Membership Var (cont)

```
if(D <= -TD) { /* D<=-TD  */
  Down=255; Constant=0; Up=0;
} else if (D < 0) { /* -TD<D<0 */
  Down=(255*(-D))/TD; Constant=255-Down; Up=0;
} else if (D < TD) { /*  0<D<TD   */
  Down=0; Up=(255*D)/TD; Constant=255-Up;
} else { /* +TD <= D     */
  Down=0; Constant=0; Up=255;}}
```


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Fuzzy Logic Rules

E \ D	*Down*	*Constant*	*Up*
Slow	*Increase*	*Increase*	
OK	*Increase*	*Same*	*Decrease*
Fast		*Decrease*	*Decrease*

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Calculation of the Output Fuzzy Membership

```
unsigned char min(unsigned char u1,unsigned char u2){
     if(u1>u2) return(u2);
     else return(u1);}
unsigned char max(unsigned char u1,unsigned char u2){
     if(u1<u2) return(u2);
     else return(u1);}
void OutputMembership(void){
     Same=min(OK,Constant);
     Decrease=min(OK,Up)
     Decrease=max(Decrease,min(Fast,Constant));
     Decrease=max(Decrease,min(Fast,Up));
     Increase=min(OK,Down)
     Increase=max(Increase,min(Slow,Constant));
     Increase=max(Increase,min(Slow,Down));}
```