Fuzzy Control Methods For Active Noise Control

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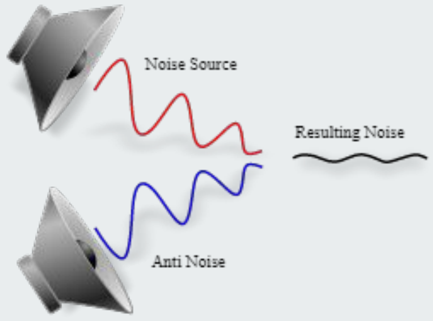
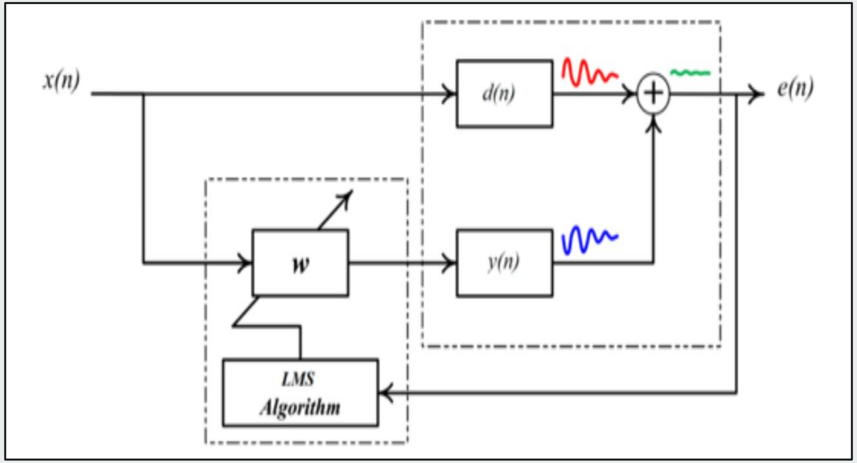
Active Noise Control



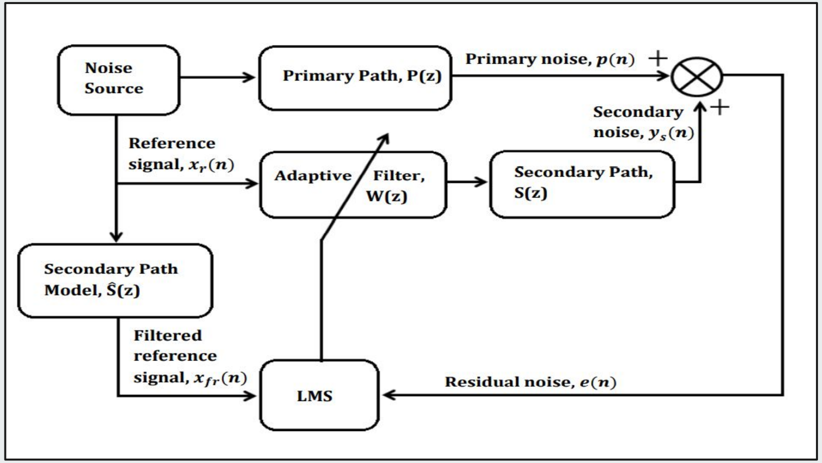
- ANC uses a noise cancelling system to reduce unwanted background noise.
- The principle of destructive interference between the sound fields generated by the original primary sound source and that due to other secondary sources.
- For eg, a microphone that “listen” to the sounds outside and inside of an earphone, an ANC chipset inverting the soundwaves and a speaker inside the earphone cancelling the outside sound by the neutralising soundwaves.

LMS Algorithm



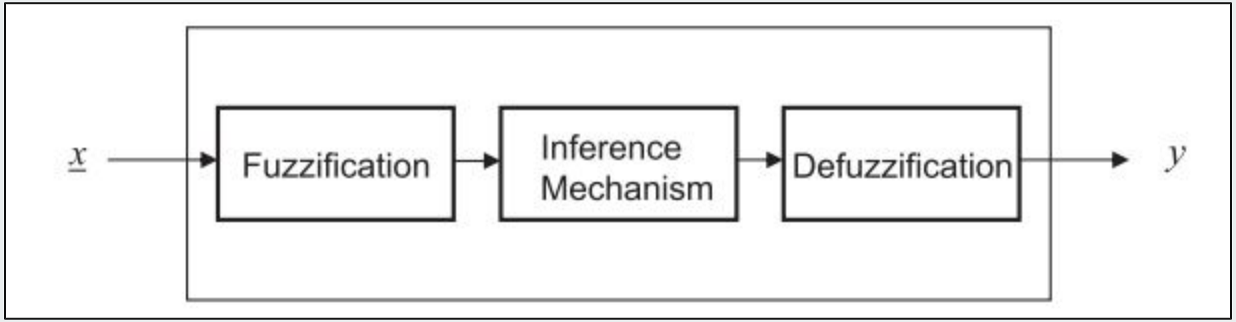
- It uses a stochastic gradient descent method in that the filter is only adapted based on the error at the current time.
- Noise passed through LMS Adaptive filter is used to calculate error.
- Error further used to update the weights by gradient descent method, results in its minimization.

FxLMS Algorithm



- Similar to LMS, in using the gradient descent method.
- Involves an extra secondary path .
- The path from the output of the adaptive filter to the output of the error sensor.
- Taking the noise from both primary and secondary path and similar LMS algorithm.

FUZZY SYSTEMS



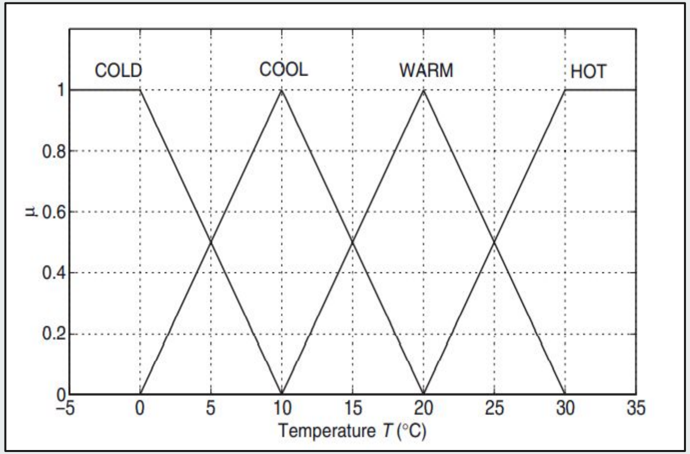
Fuzzification: To convert the measured quantities into fuzzy sets.

Inference: To determine the degree of firing of each rule in the rule base.

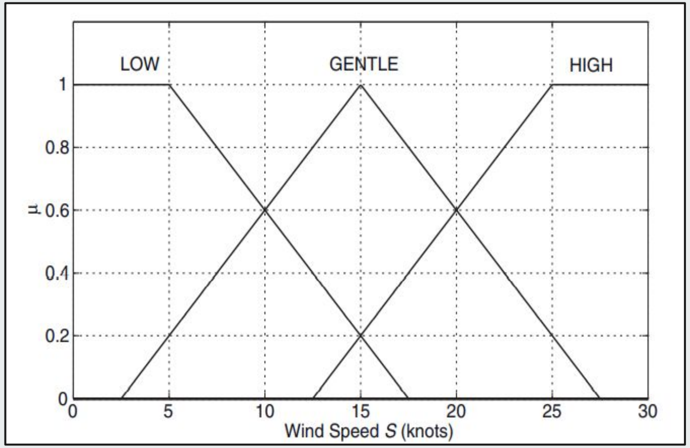
Defuzzification: To convert the collection of recommendation of all rules into a crisp output.

Example: WIND CHILL

Input Linguistic Variables and corresponding Fuzzy set for temperature :



Input Linguistic Variables and corresponding Fuzzy set for wind speed :



INFERENCE :

Rules:

1. If TEMPERATURE is COLD and WIND SPEED is LOW, then WIND CHILL is BEARABLE.
2. If TEMPERATURE is COLD and WIND SPEED is GENTLE, then WIND CHILL is BAD.
3. If TEMPERATURE is COLD and WIND SPEED is HIGH, then WIND CHILL is SEVERE.
4. If TEMPERATURE is COOL and WIND SPEED is LOW, then WIND CHILL is MILD.
5. If TEMPERATURE is COOL and WIND SPEED is GENTLE, then WIND CHILL is BEARABLE.
6. If TEMPERATURE is COOL and WIND SPEED is HIGH, then WIND CHILL is BAD.
7. If TEMPERATURE is WARM and WIND SPEED is LOW, then WIND CHILL is UNNOTICEABLE.
8. If TEMPERATURE is WARM and WIND SPEED is GENTLE, then WIND CHILL is MILD.
9. If TEMPERATURE is WARM and WIND SPEED is HIGH, then WIND CHILL is BEARABLE.
10. If TEMPERATURE is HOT and WIND SPEED is LOW, then WIND CHILL is UNNOTICEABLE.
11. If TEMPERATURE is HOT and WIND SPEED is GENTLE, then WIND CHILL is UNNOTICEABLE.
12. If TEMPERATURE is HOT and WIND SPEED is HIGH, then WIND CHILL is MILD.

Only 4 rules are ON.

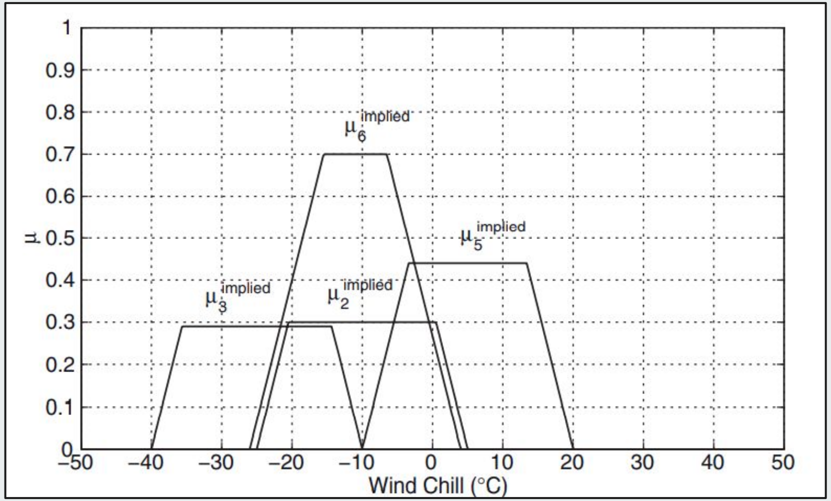
$$R_2 : \mu_2(7, 22) = \mu^{\mathrm{COLD} \cap \mathrm{GENTLE}} = \min(0.3, 0.44) = 0.3$$

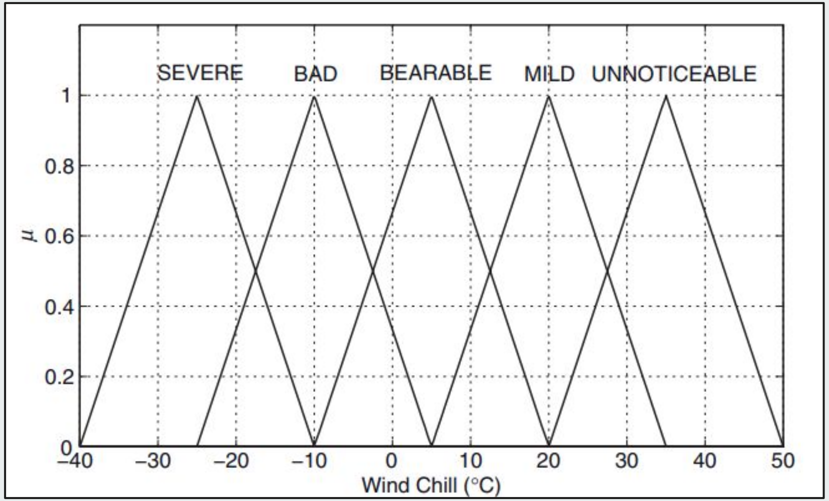
$$R_3 : \mu_3(7, 22) = \mu^{\mathrm{COLD} \cap \mathrm{HIGH}} = \min(0.3, 0.76) = 0.3$$

$$R_5 : \mu_5(7, 22) = \mu^{\mathrm{COOL} \cap \mathrm{GENTLE}} = \min(0.7, 0.44) = 0.44$$

$$R_6 : \mu_6(7, 22) = \mu^{\mathrm{COOL} \cap \mathrm{HIGH}} = \min(0.7, 0.76) = 0.7$$

DEFUZZIFICATION:



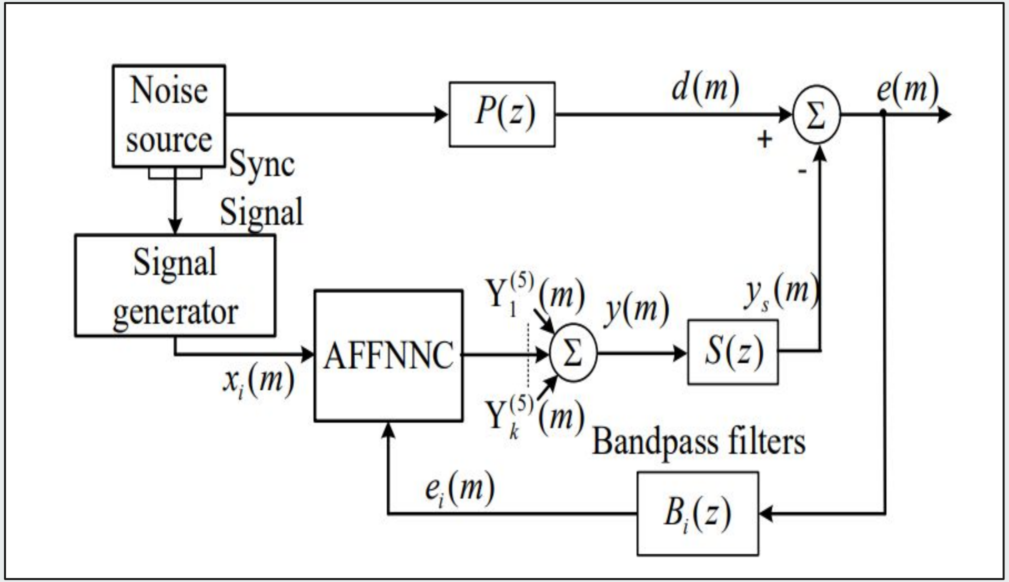


$$y^{crisp} = \frac{-10(7.65) - 25(7.65) + 5(10.296) - 10(13.65)}{7.65 + 7.65 + 10.296 + 13.65} = -8.9887°C$$

AFFNNC:

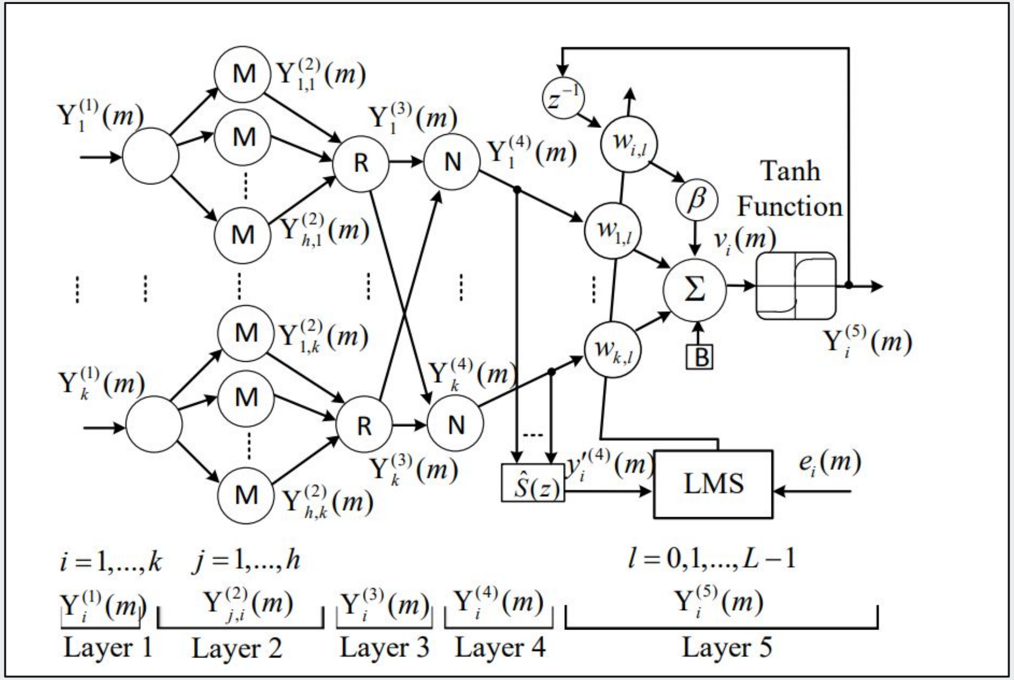
(Proposed Controller)

- Uses an AFFNNC structure which implements the fuzzy logic in active noise control.
- Makes use of FSLMS algorithm for taking into account the error for weight updation.



Internal Structure of AFFNNC

- The AFFNNC block accounts for different layers.
- The signal transforms layer by layer.
- Every subpart of Fuzzy control system is implemented in one of the layers.



Primary Noise Signal
(Passed into AFFNNC structure)

$$d(m) \equiv \sum_{i=1}^{k} \cos(\omega_i m) + u(m),$$

Layer 1 Output

$$Y_i^{(1)}(m) = x_i(m).$$

Layer 2 Output

$$Y_{j,i}^{(2)}(m) = \exp\left\{ -\frac{\left(Y_i^{(1)}(m) - c_{j,i}\right)^2}{\varpi_{j,i}^2} \right\}$$

Layer 3 Output

$$Y_i^{(3)}(m) = \prod_{j=1}^{h} Y_{j,i}^{(2)}(m).$$

Layer 4 Output

$$Y_i^{(4)}(m) = \frac{Y_i^{(3)}(m)}{\sum_{i=1}^{k} Y_i^{(3)}(m)}.$$

Layer 5 Output:

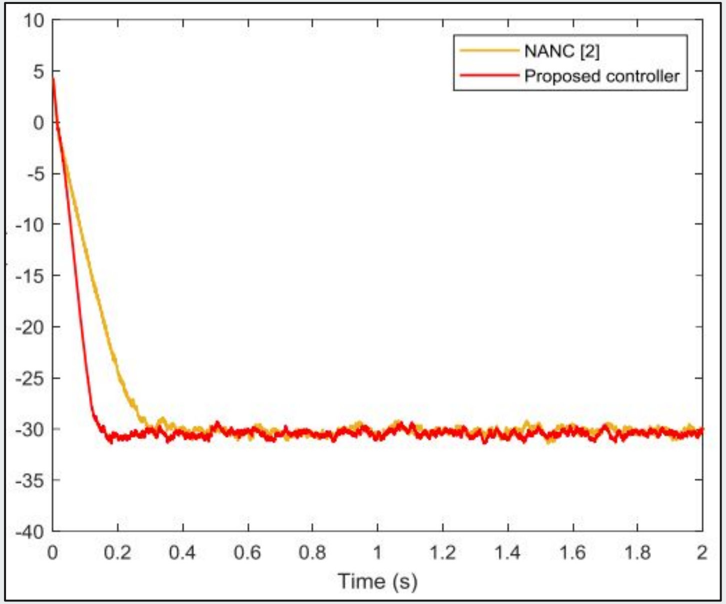
$$v_i(m) = \sum_{l=0}^{L-1}\left(w_{i,l}(m)Y_i^{(4)}(m-l) + \beta w_{i,l}(m)Y_i^{(5)}(m-l-1)\right)$$

$$Y_i^{(5)}(m) = \mathrm{Tanh}(v_i(m)) = \frac{\exp(v_i(m)) - \exp(-v_i(m))}{\exp(v_i(m)) + \exp(-v_i(m))}$$

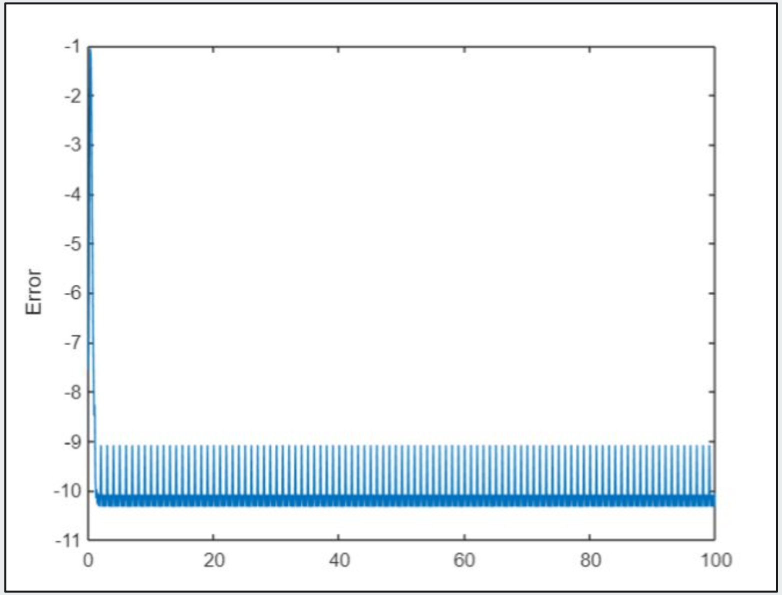
$$\boldsymbol{w}_i(m+1) = \boldsymbol{w}_i(m) - \frac{\mu_i}{2}\nabla\xi_i(m) \longrightarrow \boldsymbol{w}_i(m+1) = \boldsymbol{w}_i(m) + \mu_i\left(1-\left[Y_i^{(5)}(m)\right]^2\right)e_i(m)\boldsymbol{y}_i'^{(4)}(m)$$

$$y_i'^{(4)}(m) = \sum_{q=0}^{Q-1}\hat{s}_q(m)Y_i^{(4)}(m-q)$$

Results:



NANC [2]
Proposed controller
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (s)



Error
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
0
20
40
60
80
100

Contributions

- Concepts of Fuzzy Logic and Fuzzy Sets (Priyanshu, Pulkit, Shashwat)
- LMS Algorithm (Pulkit & Shashwat)
- FxLMS Algorithm (Priyanshu & Pulkit)
- Working of Fuzzy Systems (Priyanshu, Pulkit, Shashwat)
- Adaptive Fuzzy Feedback Neural Network Controller (AFFNNC)
  - Layer 1,2,3,4,5 (Pulkit and Priyanshu)
  - FSLMS (Shashwat)

Approximated Time Spent: 80+ Hours

THANK YOU