# NEURONAL AND FUZZY COMPUTATION

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# FUZZY CONTROLS

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# Part A

## FUZZY CONTROLLERS

# Fuzzy inference systems

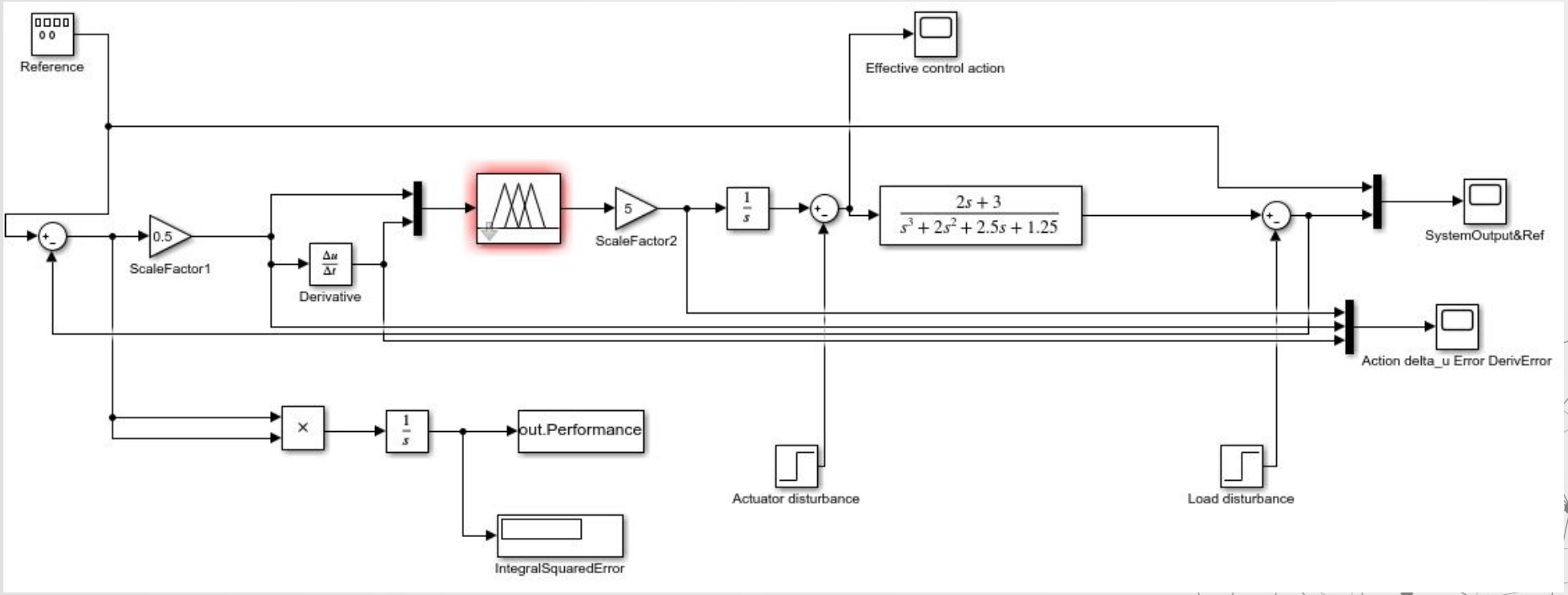
- Designed the fuzzy sets with  triangular and gaussian membership functions
- Used Mamdani and Sugeno controllers

| $e_k \mid \Delta e_k$ | N | ZE | P |
|---|---|---|---|
| **N** | N | N | Z |
| **ZE** | N | ZE | P |
| **P** | ZE | P | P |

| $e_k \mid \Delta e_k$ | NB | NS | ZE | PS | PB |
|---|---|---|---|---|---|
| **NB** | NB | NB | NB | NS | ZE |
| **NS** | NB | NS | ZE | PS | PB |
| **ZE** | NB | NS | ZE | PS | PB |
| **PS** | NS | ZE | PS | PB | PB |
| **PB** | ZE | PS | PB | PB | PB |

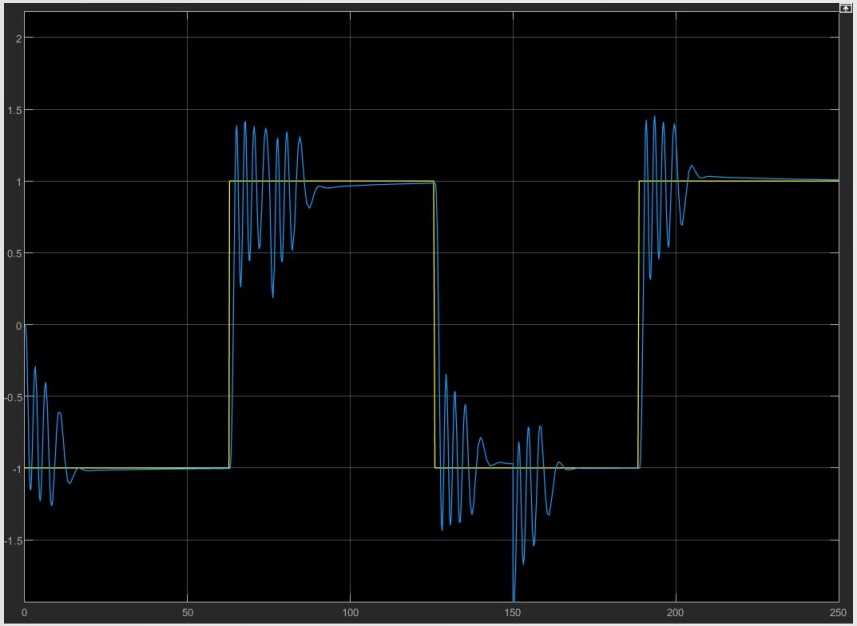
| $e_k \mid \Delta e_k$ | N | ZE | P |
|---|---|---|---|
| **N** | NB | N | Z |
| **ZE** | N | ZE | P |
| **P** | ZE | P | PB |

# Graphical Representation of the System

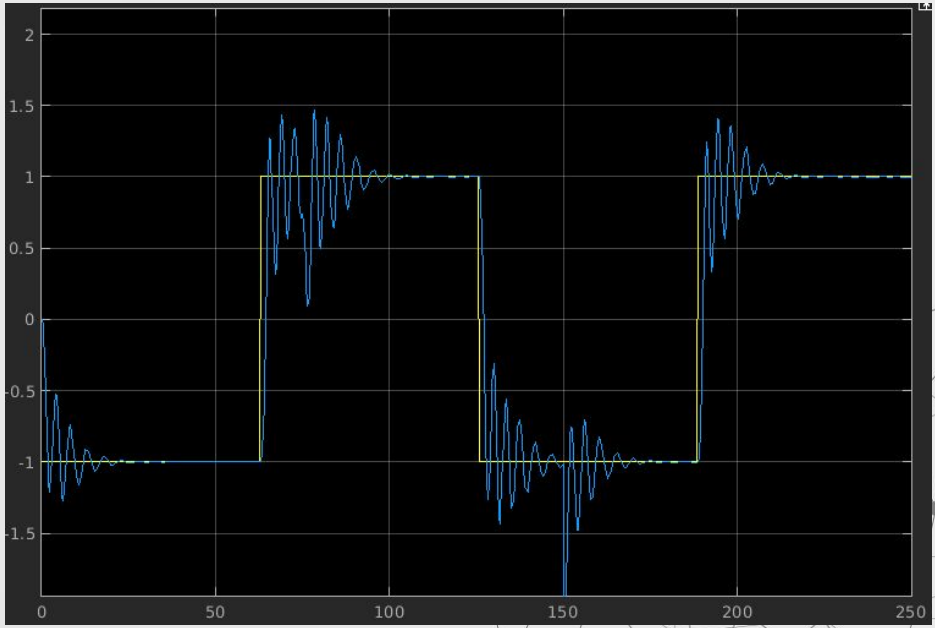


# Best results Square Signal

| Controller | Membership Fcn | Rules Number | Input Factor | Output Factor | Integral Squared Error |
|---|---|---|---|---|---|
| Mamdani | Gaussian | 9 | 0.7 | 5.4 | 22.83 |
| Sugeno | Gaussian | 9 | 0.7 | 1.5 | 22.54 |



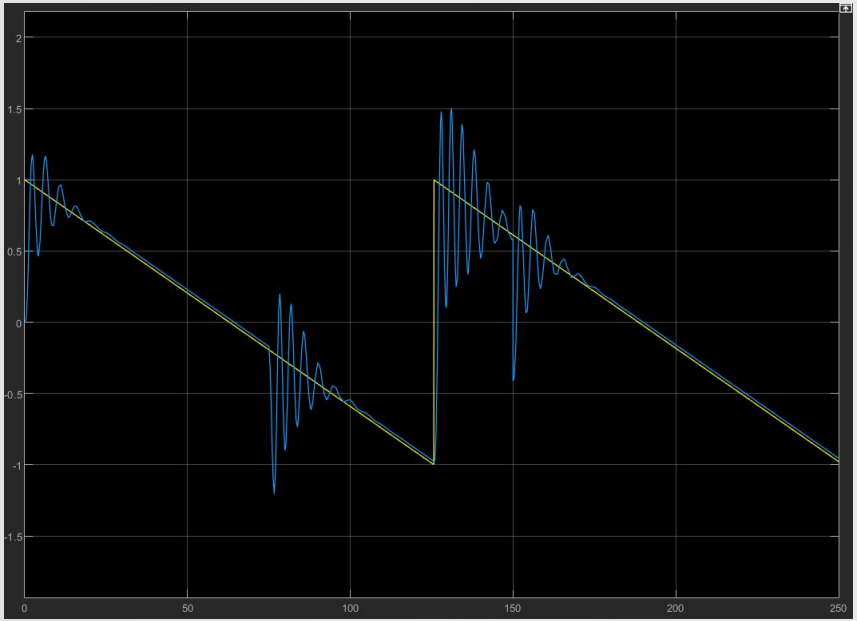

**Controller:** Mamdani




**Controller:** Sugeno

# Best results Sawtooth Signal

| Controller | Membership Fcn | Rules Number | Input Factor | Output Factor | Integral Squared Error |
|---|---|---|---|---|---|
| Mamdani | Gaussian | 9 (5 otp. feat.) | 0.5 | 5.7 | 11.18 |
| Sugeno | Gaussian | 9 (5 otp. feat.) | 0.5 | 2.5 | 10.28 |

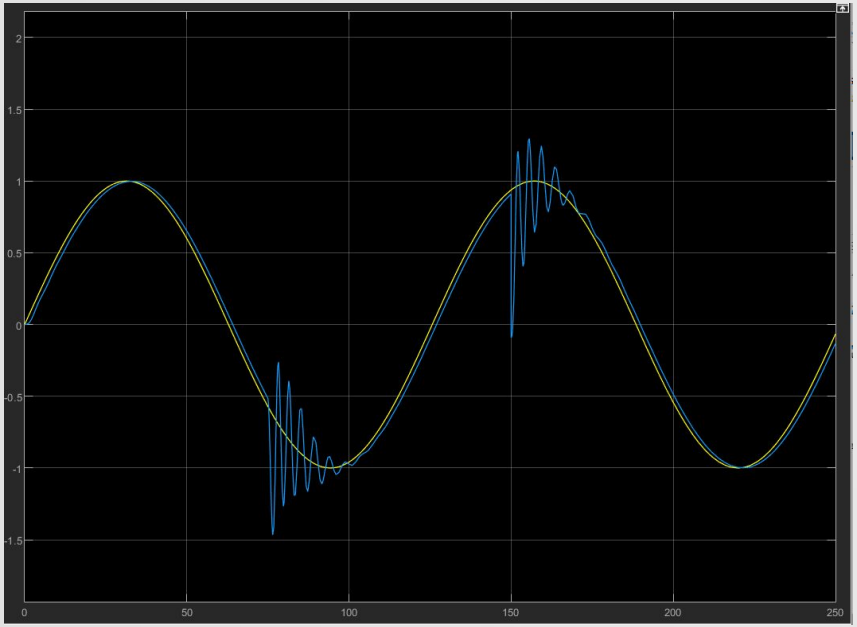



**Controller:** Mamdani

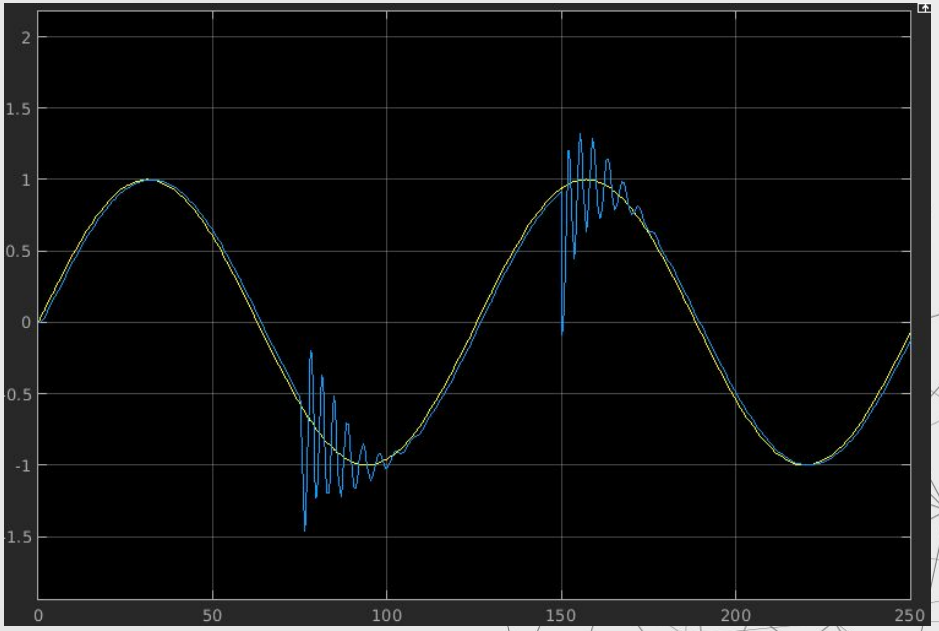

**Controller:** Sugeno

# Best results Sinusoidal Signal

| Controller | Membership Fcn | Rules Number | Input Factor | Output Factor | Integral Squared Error |
|---|---|---|---|---|---|
| Mamdani | Gaussian | 9 (5 otp. feat.) | 0.6 | 5 | 3.83 |
| Sugeno | Gaussian | 9 | 0.7 | 1.8 | 3.87 |




**Controller:** Mamdani




**Controller:** Sugeno

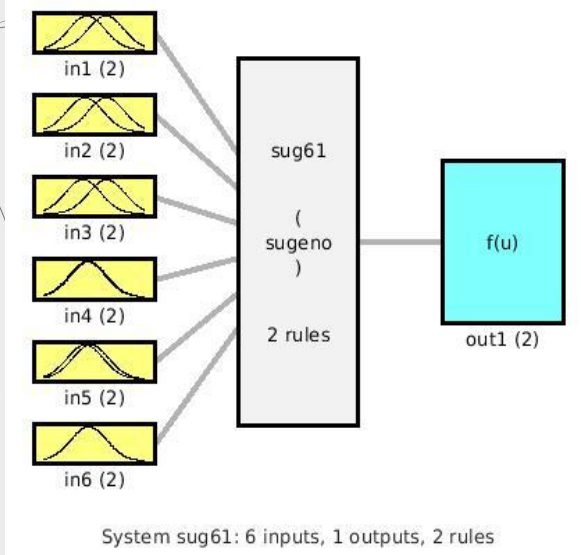
# Conclusions

- Best results were obtained using the sinusoidal. It was expected since it it the type of signal with less abrupt signal changes;
- Between the controllers, the results didn't differ that much. However, Sugeno has a little advantage since it performed slightly better for two of the three signals;
- The gaussian membership function was recurrently the best function to model the systems;
- Using 9 rules was constantly the best option. Try using 9 rules with 5 output features was worth because it  achieved better results in some cases.

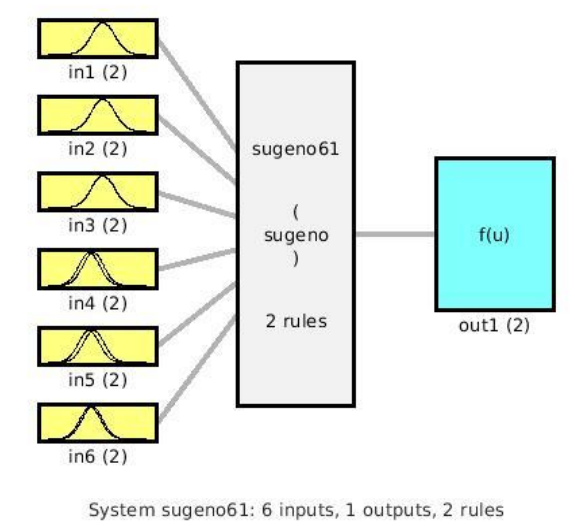
# Part B

## NEURO-FUZZY SYSTEMS FOR MODELING DYNAMIC PROCESSES

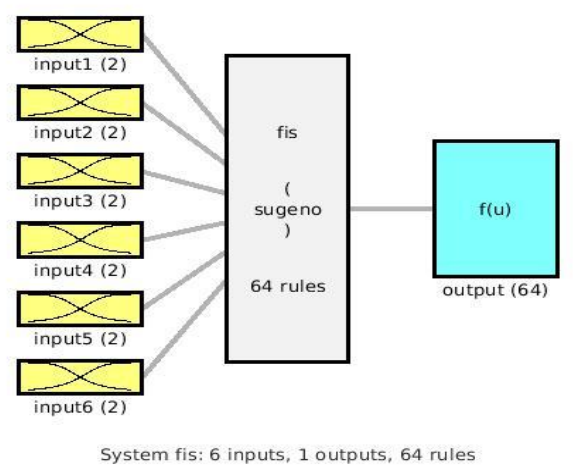
# FIS GENERATION




**Subtractive Clustering**

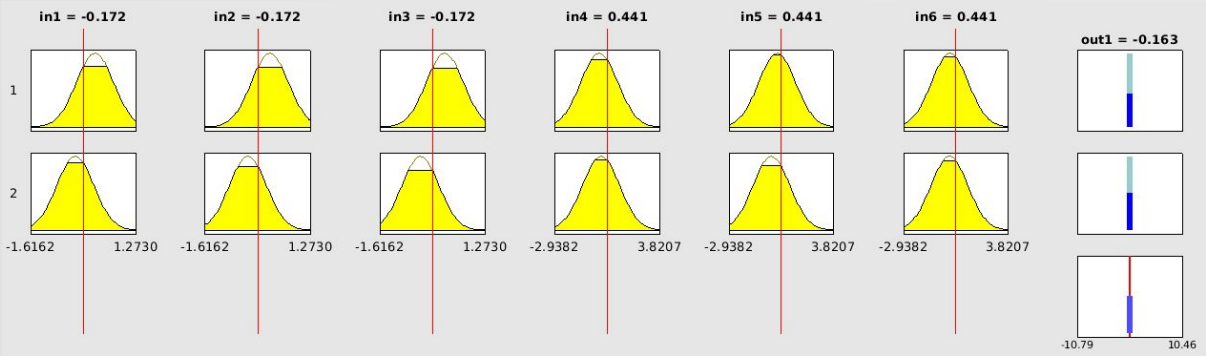



**Fuzzy c-means clustering**



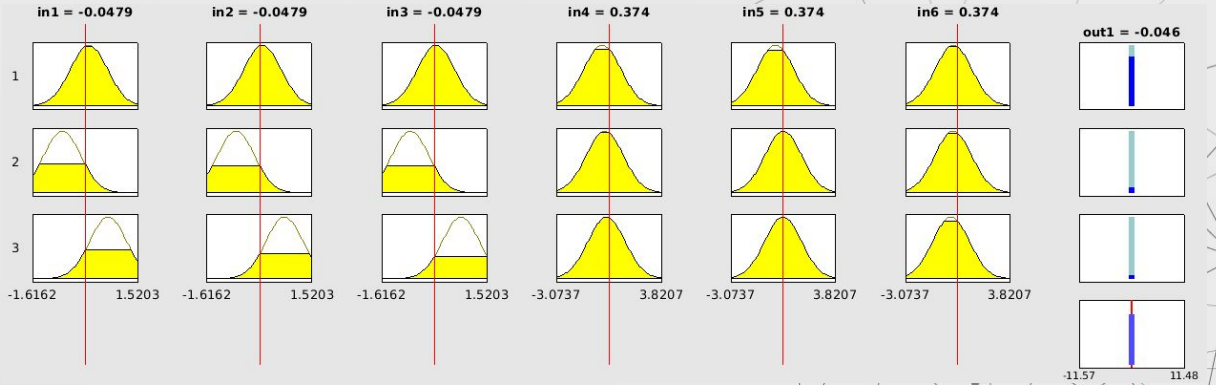

**Grid Partition Clustering**

# Rules After Optimization

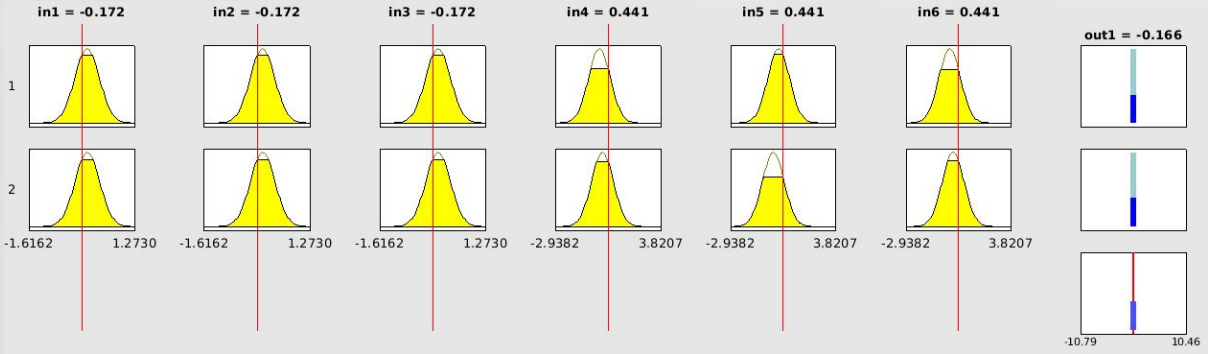



**Backpropagation + Subtractive Clustering**

**Hybrid + Subtractive Clustering**

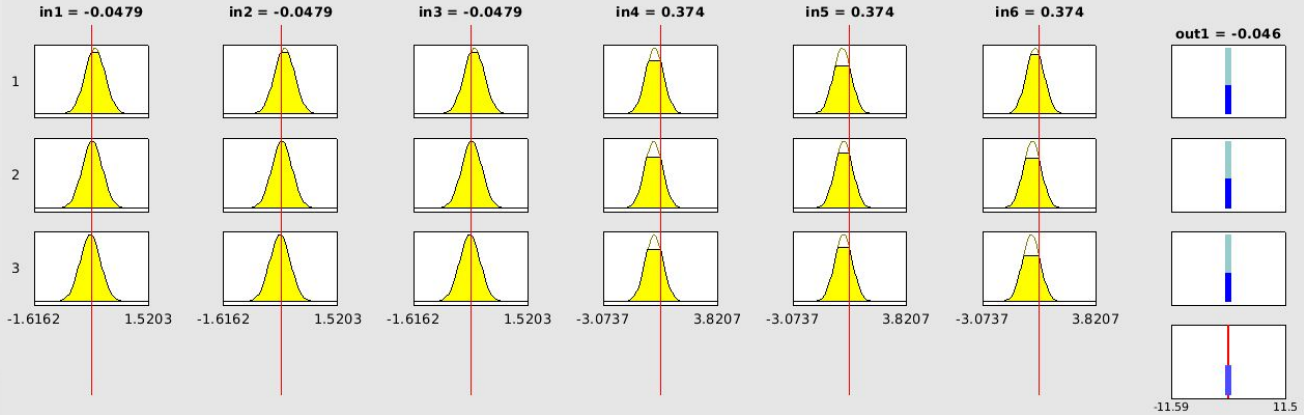


# Rules After Optimization




**Backpropagation +**
**Fuzzy c-means Clustering**

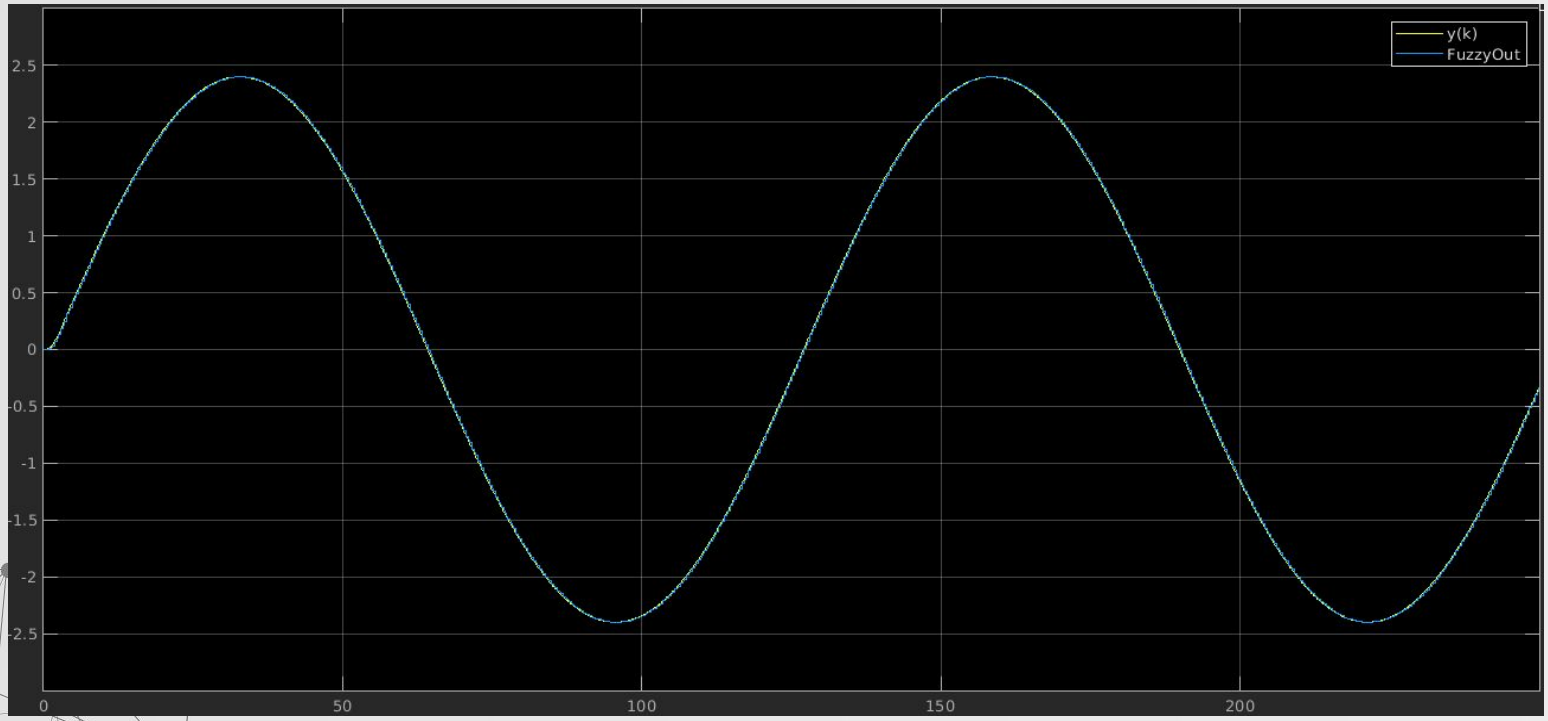
**Hybrid +**
**Fuzzy c-means Clustering**



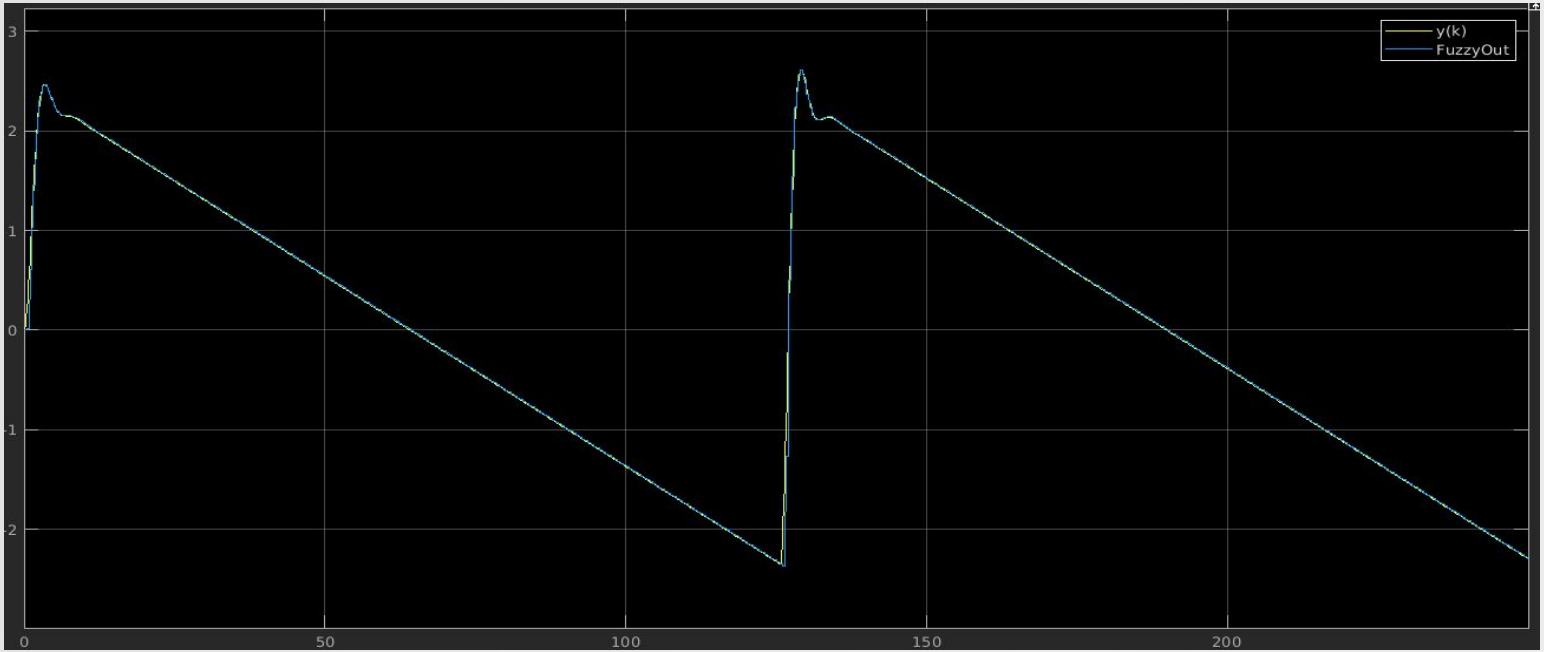
# Optimization results

| Optimization Method | Clustering Method | Mean Squared Error |
|---|---|---|
| Backpropagation | Subtractive | 7.026356e-05 |
| | Fuzzy c-means | 4.972599e-05 |
| | Grid Partition | 3.048162e-01 |
| Hybrid | Subtractive | 4.023544e-11 |
| | Fuzzy c-means | 3.060494e-11 |
| | Grid Partition | 1.272667e-07 |

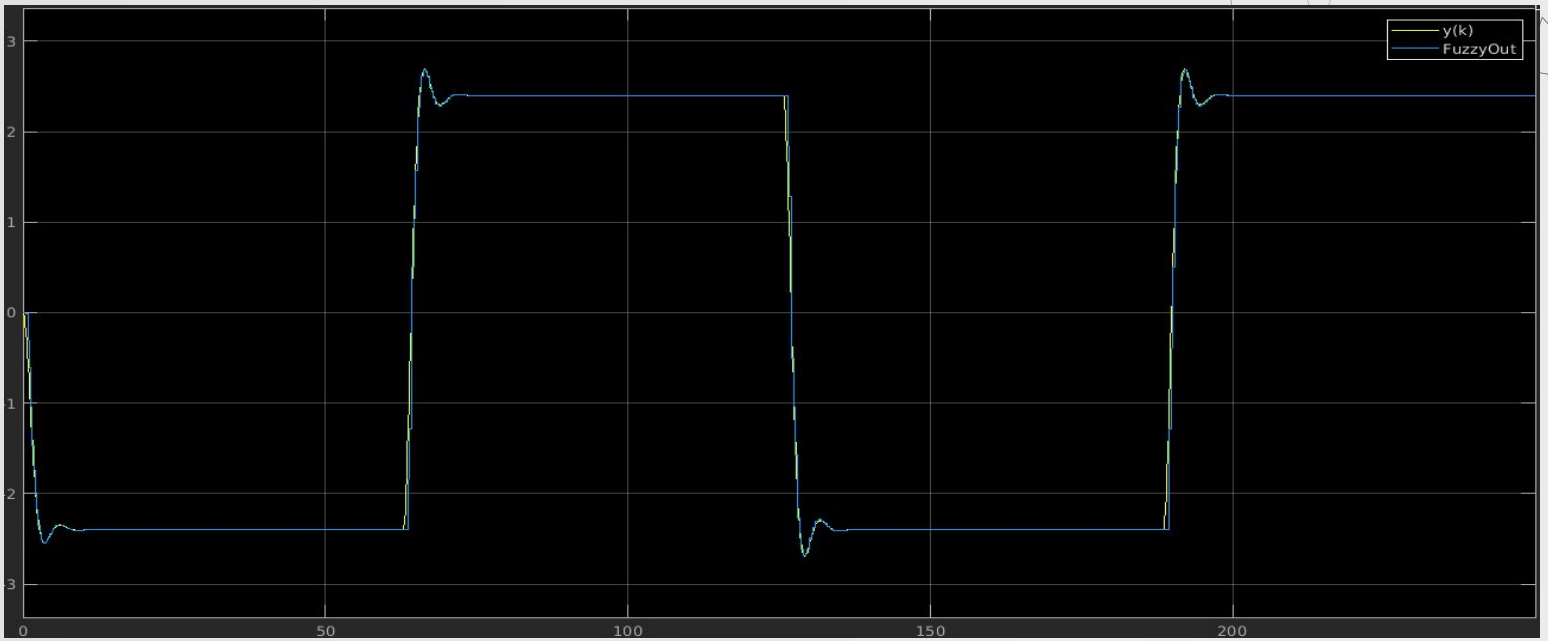
# Hybrid + Fuzzy c-means



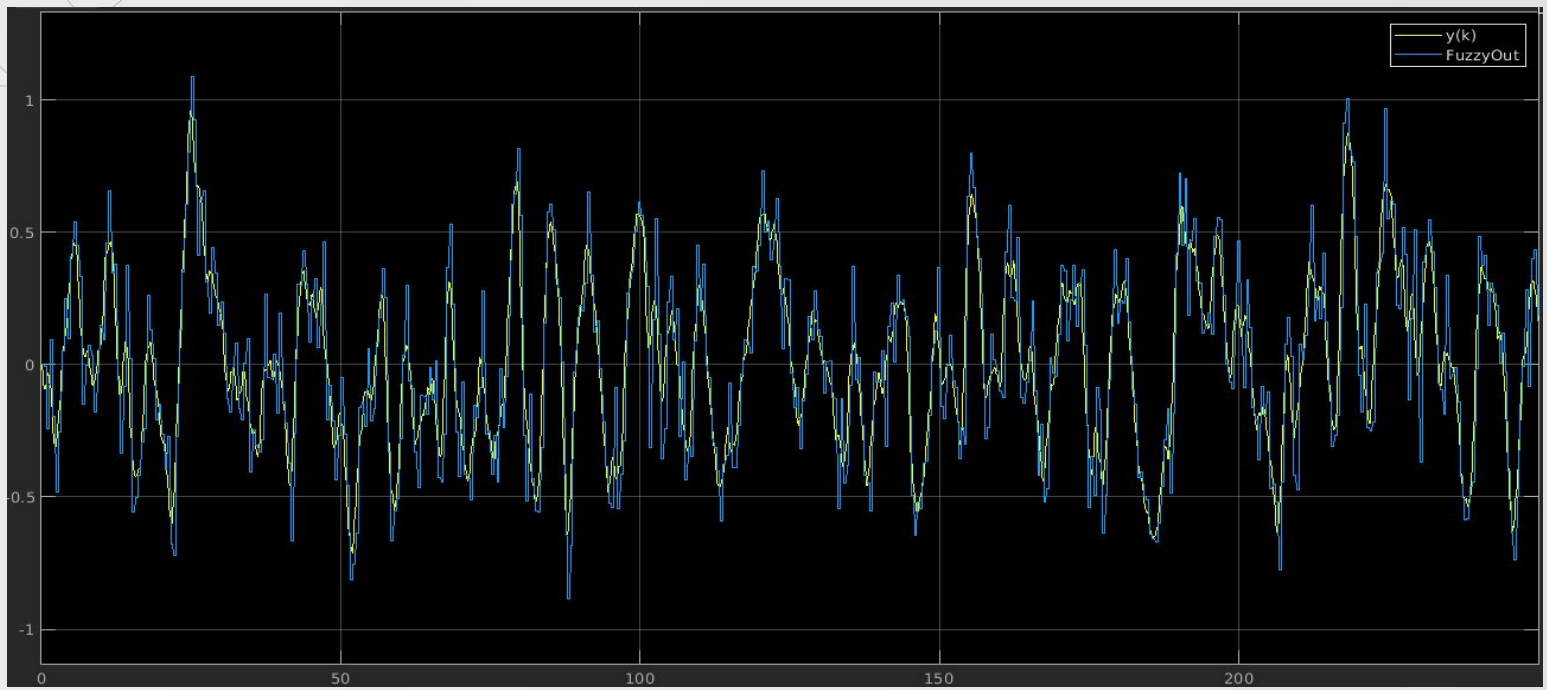
# Backpropagation + Fuzzy c-means opt.



# Backpropagation + Fuzzy c-means opt.



# Backpropagation + Fuzzy c-means opt.



# Conclusions

- Subtractive and fuzzy c-means better than grid partition since they're able to build fuzzy systems with a smaller number of rules;
- Fuzzy c-means clustering presents the smaller mean squared error;
- Testing the FIS with dynamic process produced an almost perfect response to the generated signal (for square, sinusoidal, sawtooth and even random).