# Intelligent Control

# Intelligent Control Technologies

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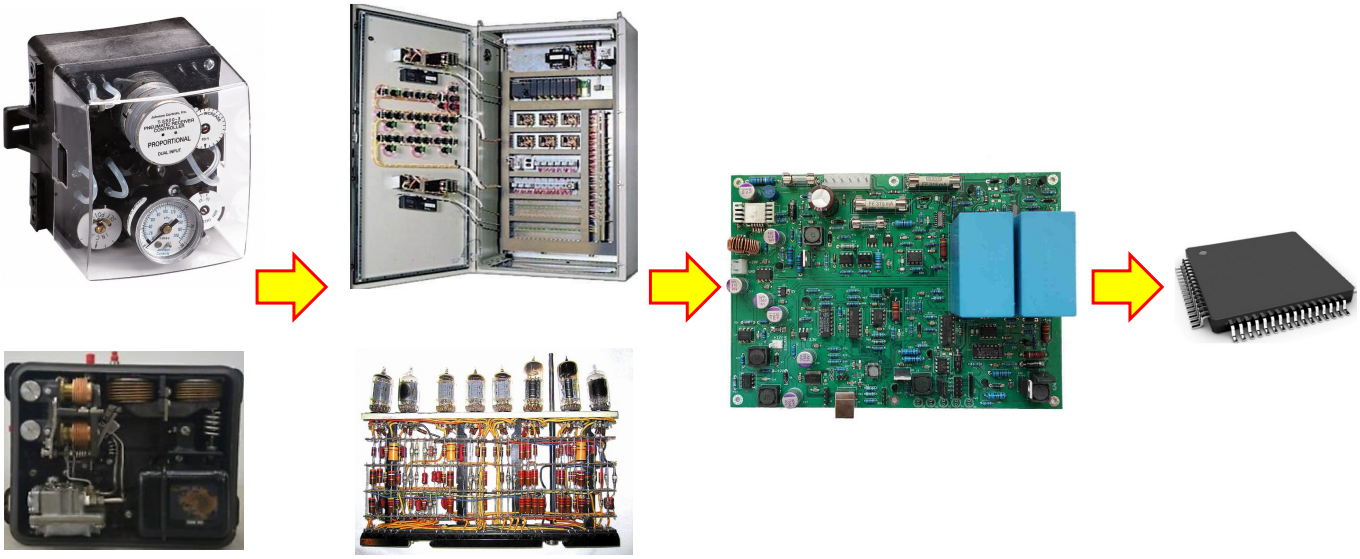
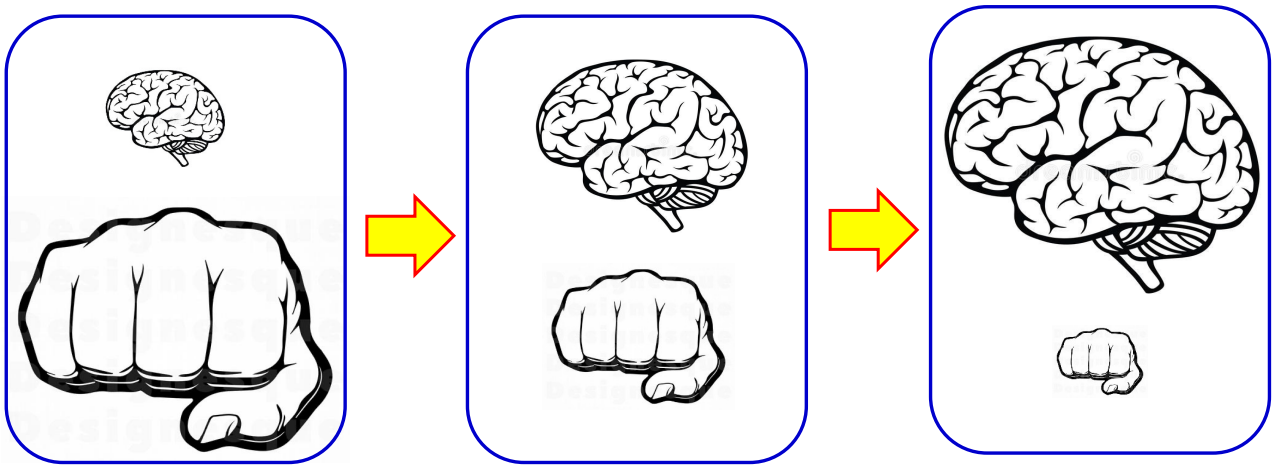
# Control Systems Development



Time

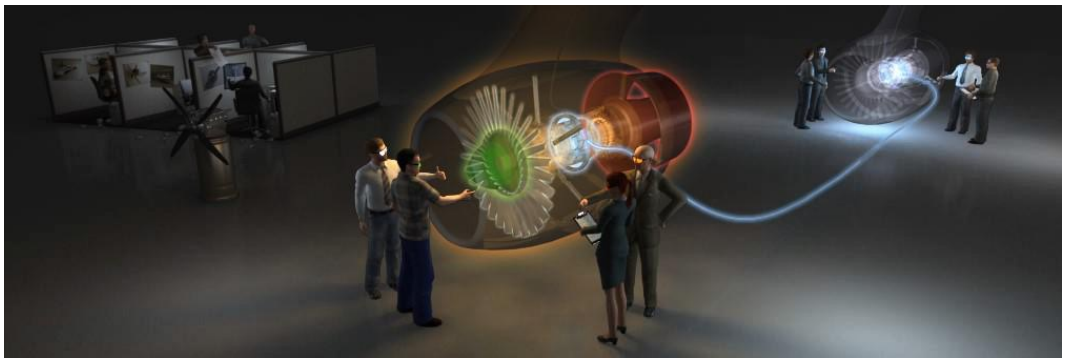


# Control Systems Development



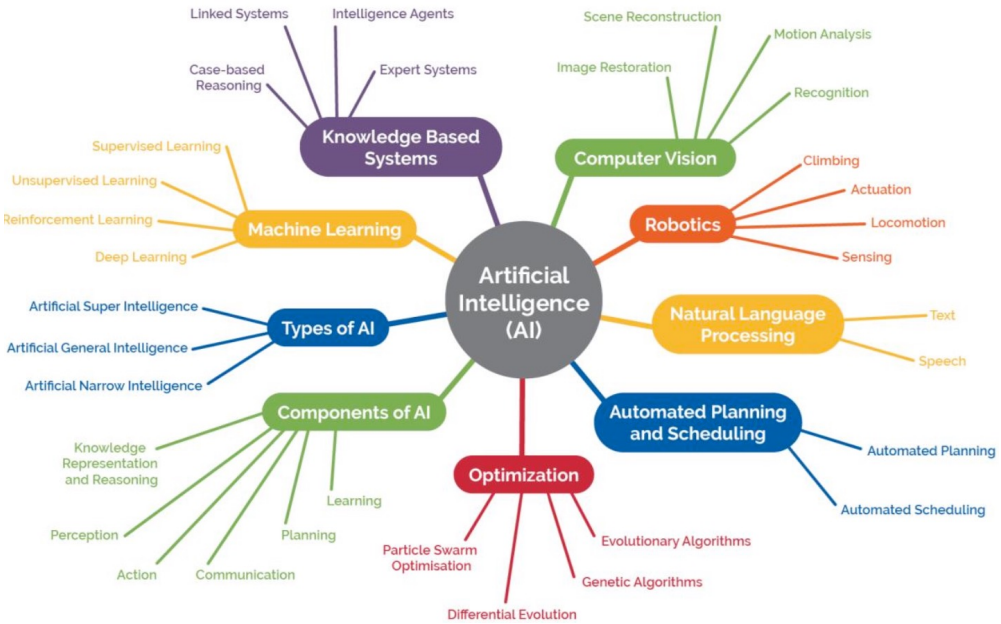
Time

# Control Systems Development



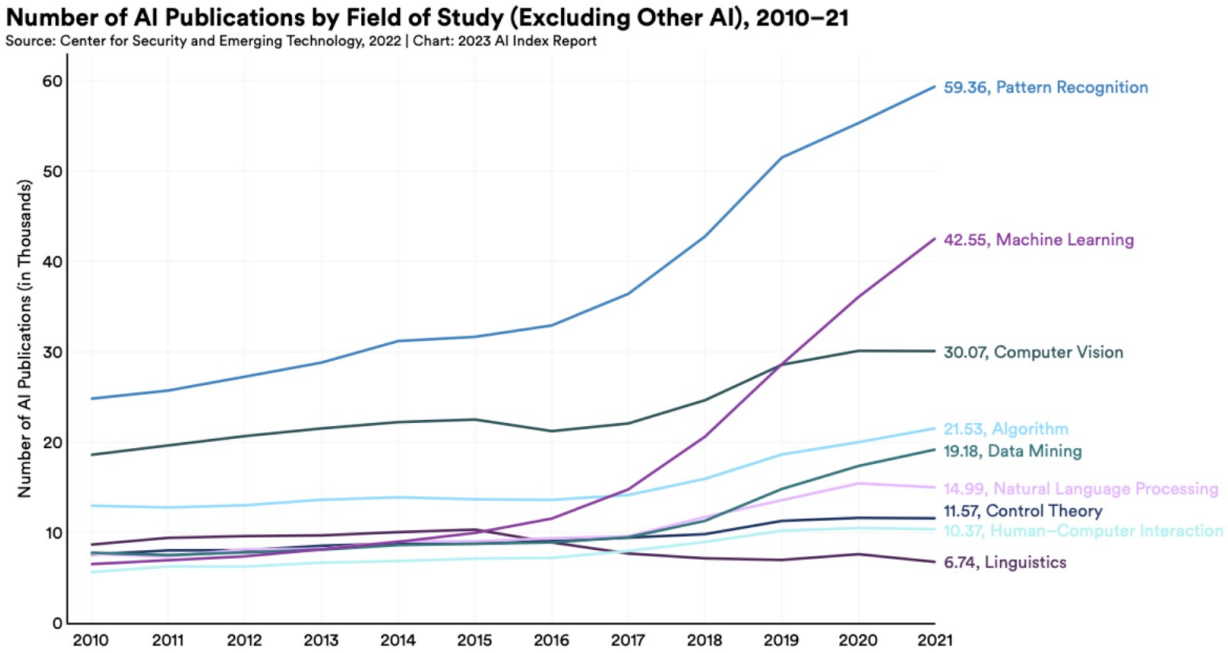


# AI: Components, types, and Subfields




Regona, Massimo & Yigitcanlar, Tan & Xia, Bo & Li, R.Y.M. (2022). Opportunities and adoption challenges of AI in the construction industry: A PRISMA review. *Journal of Open Innovation Technology Market and Complexity, 8(45).* https://doi.org/10.3390/joitmc8010045

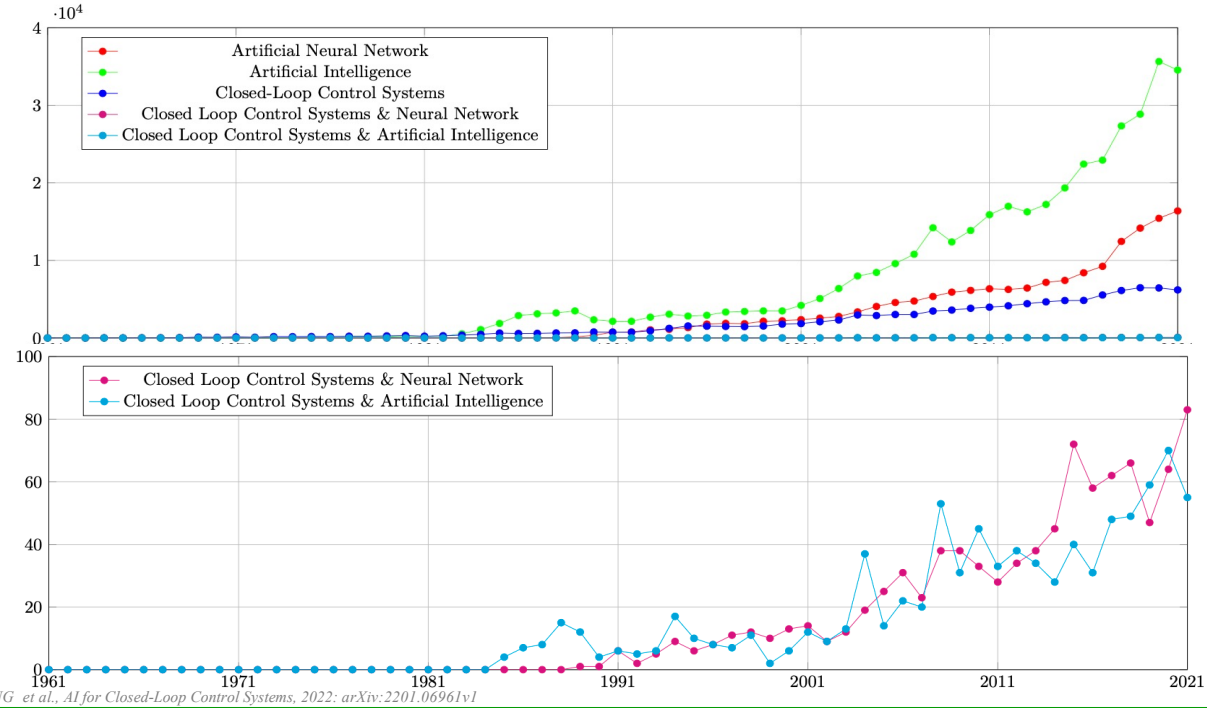
# AI Publications




*Artificial Intelligence Index Report, Stanford Univ., 2023*

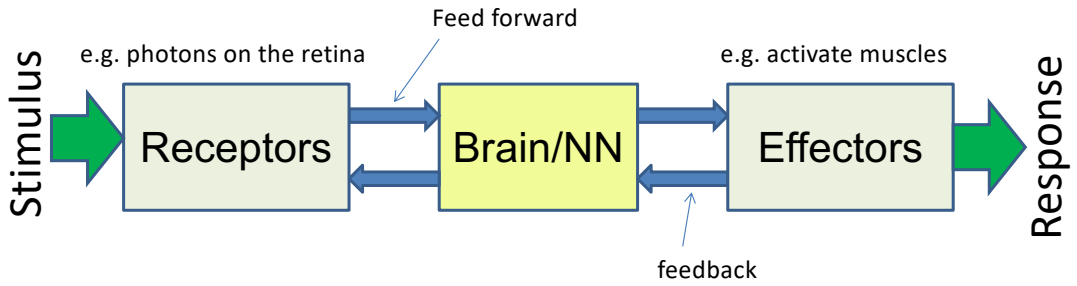


# AI Publications: using keywords



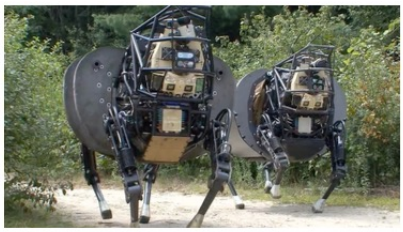

*J. SCHÖNING et al., AI for Closed-Loop Control Systems, 2022: arXiv:2201.06961v1*

## Human Nervous System






## AI Today




- Autonomous planning (NASA), logistics (Army)
- Games (AlphaGo)
- Automatic control (self-driving cars)
- Diagnostic (expert level, in Medicine)
- Robotics
- Many application fields:
  - smart home, driving assistance, BRMS, recommendation, image recognition to unlock, personal assistants, smart grids, ...

BRMS: Business rules management systems

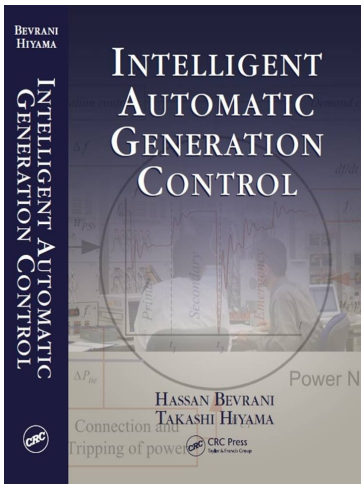
## Intelligent Control (Why?)

- Due to increase of **complexity**, **uncertainty** and emerging **new functions**, conventional techniques **fail** to meet all specified objectives and new demands.
- Conventional model-based schemes and analytical methods are provided for **specific situations, assumptions**, and they are so **time-consuming**.
- Recent advances in **computing and communication** technologies, provides a strong support for intelligent techniques.
- Due to some characteristics such as **simplicity**, **learnability**, **flexibility**, and **free-model** based property, they are suitable for nonlinear, variable structure, and complex systems.



## Areas of Intelligent Systems Applications (Japan, 2011)

| Application Areas | Number of Utilities |
|---|---|
| Planning, expansion | 2 |
| Load forecasting | 6 |
| Reconfiguration | 4 |
| Unit commitment | 3 |
| Fault diagnosis | 5 |
| Control, Economic load dispatch | 5 |
| Restoration, Simulators for training | 6 |



## Applied Intelligent Techniques

| Application Areas | Intelligent Techniques |
|---|---|
| Planning, expansion | Expert System, GA, Tabu Search |
| Load forecasting | ANN, Fuzzy logic |
| Reconfiguration | Expert System, GA, Tabu Search |
| Unit commitment | Tabu Search |
| Fault diagnosis | Expert Systems, ANN |
| Stabilization, control | Fuzzy Logic |
| Restoration, Simulators for training | Data Base System, Expert System Fuzzy logic, GA, Tabu Search |



## Fault Diagnosis

| Fault | Accurate Identification | Inaccurate Identification | Accuracy (%) |
|---|---|---|---|
| Lightning | 65 | 0 | 100 |
| Construction machine | 4 | 1 | 80 |
| Tree branch | 15 | 0 | 100 |
| Small animal | 10 | 3 | 77 |
| Snow, wind and galloping | 7 | 3 | 70 |

## Some Applications in Control

- ✓ Damping control of oscillations
- ✓ Control of generators including PSS
- ✓ Control of FACTS devices
- ✓ Voltage and reactive power control
- ✓ Automatic generation control



## Challenges!

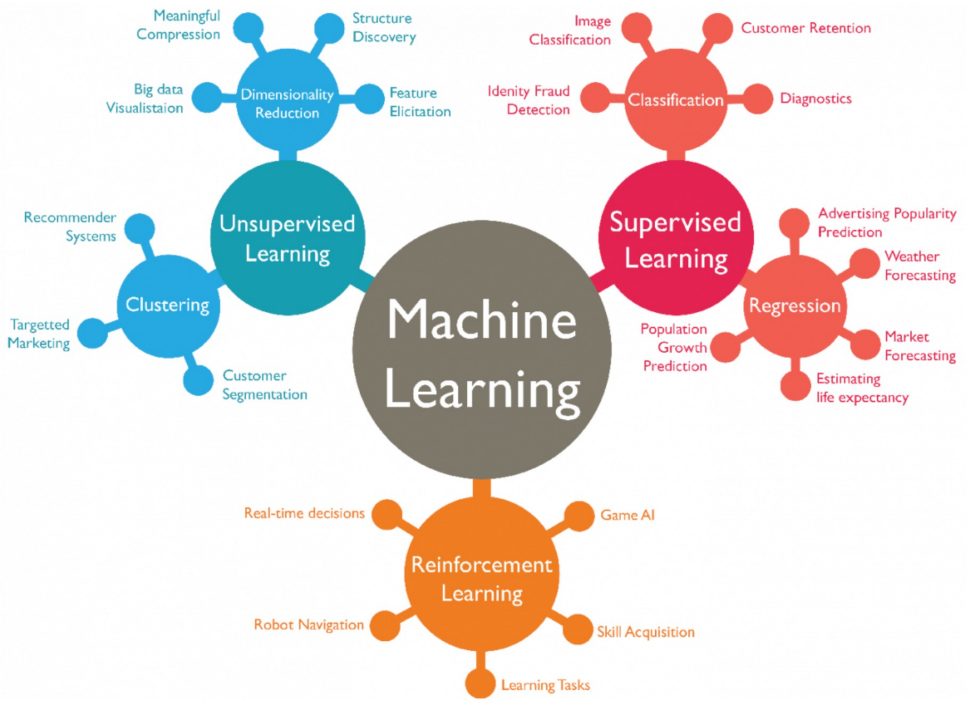
- ✓ Amount of additional investment
- ✓ Cost of maintenance
- ✓ Required processing speed
- ✓ Shortage of actual operation
- ✓ Black box-based operation
- ✓ Accuracy of solutions
- ✓ Acceptability by human operator
- ✓ Industry owners are too conservative!

## Importance of AI Technology

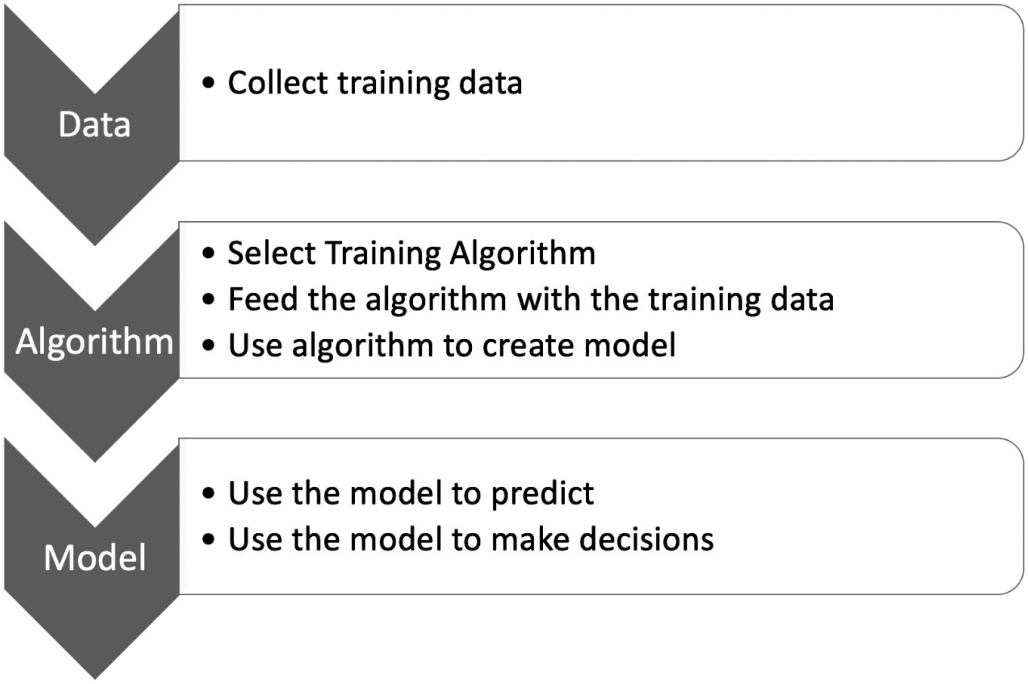
AI Technology provides extremely powerful computational devices with capability of parallel processing, learning, generalization, and fault/noise tolerating.



## Learning Methods

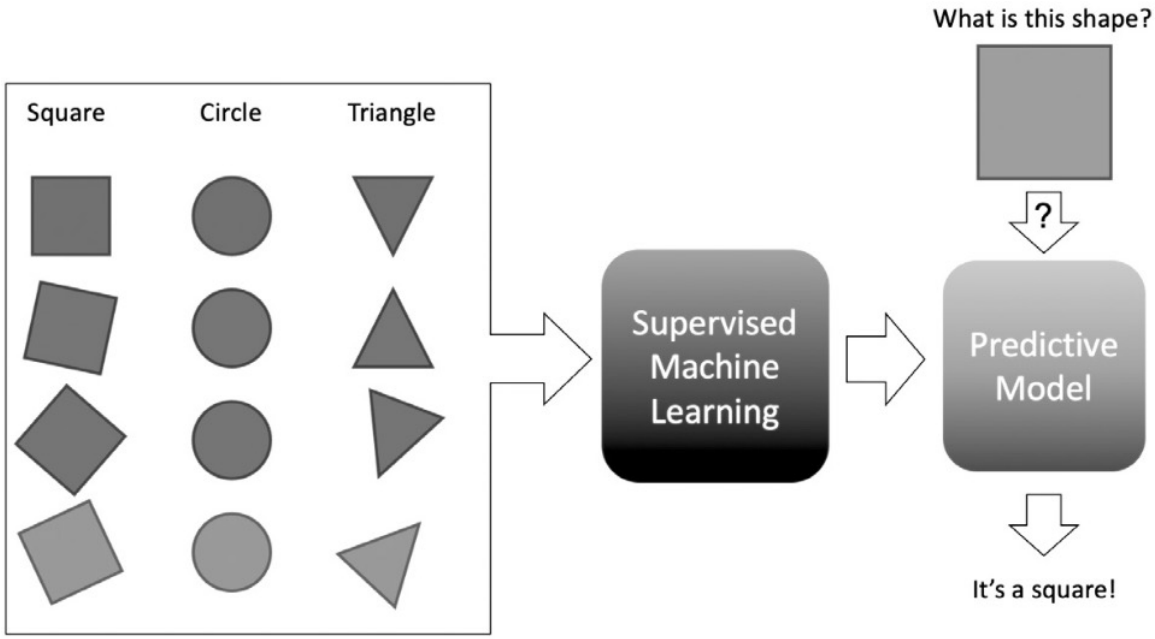


## Learning Process Steps

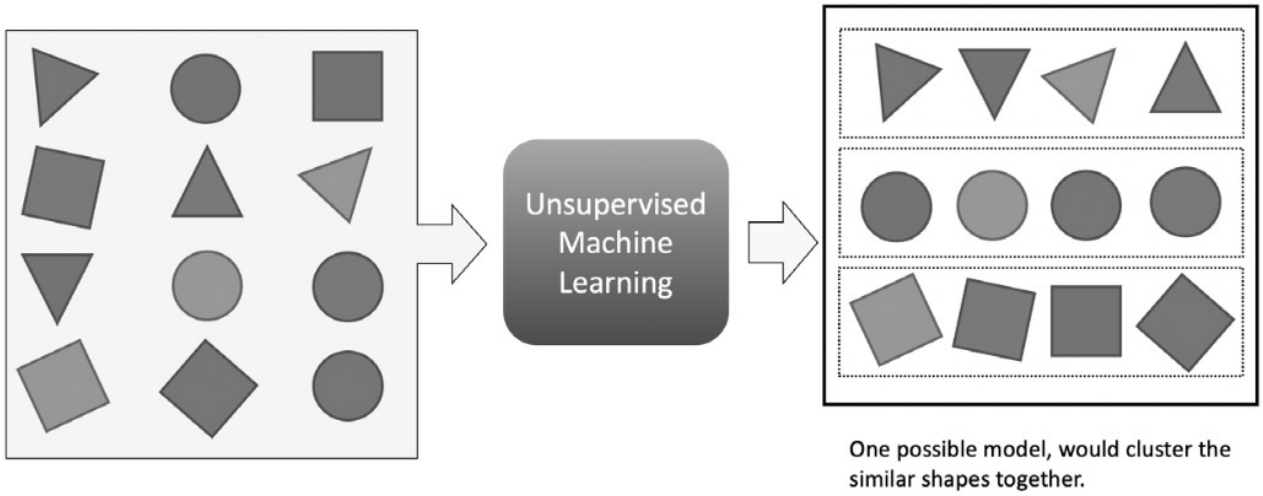





## Supervised Learning



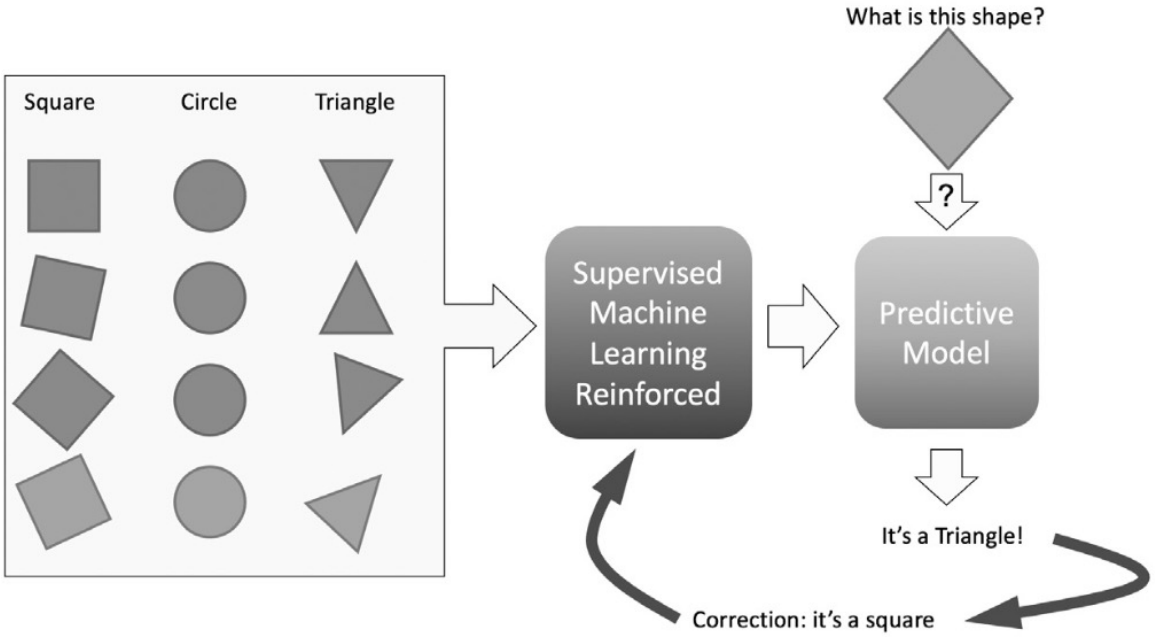
# Unsupervised Learning



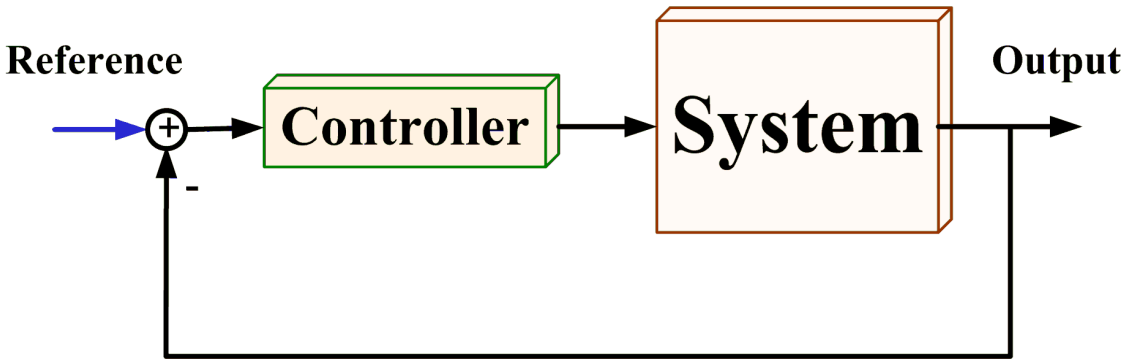

One possible model, would cluster the similar shapes together.



# Reinforcement Learning



## Control Systems

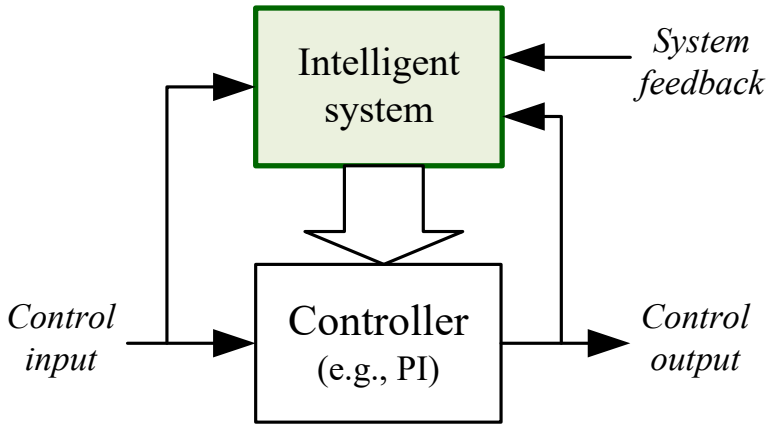





## Intelligent Control Frameworks

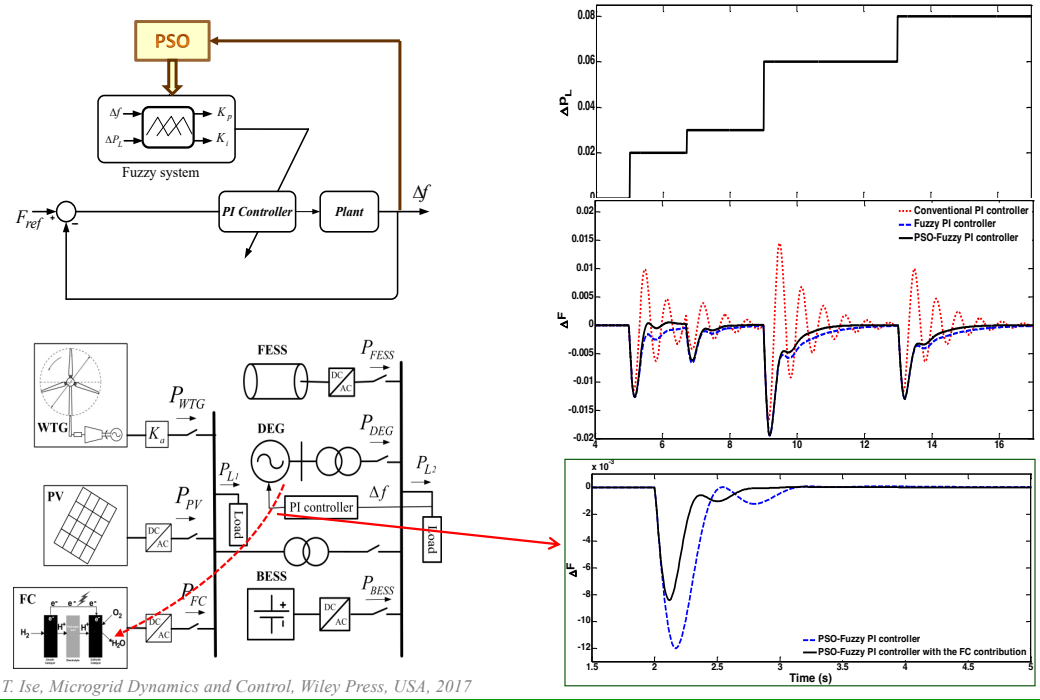
1. Tuner of Controller Parameters
2. Supplementary Controller
3. Main Controller

# 1. Tuner of Controller Parameters



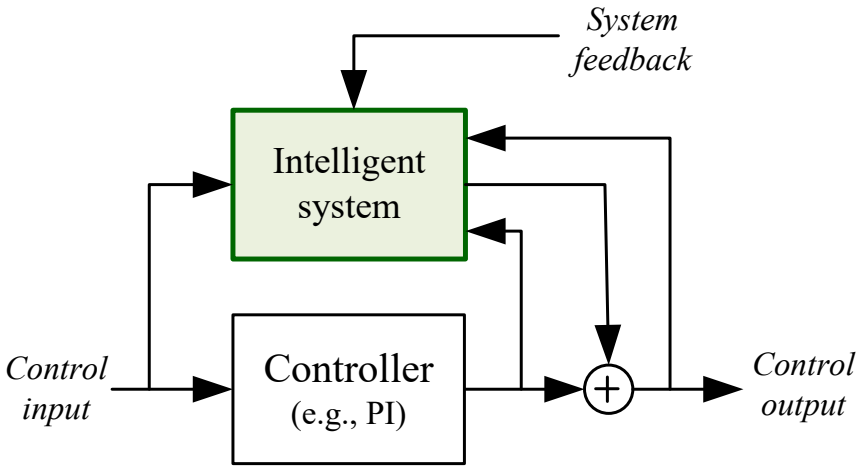



# Example 1: Fuzzy logic system as a tuning controller



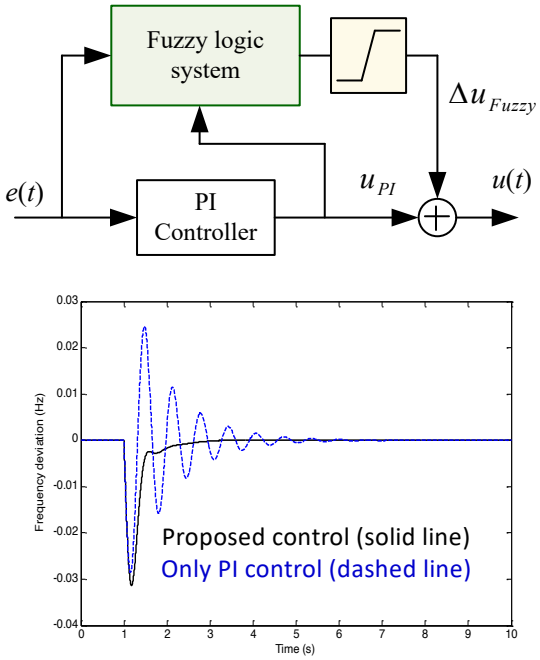

*H. Bevrani, B. Francois, T. Ise, Microgrid Dynamics and Control, Wiley Press, USA, 2017*

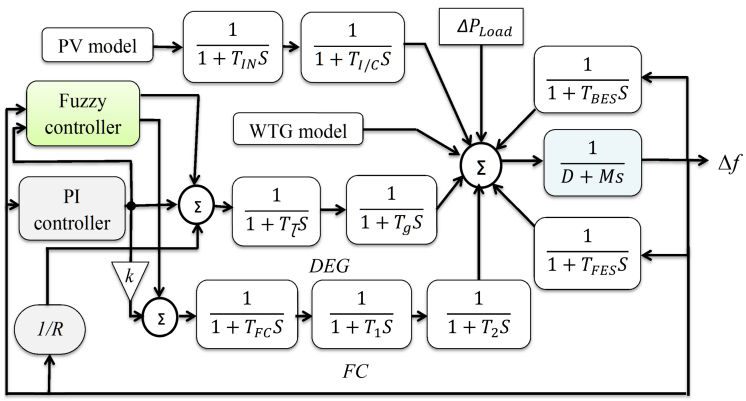
# 2. Supplementary Controller





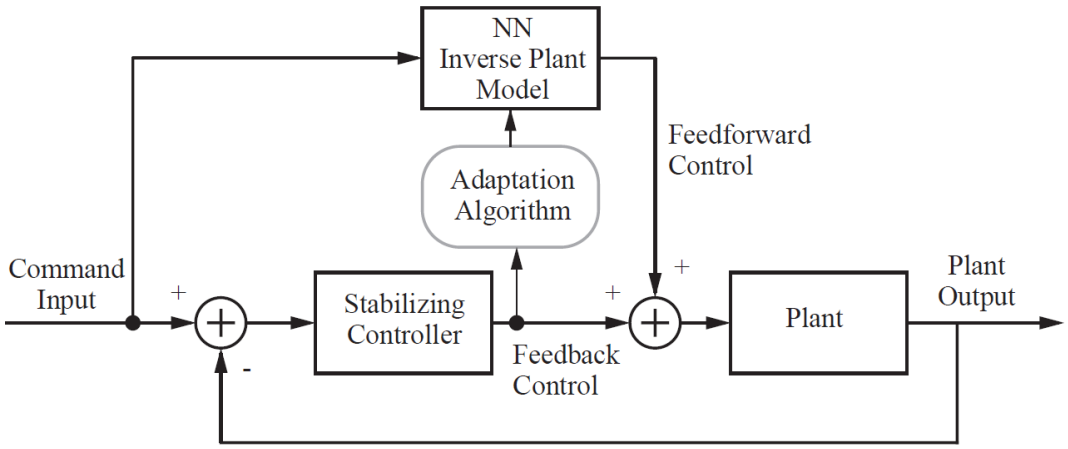

# Example 2: Fuzzy logic system as a supplementary controller



## Example 3: Robot Arm Trajectory

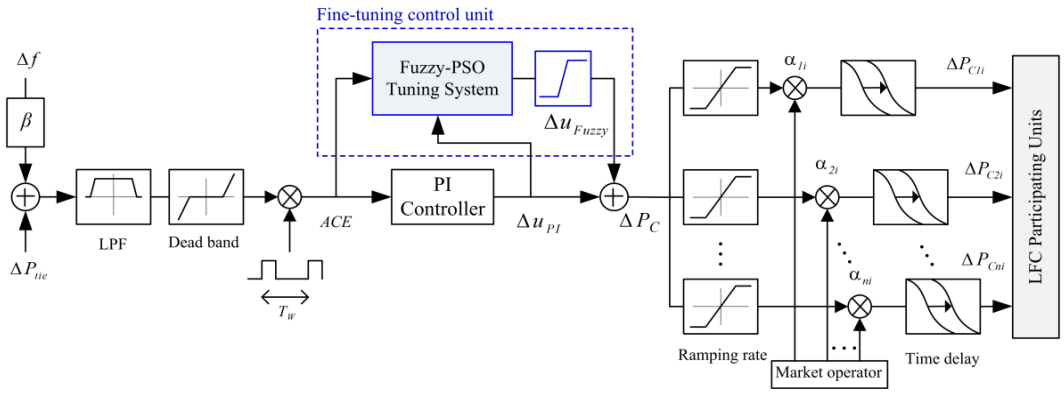
- The advantage is in starting with a stable system, even though the ANN has not been adequately trained.

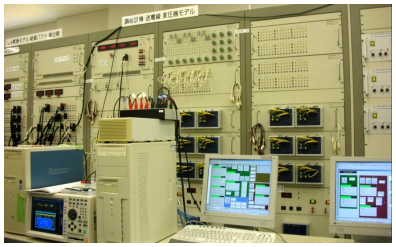



*M. T. Hagan, H. B. Demuth, **Neural Networks for Control**, American Control Conf., San Diego, CA,1999.*

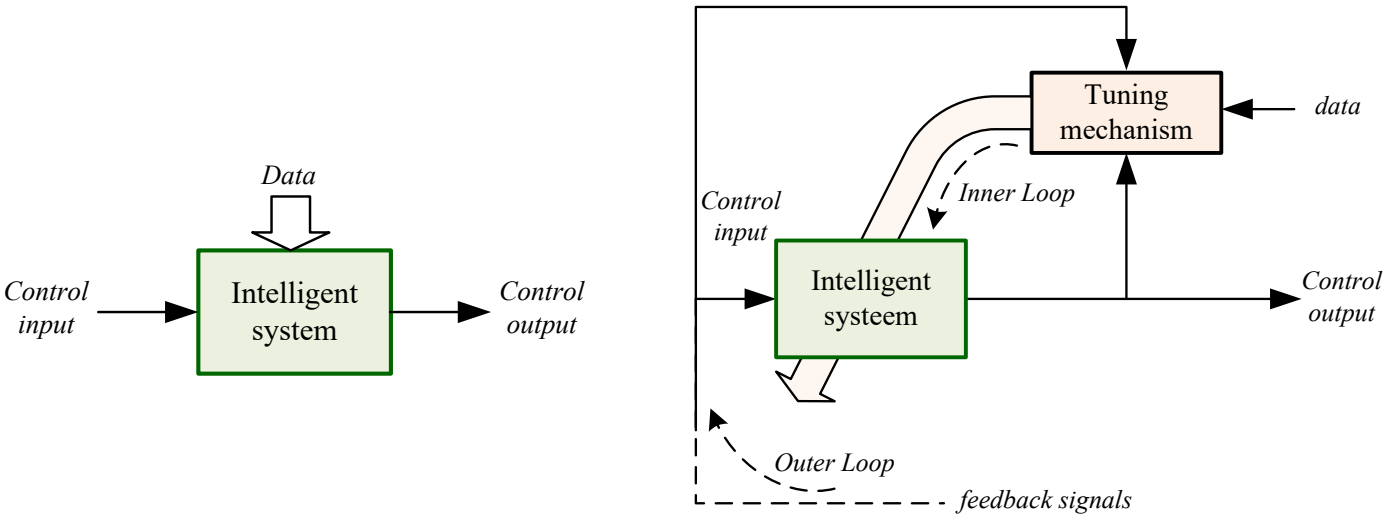


## Example 4: Intelligent AGC



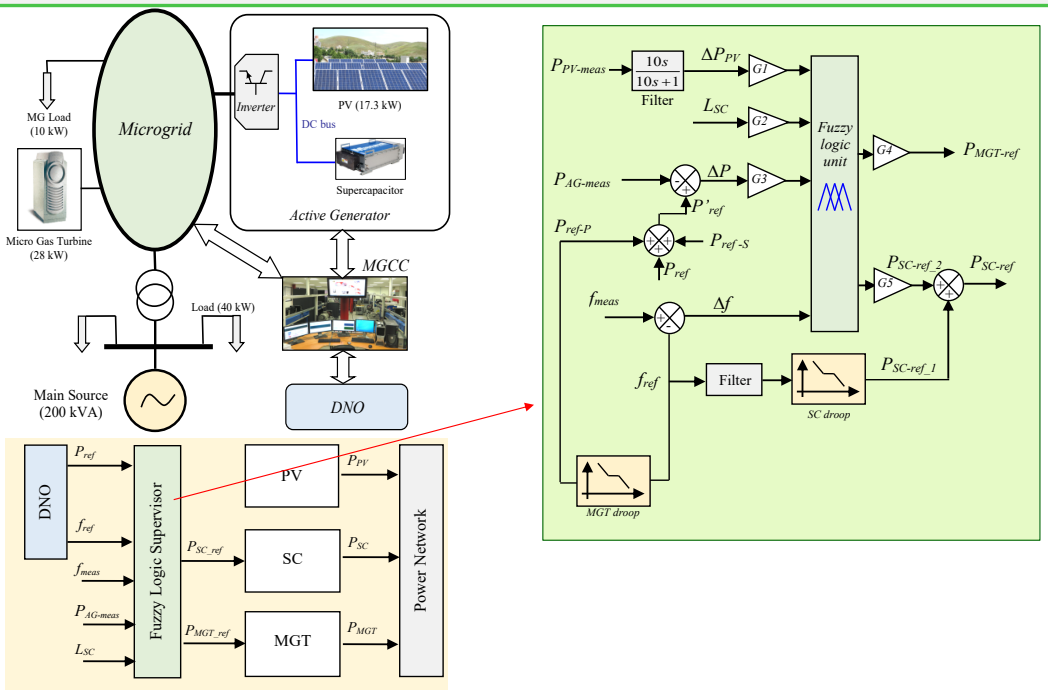



# 3. Main Controller



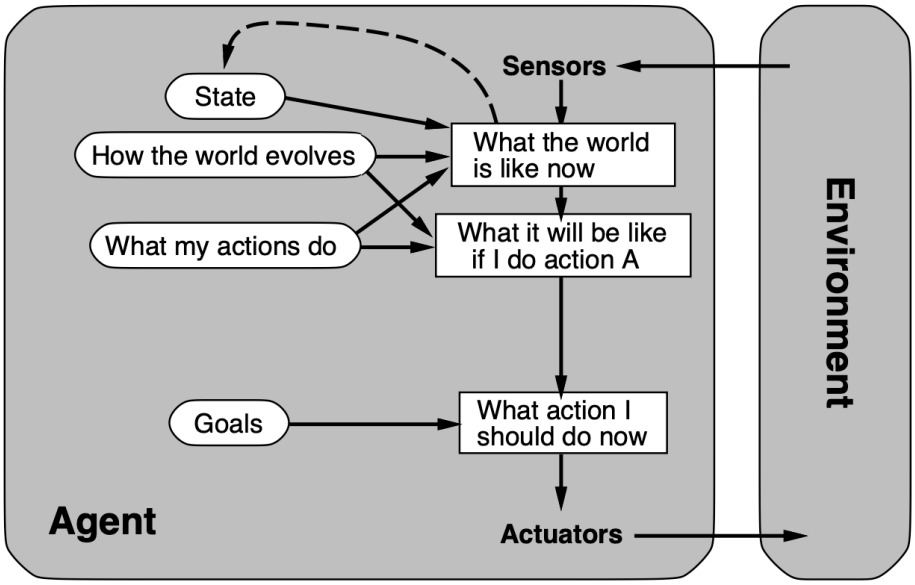



# Example 5: Fuzzy logic system as a main controller



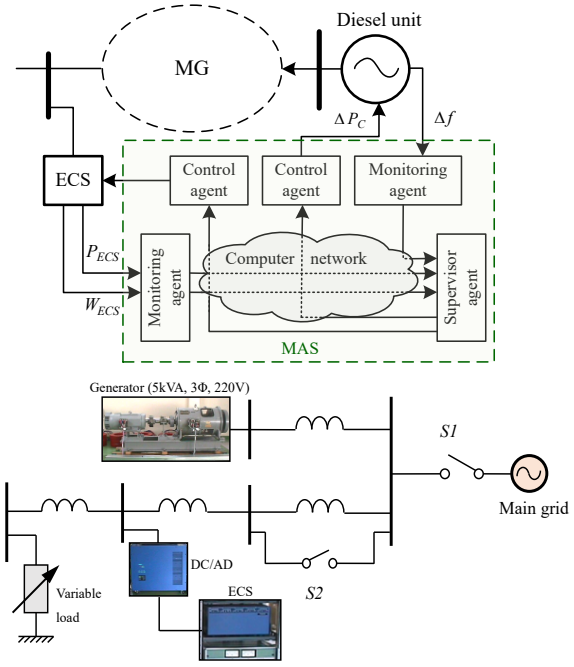

*H. Bevrani, B. Francois, T. Ise, Microgrid Dynamics and Control, Wiley Press, USA, 2017*

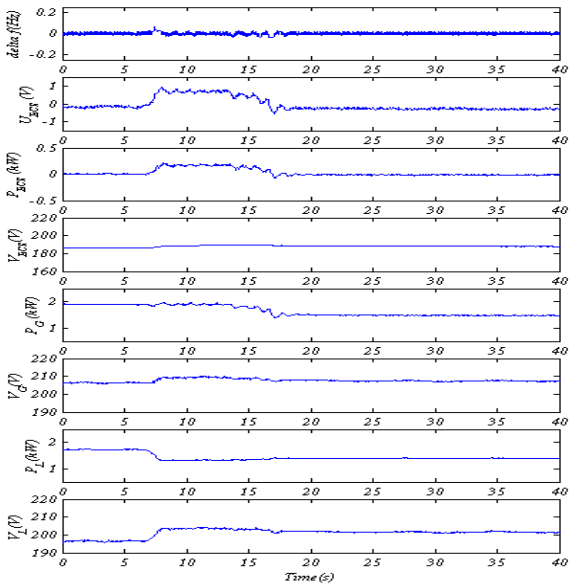
# Intelligent Agent Control (Mid-90's)






# Example 6: Multiagent-based Secondary Frequency Control

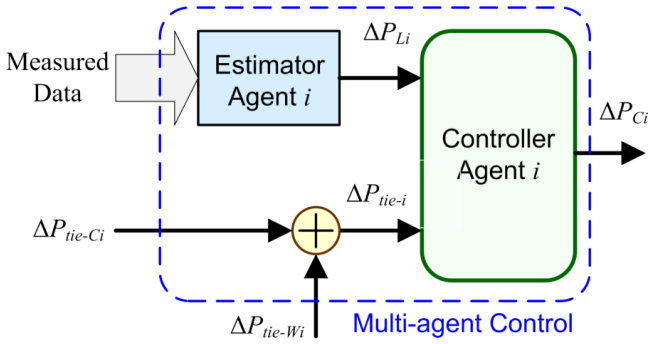


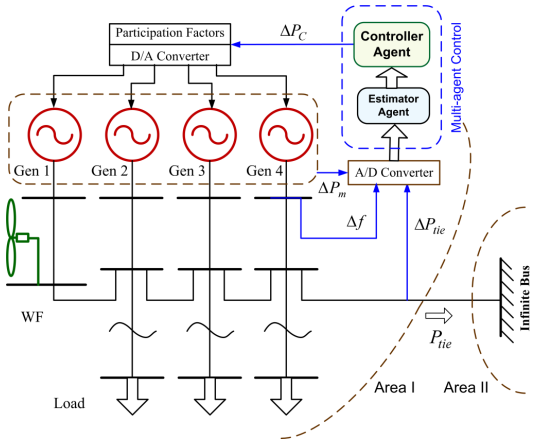




| AGC scheme | Δfave(Hz) | Δfmax(Hz) |
|---|---|---|
| Conventional | 0.0623 | 0.4771 |
| Multi-agent | 0.0085 | 0.0609 |

*H. Bevrani, T. Hiyama, intelligent Automatic Generation Control, CRC Press, USA, 2011*

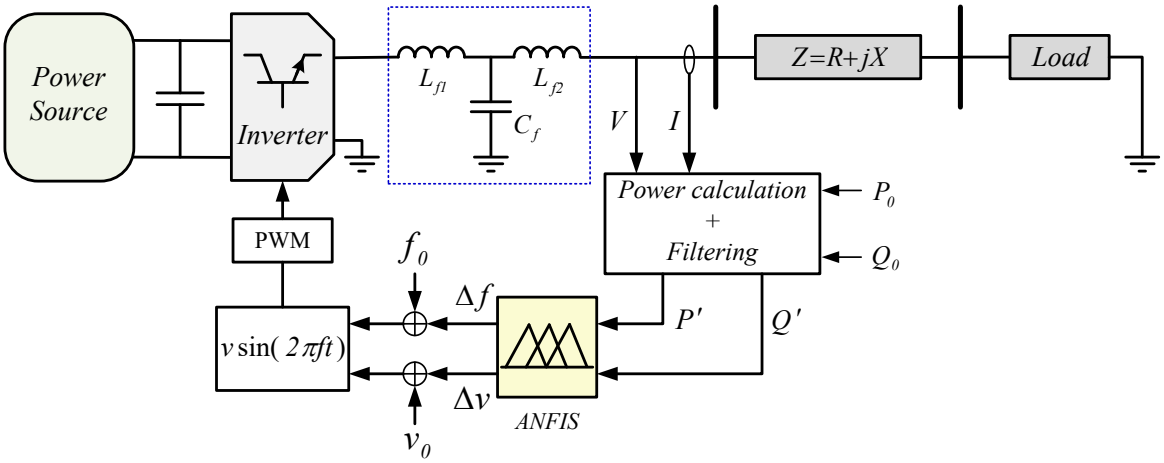
# Example 7: Intelligent AGC






# Example 8: Neuro-Fuzzy based Voltage/Frequency Control




*H. Bevrani, B. Francois, T. Ise, Microgrid Dynamics and Control, Wiley Press, USA, 2017*

# Thank you!