Computational Intelligence for Industrial and Environmental Applications

Vincenzo Piuri, Fabio Scotti
University of Milan

IS 2016 – 5 September 2016

Summary

1. Introduction to industrial and environmental applications
2. Computational intelligence in industrial and environmental applications
3. Intelligent monitoring and control systems design methodology
   - Computational intelligence for ***sensors***
   - Signal ***preprocessing***
   - Feature ***extraction*** and ***selection***
   - Computational intelligence for ***data fusion***
   - Computational intelligence for ***classification*** and ***quality measurement***
   - Computational intelligence for ***system optimization***
4. Conclusions

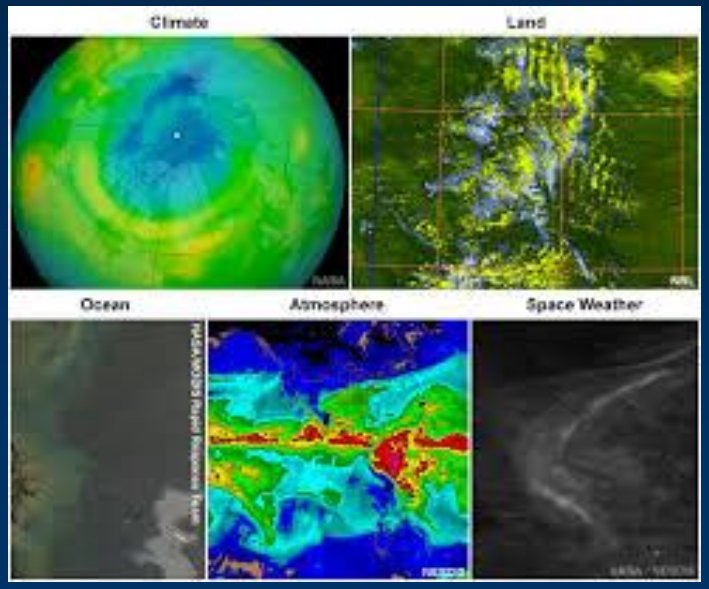
Industrial Applications

Manufacturing Process

Quality Control

Environmental Applications

Monitoring Systems



Industrial and Environmental Analysis

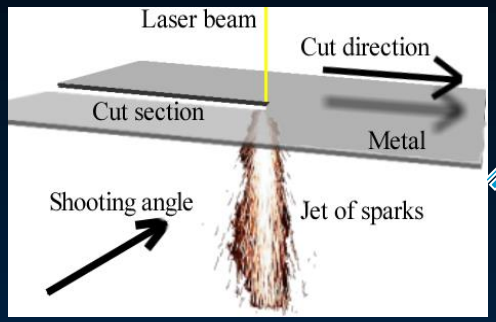
- Boring,
  repetitive,
  exhausting and
  dangerous
  for human operators

- A computer does not get tired

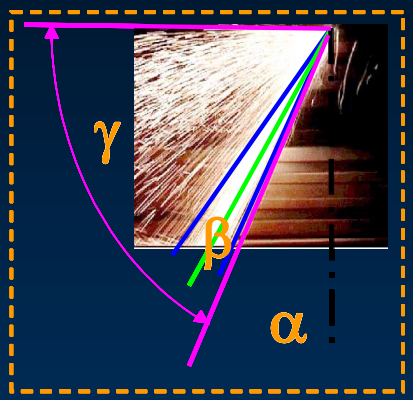
Automatic Monitoring and Control Systems

- Accurate
- Often non invasive
- Standardized

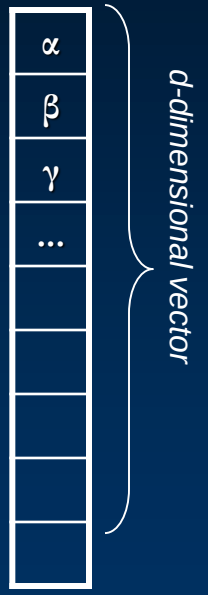
Automatic Monitoring and Control Systems



Signal and image acquisition and preprocessing



Feature extraction and measurement



Analysis

QUALITY MEASUREMENT

Technologies for Monitoring and Control Systems

- Sensors and measurement systems
- Signal processing
- Image processing
- Sensor data fusion
- Classification and clustering

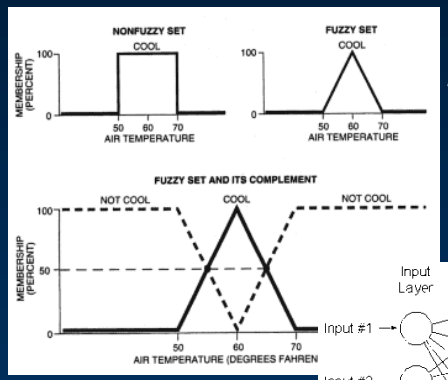
Conventional Algorithmic Techniques

- ⬆ Computational complexity

- ⬇ Require a model
- ⬇ Not able to learn from experience

Computational Intelligence in Monitoring and Control Systems

Fuzzy Systems

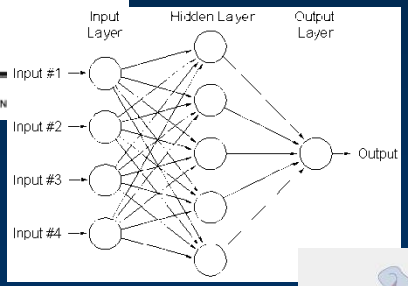


Intelligent

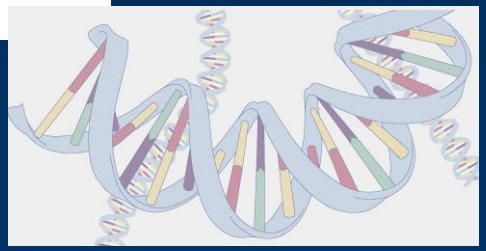
Smarter

Adaptive

Neural Networks

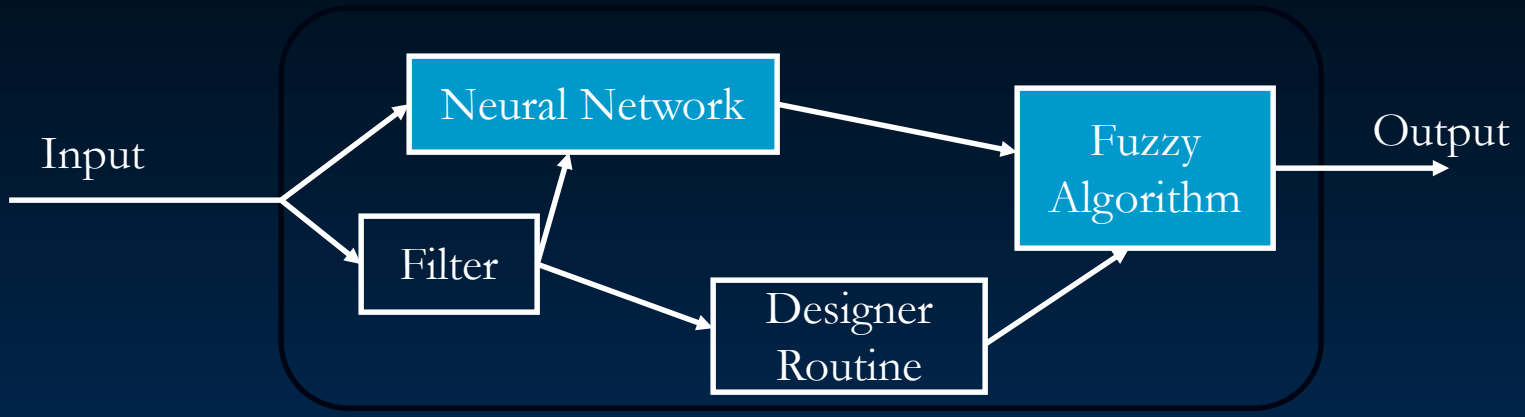


Evolvable



Evolutionary Computing

Composite Systems



TRADITIONAL PARADIGMS +
COMPUTATIONAL INTELLIGENCE =

+ MORE DESIGN DEGREES OF FREEDOM
+ ACCURACY
+ PERFORMACE

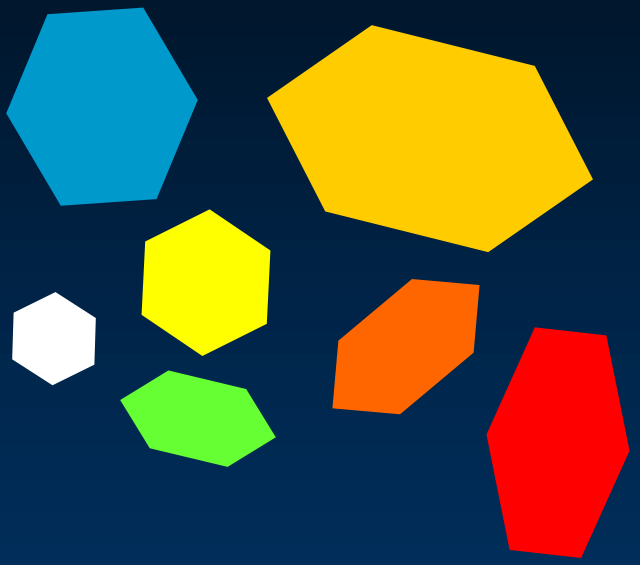
The Main Problem

Tackling *very* different aspects at the same time:

- instrumentation and measurement systems
- image and signal processing.
- feature extraction
- sensor fusion
- system modeling
- data analysis
- classification

How to Deal with Heterogeneous Aspects?

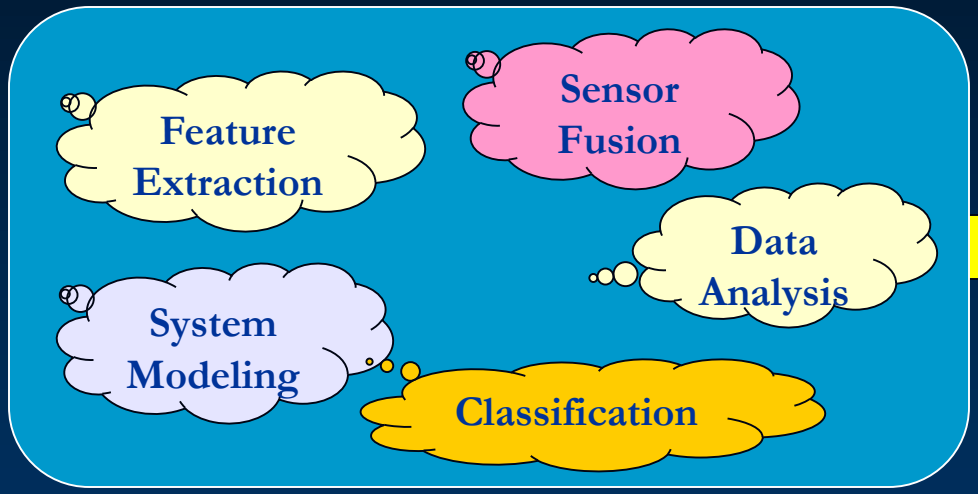
Nowadays:



- Separate issues
- Module-oriented solutions
- Ad-hoc solutions

- Limited optimization
- Limited reusability
- Limited integrability

A Comprehensive Design Approach



Design methodology

Manufacturing Applications

Design Methodology for Intelligent Monitoring and Control Systems

A. Signal and image acquisition
B. Signal and image preprocessing
C. Feature extraction and selection
D. Data fusion
E. Classification and quality measurement
F. Control
G. System optimization

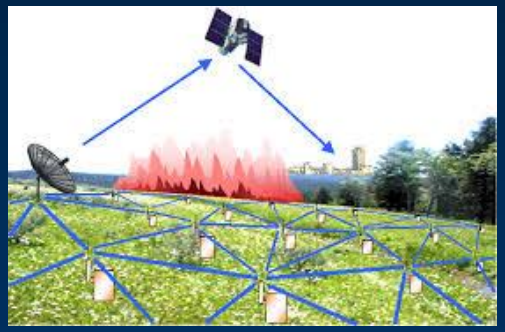
A. Signal and Image Acquisition

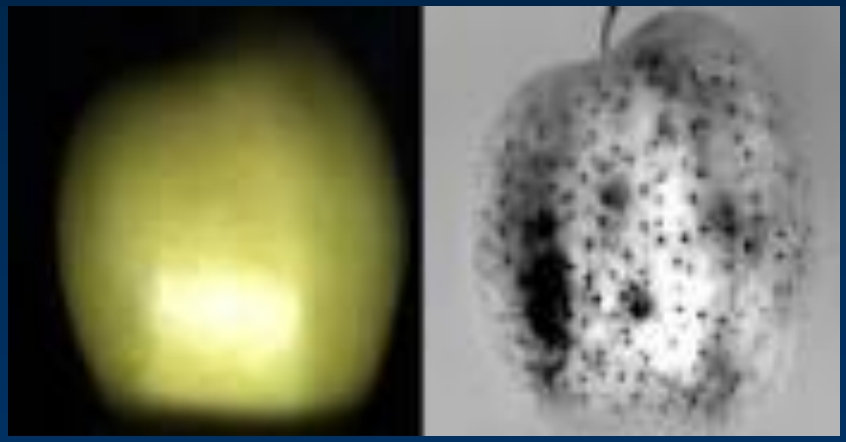
- Conventional techniques:
  - sensor enhancement
  - sensor linearization
  - sensor diagnosis
  - sensor calibration

- Computational intelligence approaches
  - self-calibration
  - non-linearities reduction
  - Error and faults detection

B. Signal Preprocessing

- *Signal preprocessing:*
  enhancing the signals and correcting the errors
- *Features processing:*
  extract from the input signals a set of features





⇨ Neural and fuzzy techniques
for signal and feature processing:

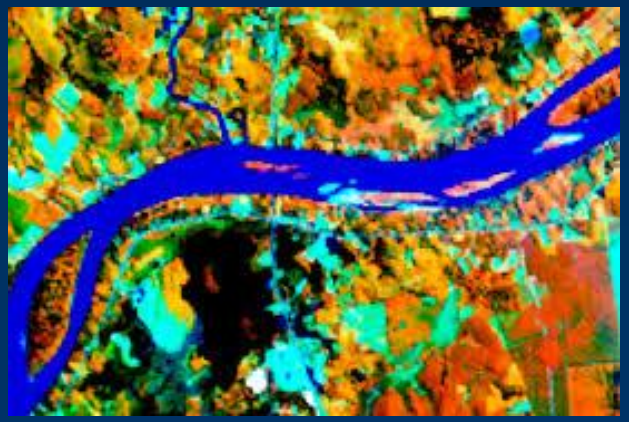
- Adaptivity, intelligence, learning from examples, ...

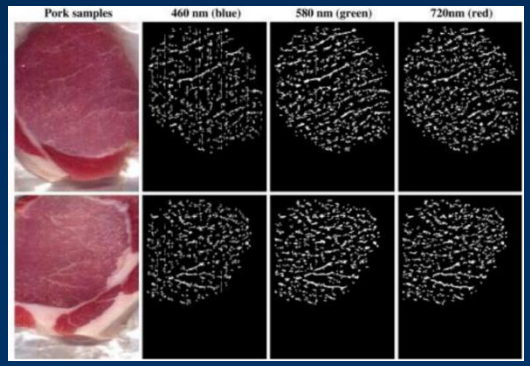
C. Feature Extraction and Selectiton

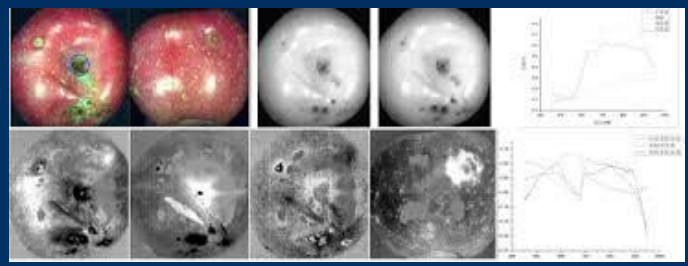
- How many features?

	Complexity	Accuracy
Few features	↓	↓
Many features	↑	↑ ↓

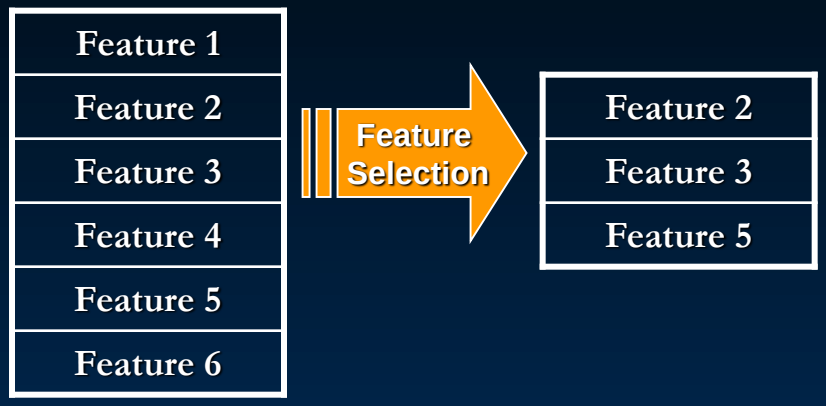
?!?

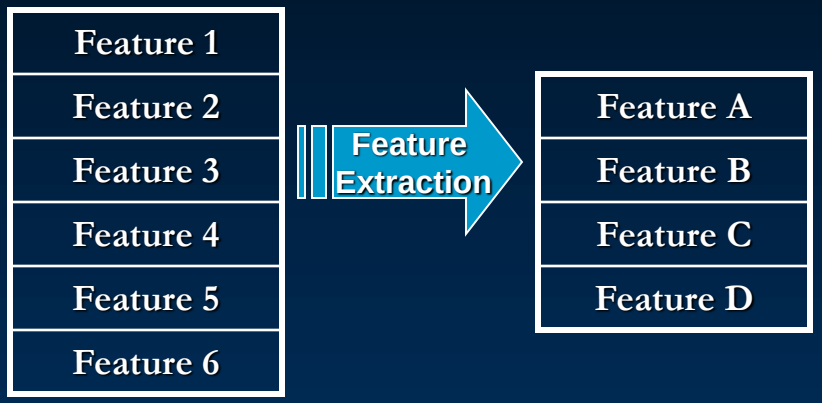


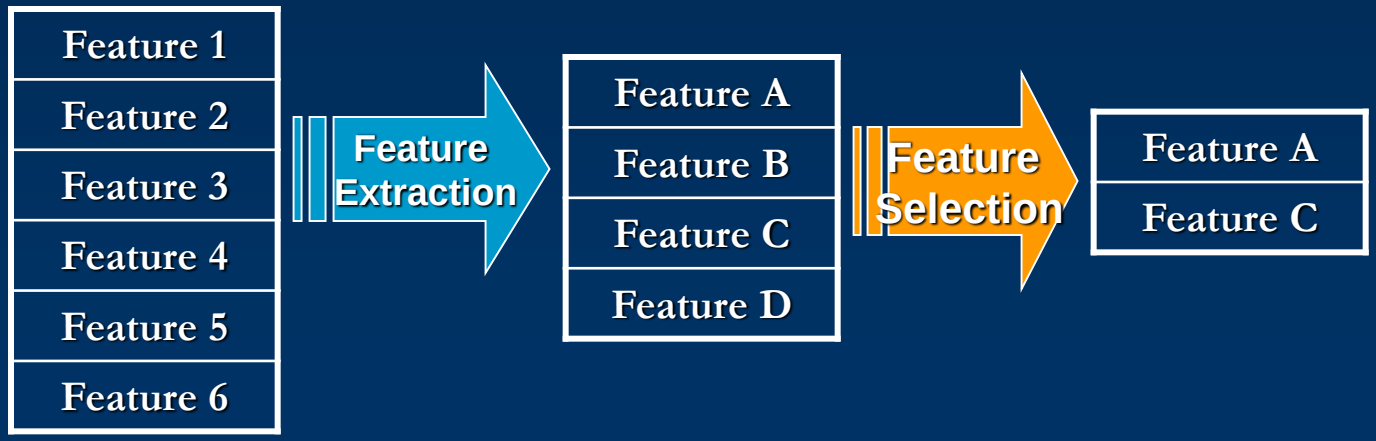




Selection, Extraction, Selection and Extraction





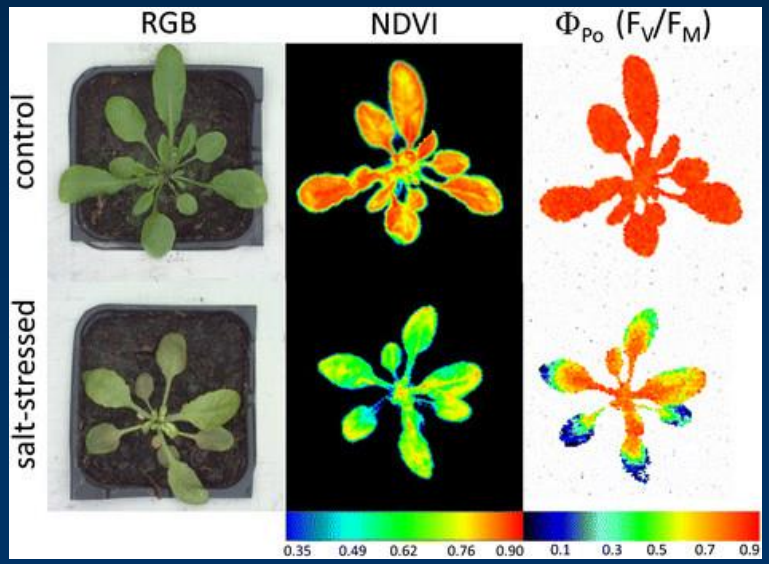


Feature Extraction Algorithms

- Principal Component Analysis
- Linear Discriminat Analysis
- Independent Component Analysis
- Kernel PCA
- PCA network
- Nonlinear PCA
- Feed-Forward Neural Networks
- Nonlinear autoassociative network
- Multidimensional Scaling
- Self-Organizing Map (MAP)

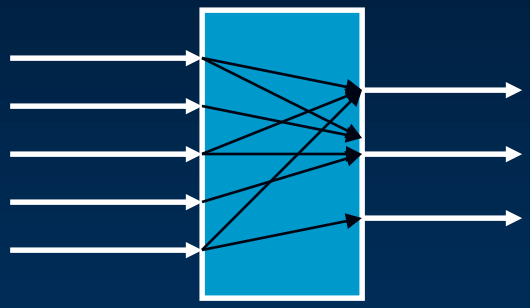
Feature Selection Algorithms

- Exhaustive Search
- Branch and Bound
- Sequential Forward Selection
- Sequential Backward Selection
- Sequential Floating Search methods

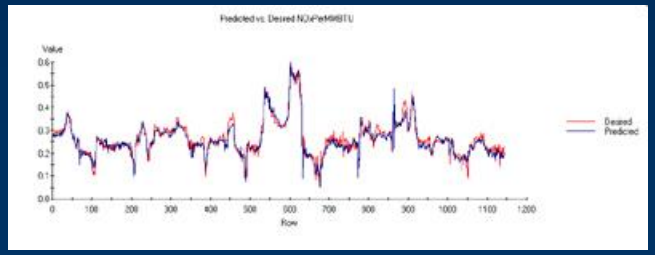


D. Computational Intelligence for Data Fusion

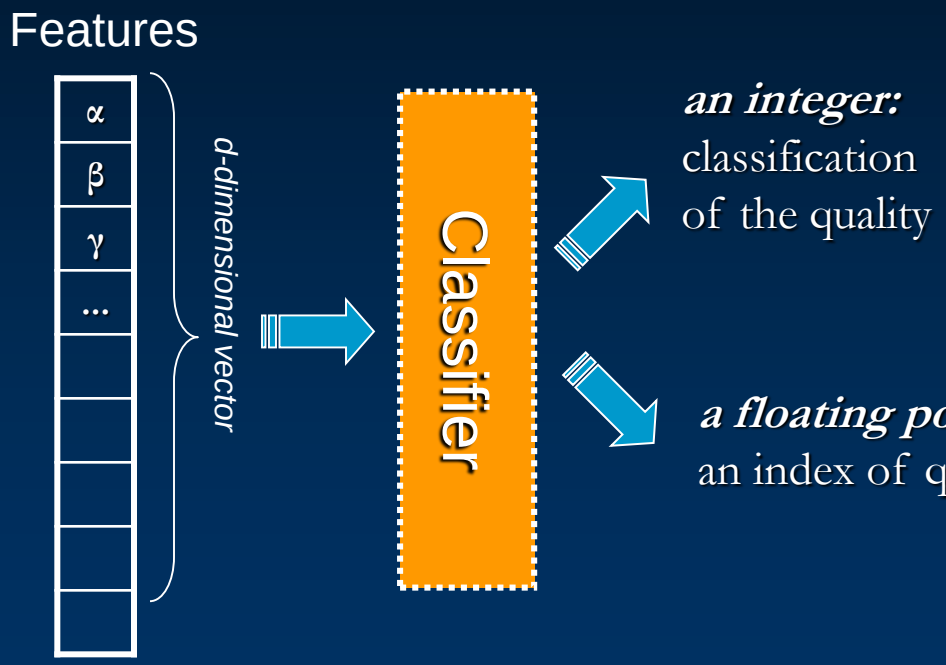
- **Fuse the available features/sensors signals to obtain more meaningful information**
  - *Sensor fusion*

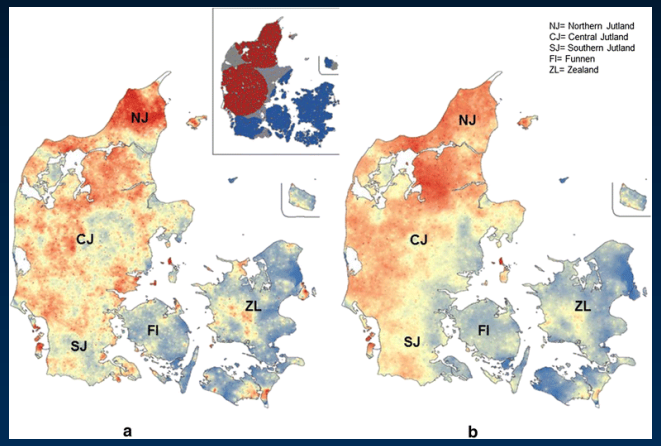


  - *Virtual sensors*



E. Computational Intelligence for Classification, Clustering and Pattern Recognition





F. Control

- Neural-based control to capture the desired behavior through examples

- Fuzzy-based control to capture non-crisp definition of quantities

G. System Optimization

- System parameters difficult to fix
- Very often *trial-and-error approaches*
- *Evolutionary computation* techniques
  can solve this optimization task

Conclusions

- Monitoring and control are critical for advanced manufacturing processes and for maintaining an economical leading role
- Monitoring is critical for advanced environmental applications and ensure a sustainable environment
- A comprehensive design methodology should deal with all aspects in an integrated way
- Computational intelligence offer additional opportunities for adaptable and evolvable systems

Thanks!

Thanks!

Thanks!