Detección de anomalías basadas en sensores virtuales y en técnicas one-class

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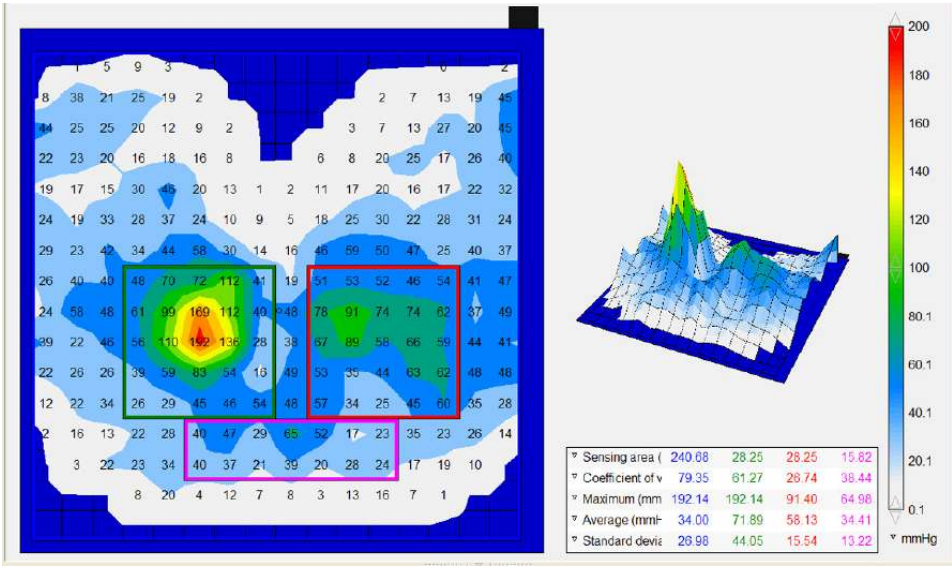
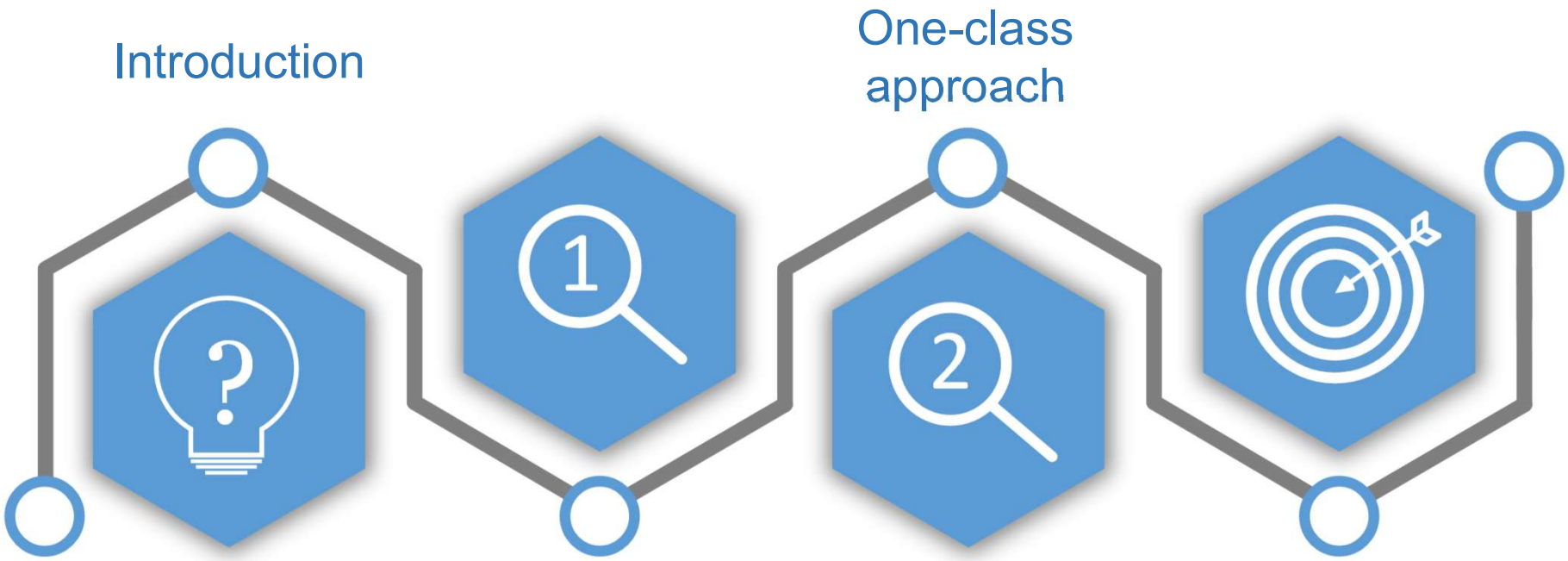
Context

Context

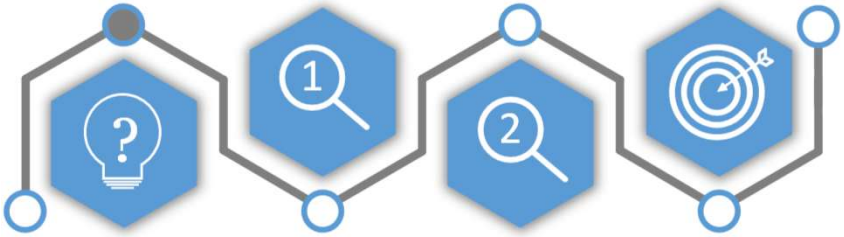
2014 – 2016. Centro Tecnológico de Automoción de Galicia CTAG. O Porriño.



General Index

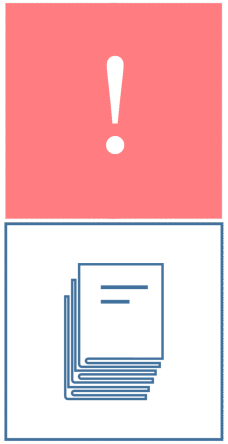


Introduction



The anomaly detection problem

- **Global context.**
  - Technological advances.
  - Economic globalization.
  - Importance of systems optimization.
  - Environmental impact.
  - Safety and quality standards.



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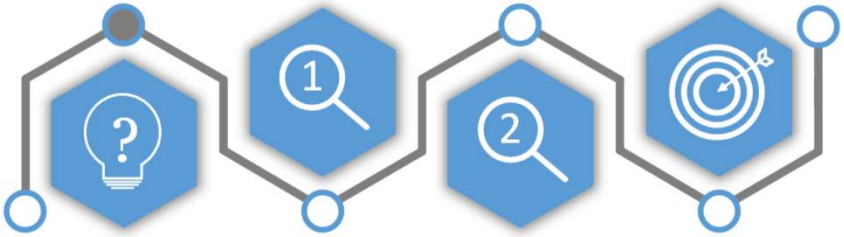
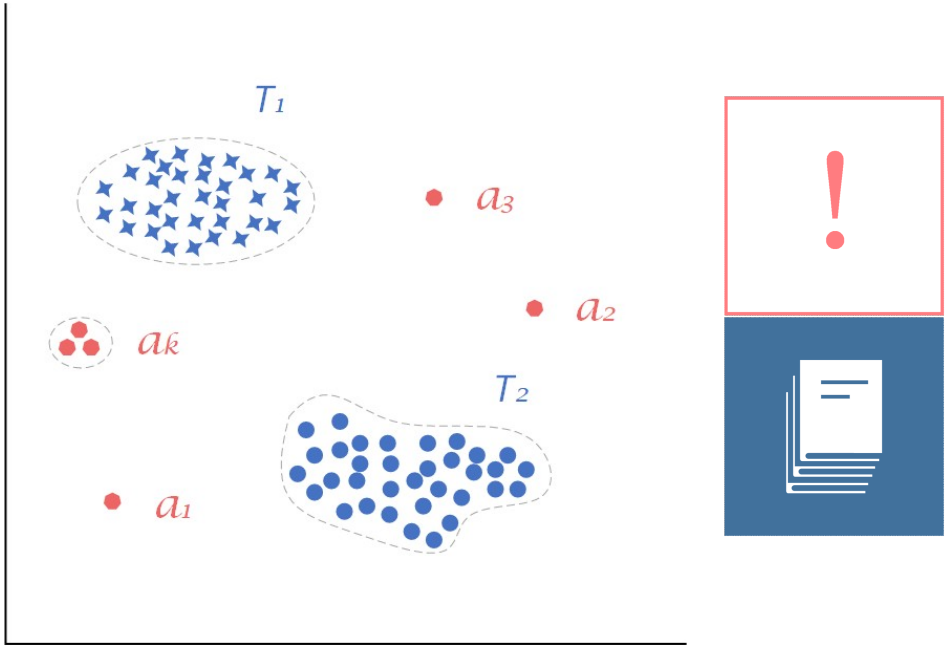


The anomaly detection problem

- **Definition.**
  - Data patterns that conform unexpected behavior.



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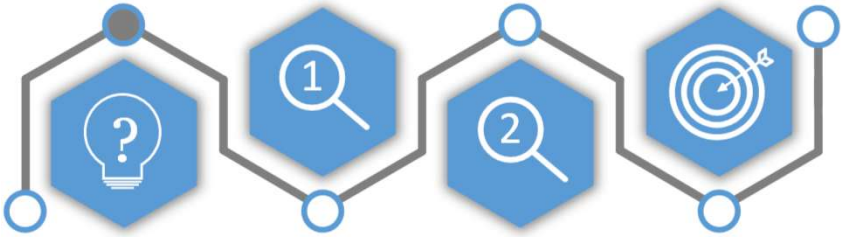
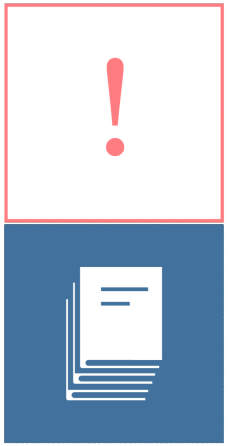


The anomaly detection problem

- Definition.
  - Data patterns that conform unexpected behavior.
- **Issues of anomaly detection.**
  - Lack of prior knowledge.
  - Unfeasibility of inducing known anomalies.
  - Noise appearance.
  - Difficulty of establishing limits between classes.



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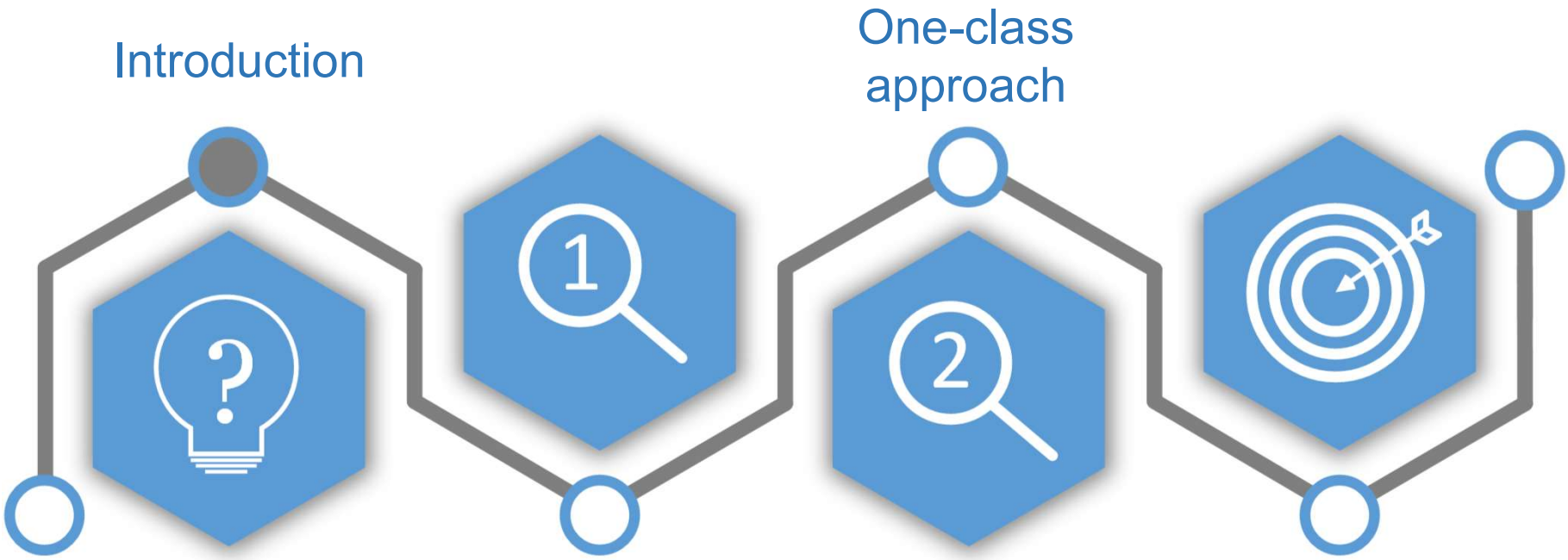
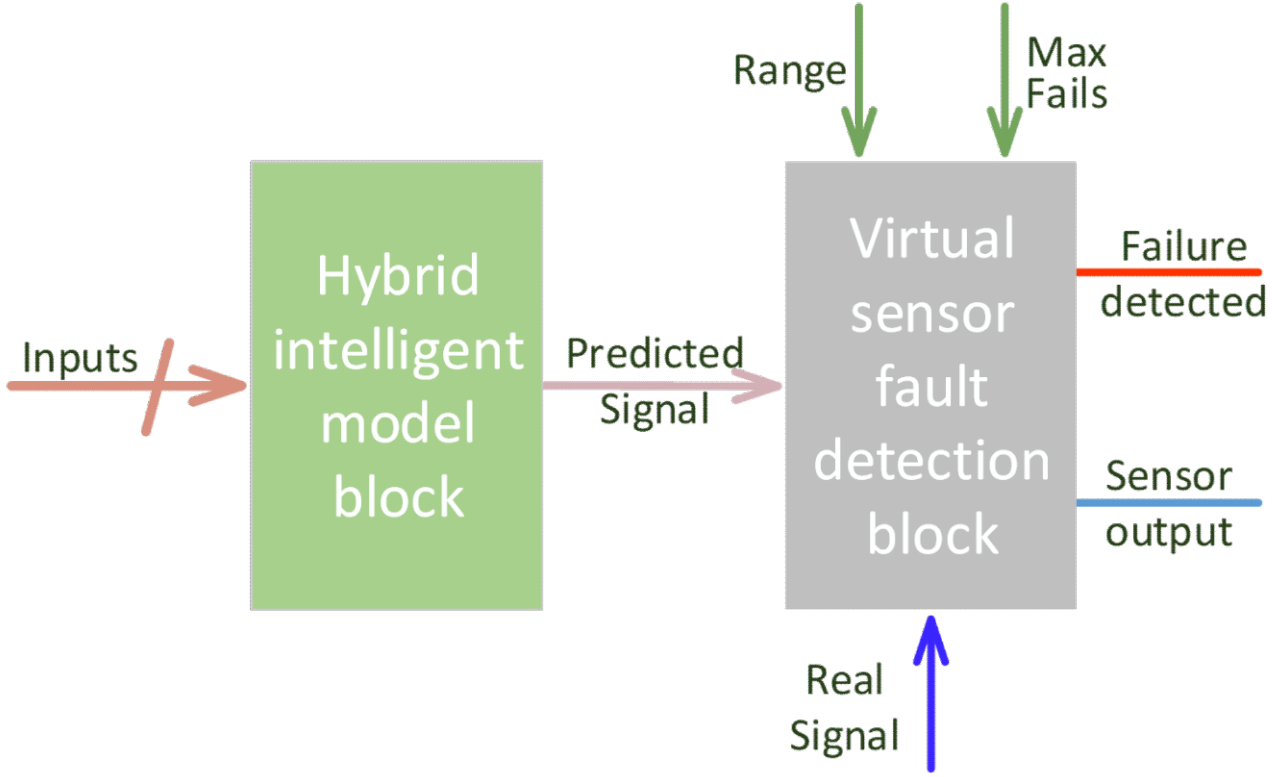
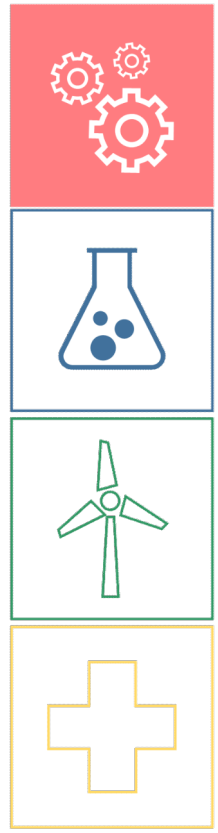


Virtual sensor approach

Fundamentals

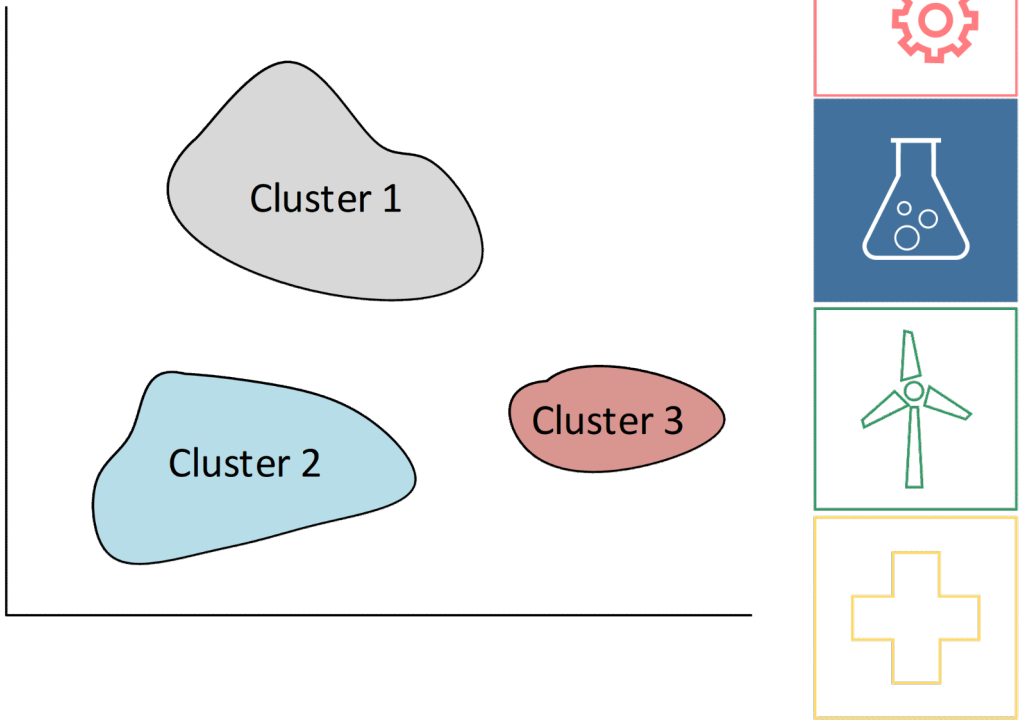




Virtual sensor approach

Implementation

- Hybrid intelligent model block.
  - **Modeling process.**



Virtual sensor approach

Implementation

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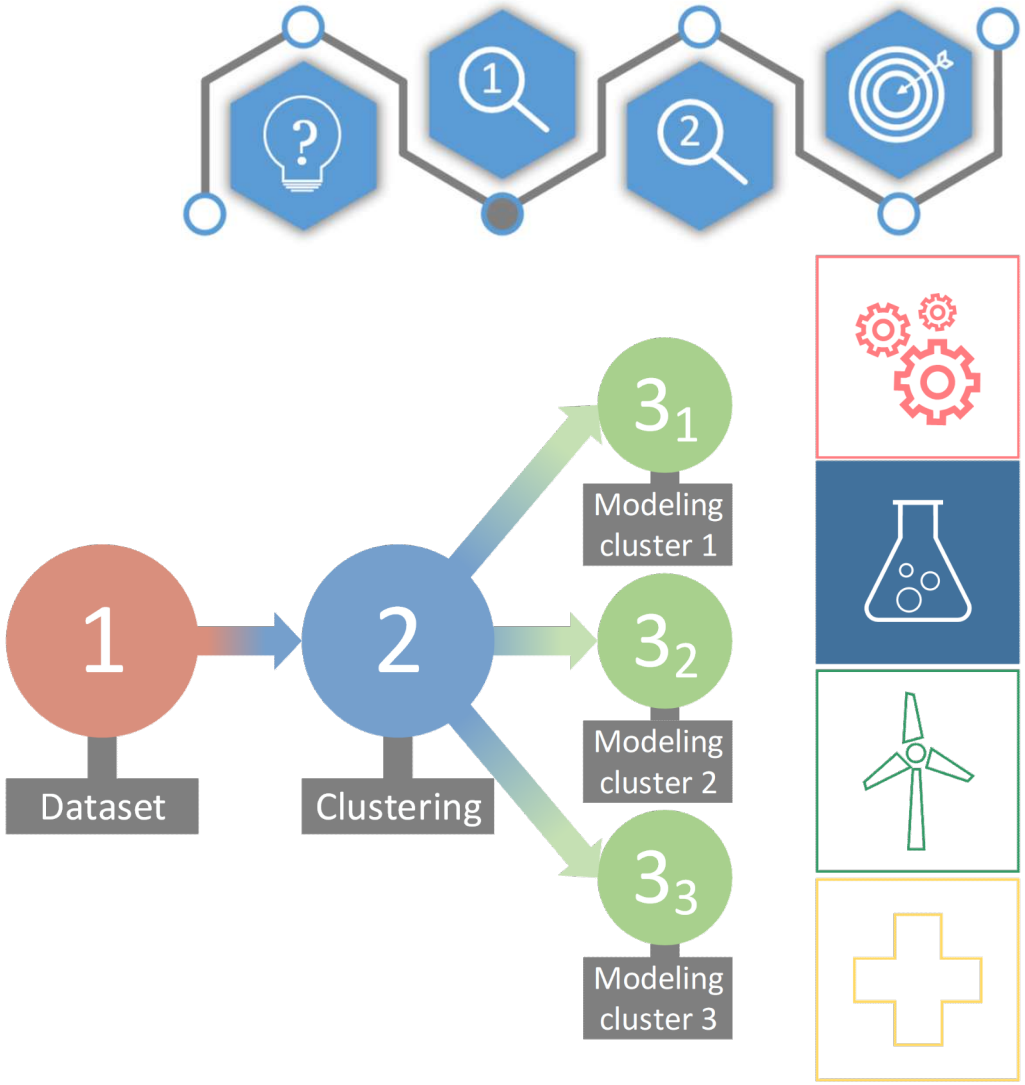
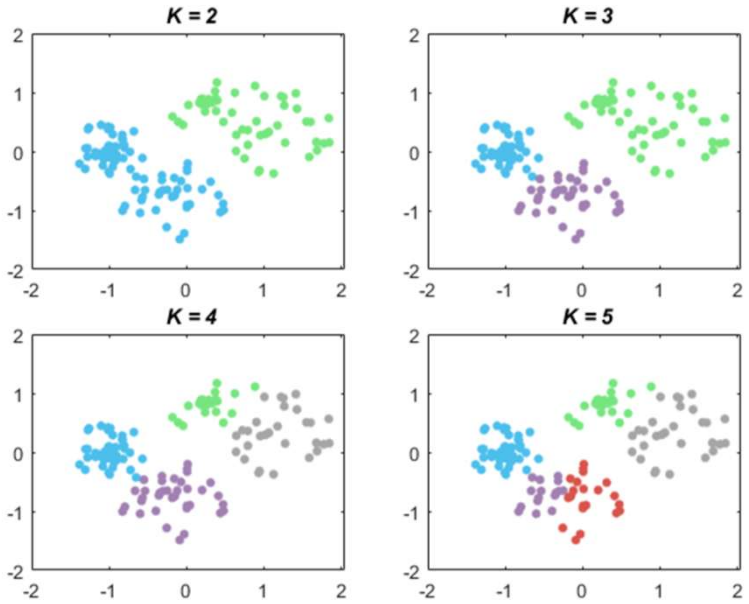


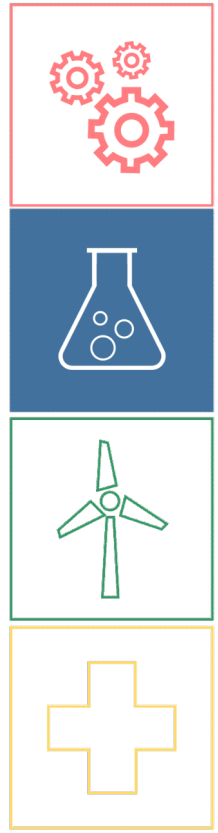
Virtual sensor approach

Implementation

- Hybrid intelligent model block.
  - Modeling process.
    - v Clustering.
      - ▫ **Kmeans.**

$$E(c_1, ..., c_K) = \sum_{i=1}^{N} \sum_{j=1}^{K} I(x_i \in G_j) \, ||x_i - c_j||$$

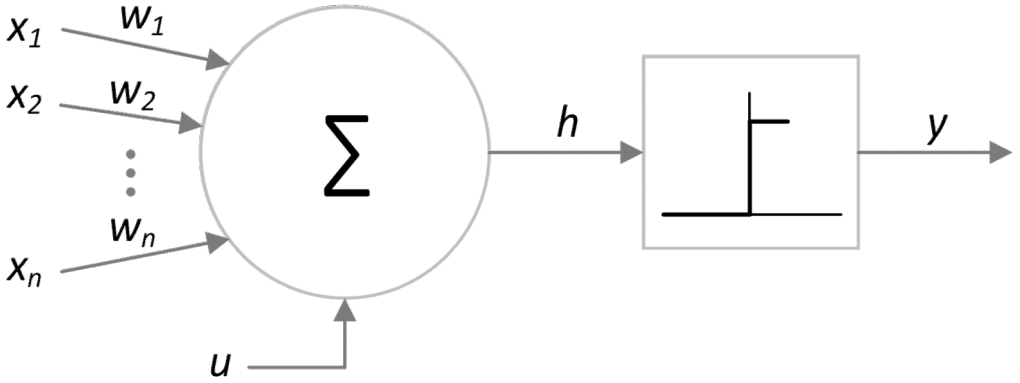


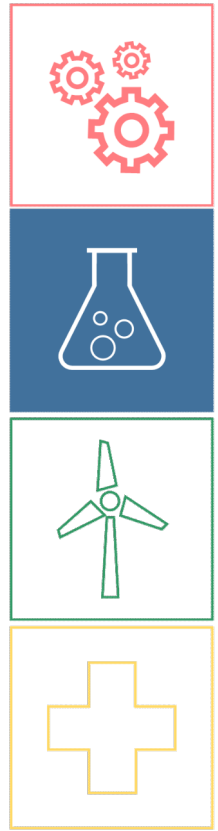


Virtual sensor approach

Implementation

- Hybrid intelligent model block.
  - Modeling process.
    - > Clustering.
    - v Modeling.
      - **MLP.**





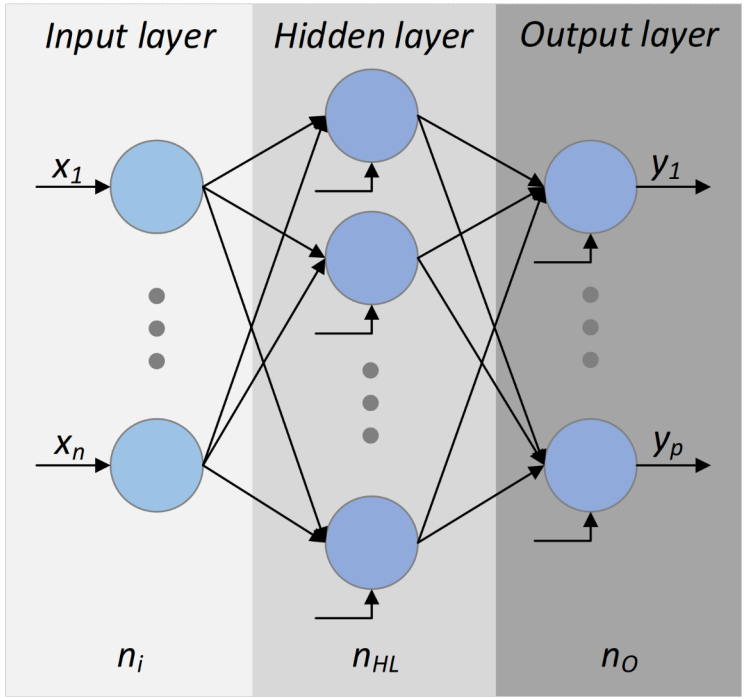
Virtual sensor approach

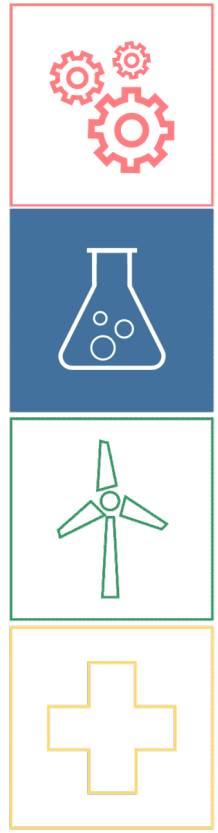
Implementation

- Hybrid intelligent model block.
  - Modeling process.
    - > Clustering.
    - v Modeling.
      - **MLP.**

$$h = f_{\theta 1}\left(xW_1 - u_1\right)$$

$$y = f_{\theta 2}\left(hW_2 - u_2\right)$$



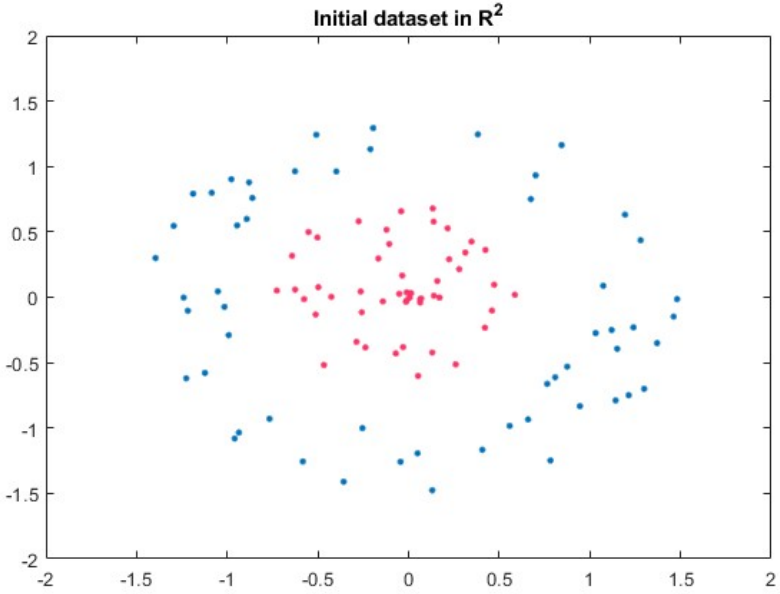


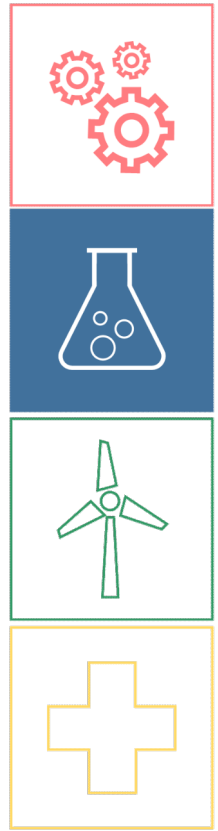
Virtual sensor approach

Implementation

- Hybrid intelligent model block.
  - Modeling process.
    - > Clustering.
    - v Modeling.
      - MLP.
      - **LS SVR.**

$$y = f(X) = w^T \delta(x) + b$$





Virtual sensor approach

Implementation

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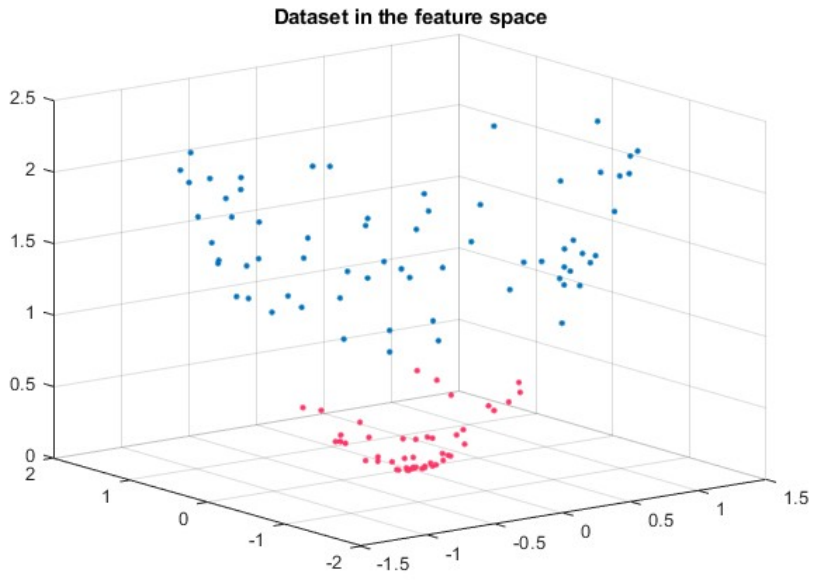
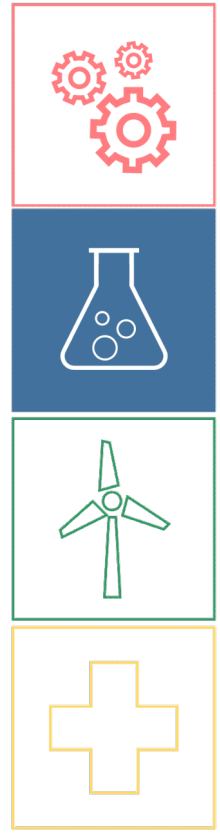
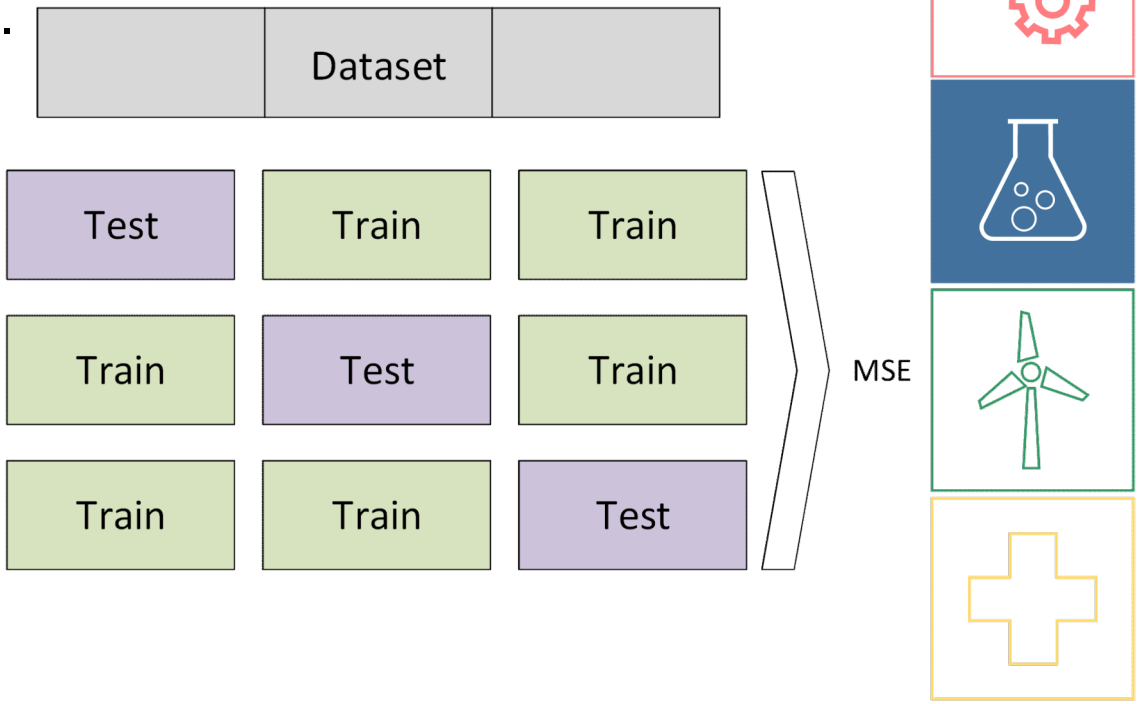




Virtual sensor approach

Implementation

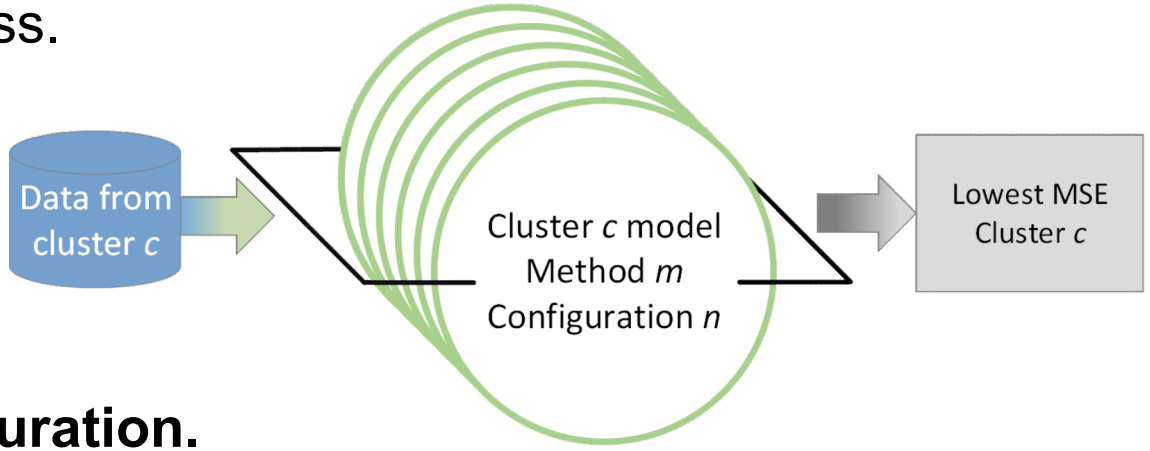
- Hybrid intelligent model block.
  - Modeling process.
    - > Clustering.
    - > Modeling.
    - > **Validation.**

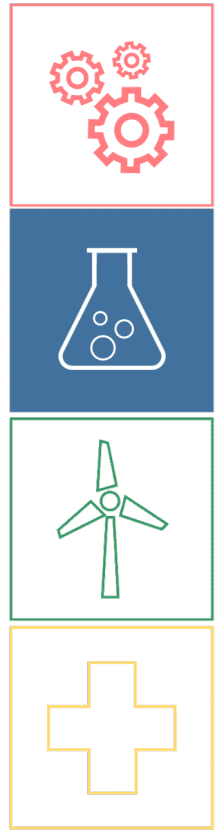


Virtual sensor approach

Implementation

- Hybrid intelligent model block.
  - Modeling process.
    - > Clustering.
    - > Modeling.
    - > Validation.
    - > **Best configuration.**





Virtual sensor approach

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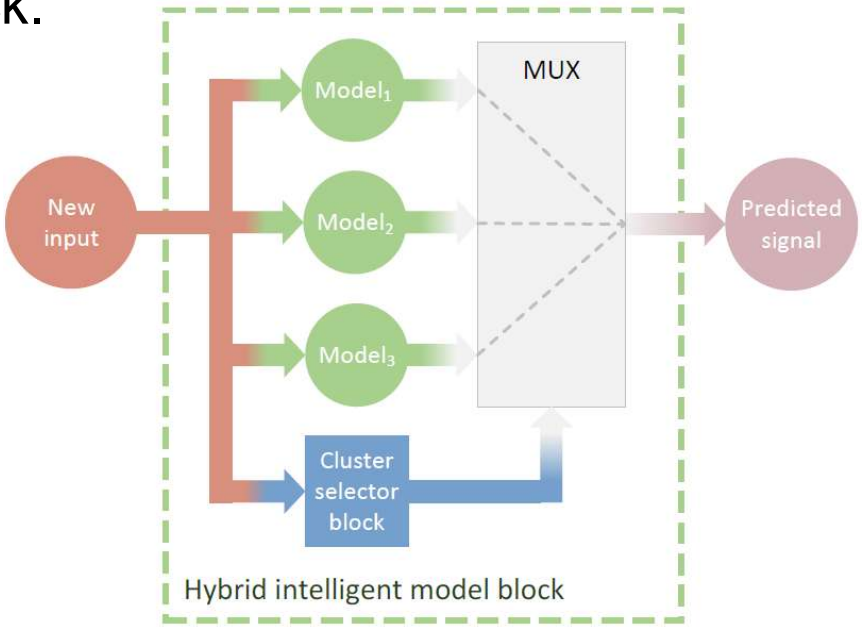
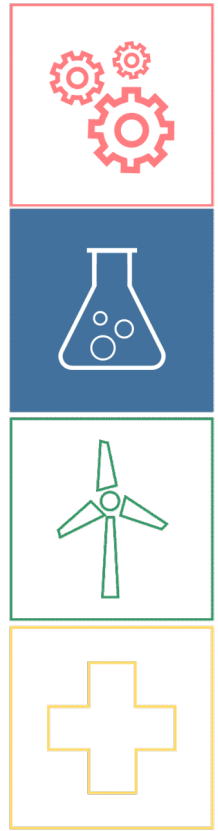
    - > Modeling.
    - > Validation.
    - > **Best configuration.**

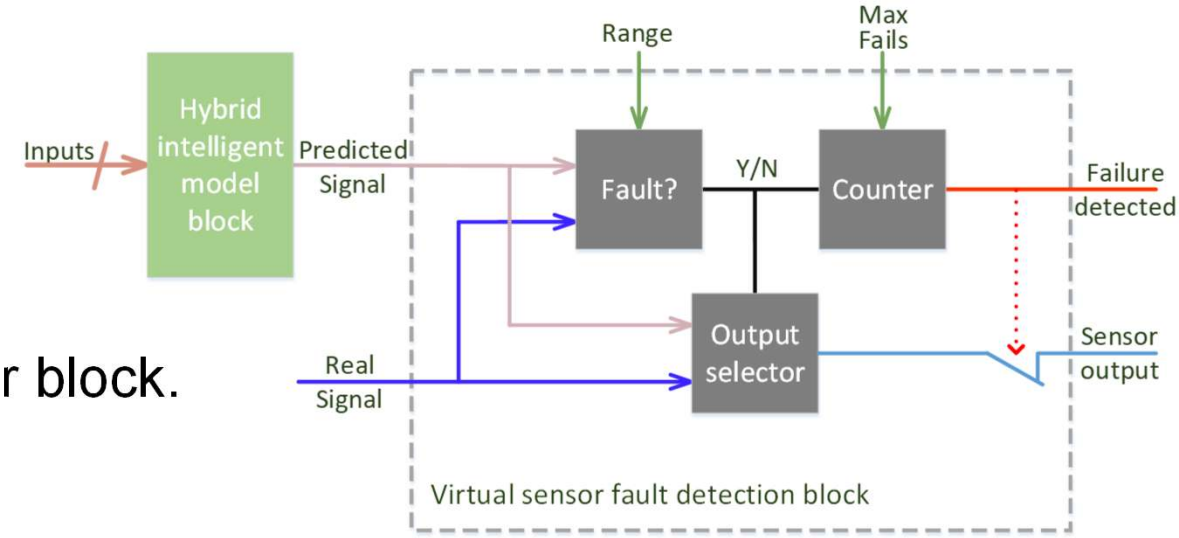




Virtual sensor approach

Implementation

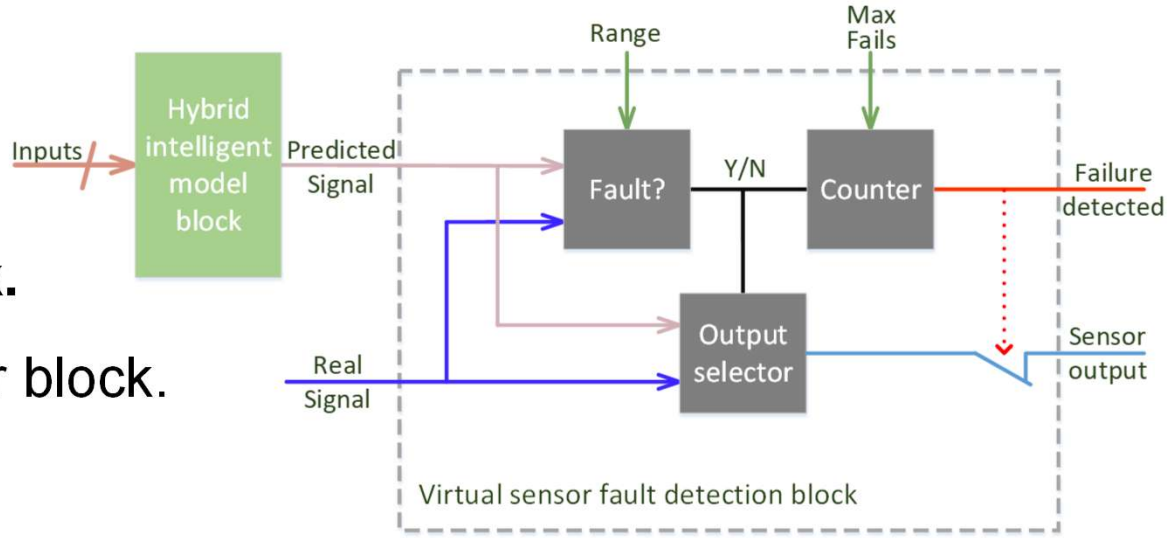
- Virtual sensor fault detection block.
  - **Fault block.**
  - Counter block.
  - Output selector block.



Virtual sensor approach

Implementation

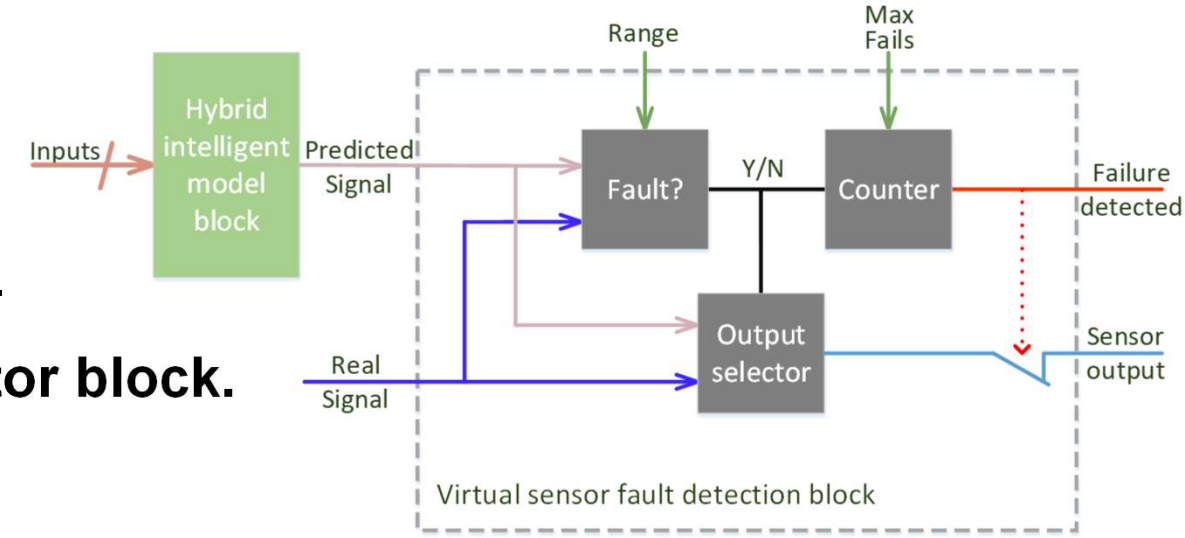
- Virtual sensor fault detection block.
  - Fault block.
  - **Counter block.**
  - Output selector block.



Virtual sensor approach

Implementation

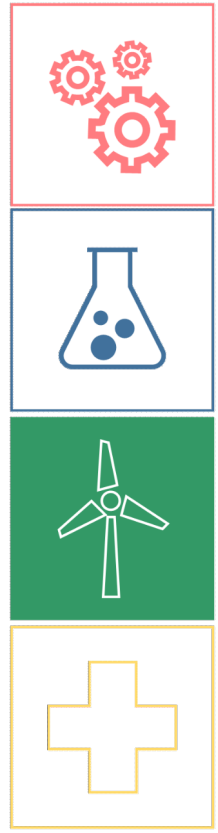
- Virtual sensor fault detection block.
  - Fault block.
  - Counter block.
  - **Output selector block.**



Virtual sensor approach

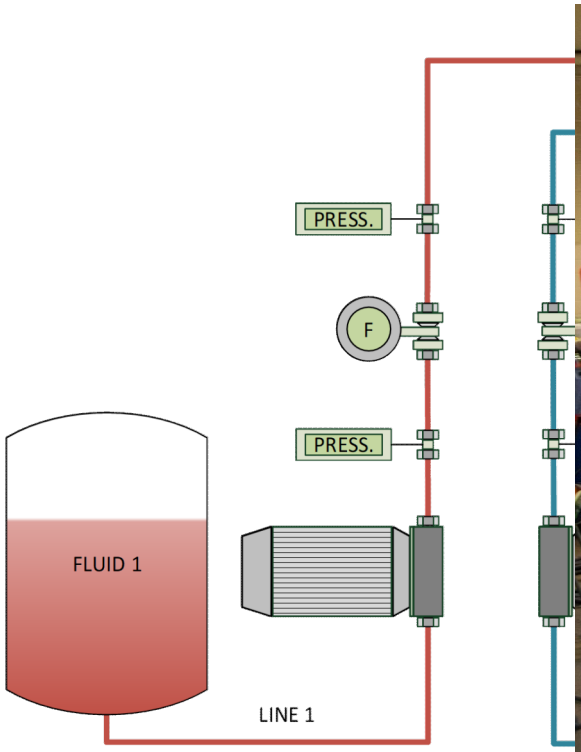
Bicomponent mixing system

- Article information.
  - **Title:** Virtual sensor for fault detection, isolation and data recovery for bicomponent mixing machine monitoring.



Virtual sensor approach

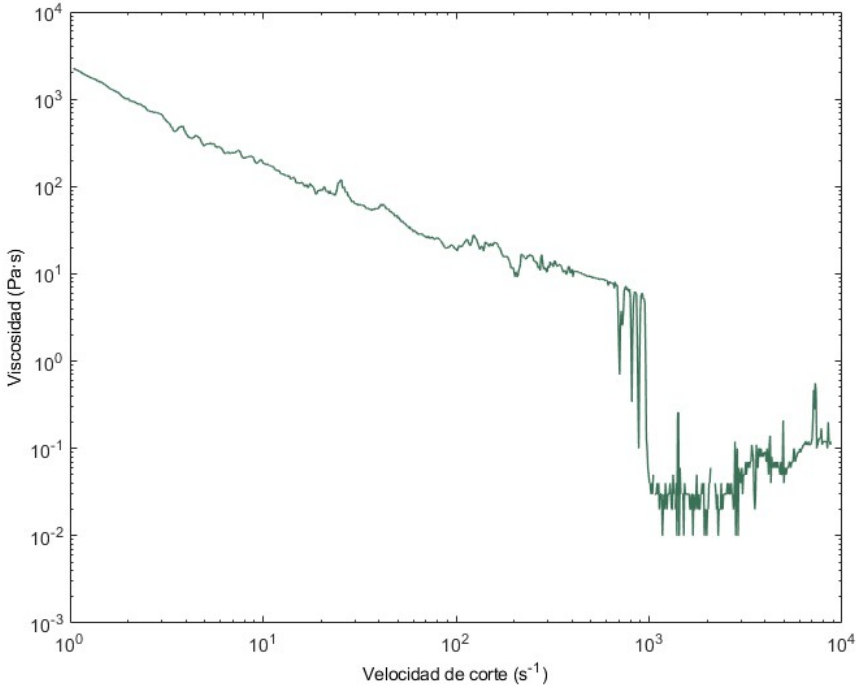
Bicomponent mixing system

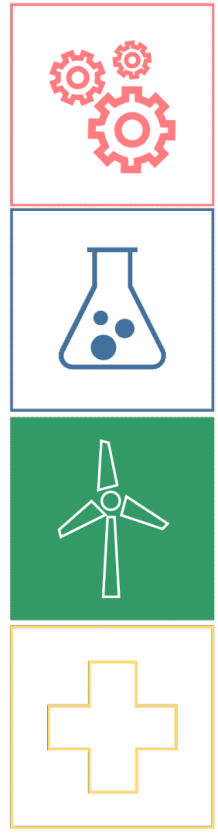


Virtual sensor approach

Bicomponent mixing system

- Monitored variables.
  - Mixing proportions.
  - Two pump speeds.
  - Three flows.
  - Four pressures.





Virtual sensor approach

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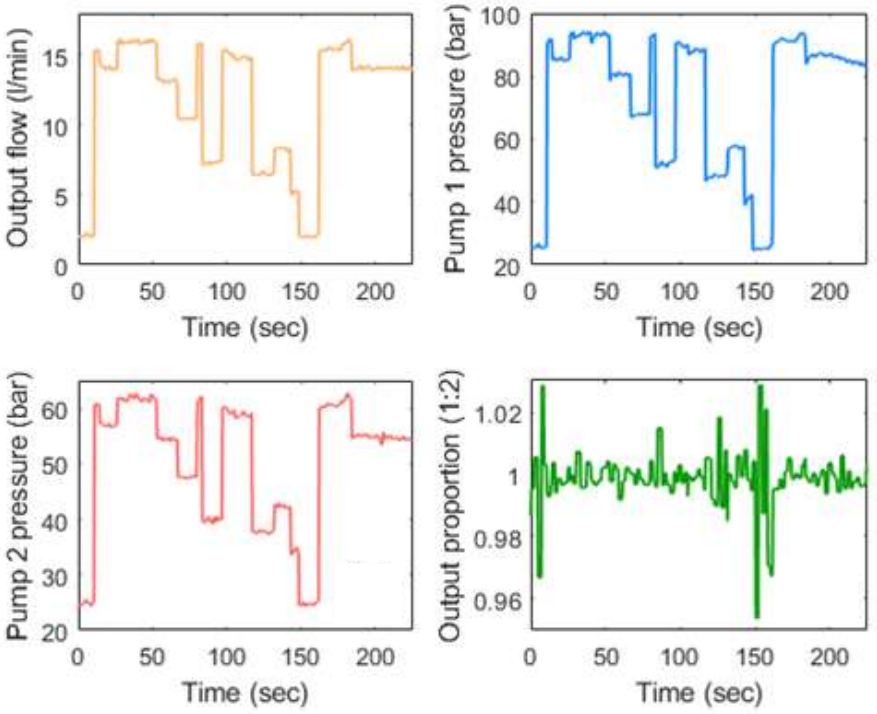
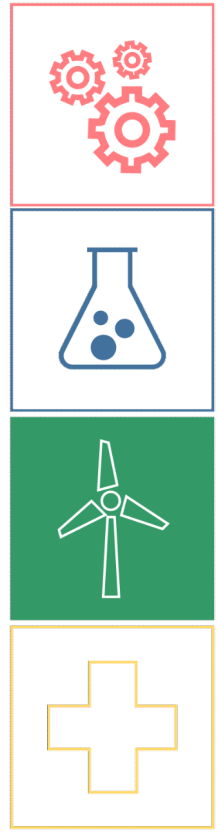
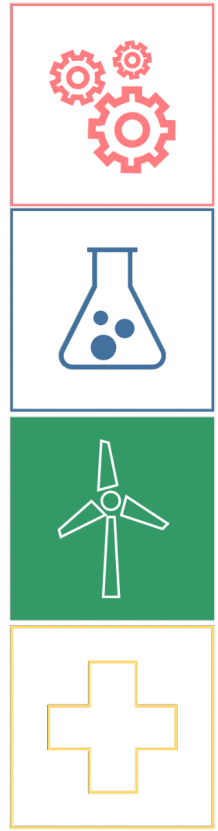




Virtual sensor approach

Bicomponent mixing system

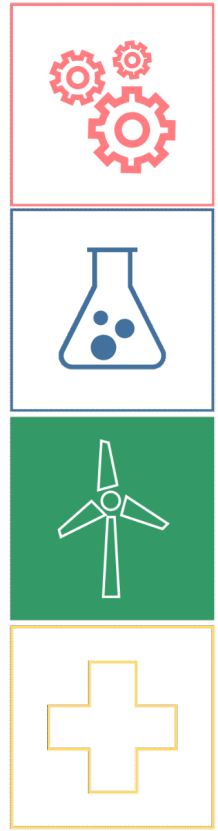
- Experiments and results.
  - Model inputs.
    - Output flow, Flow 2 (t, t-1, t-2).
    - Pumps pressures 1 and 2 (t, t-1, t-2).
    - Flowmeters pressures 1 and 2 (t, t-1, t-2).
  - Model Output.
    - Flow 1 (t).



Virtual sensor approach

Bicomponent mixing system

- Experiments and results.
  - Kmeans.
    - Clusters: 1:1:10.
  - MLP.
    - Hidden layer neurons: 1:1:15.
    - Different activation functions.
  - LS-SVR.
    - Self-tuned optimization toolbox.

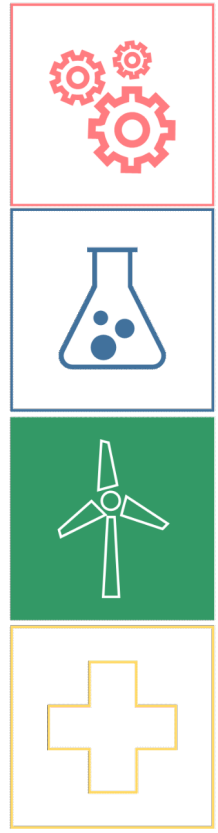


Virtual sensor approach

Bicomponent mixing system

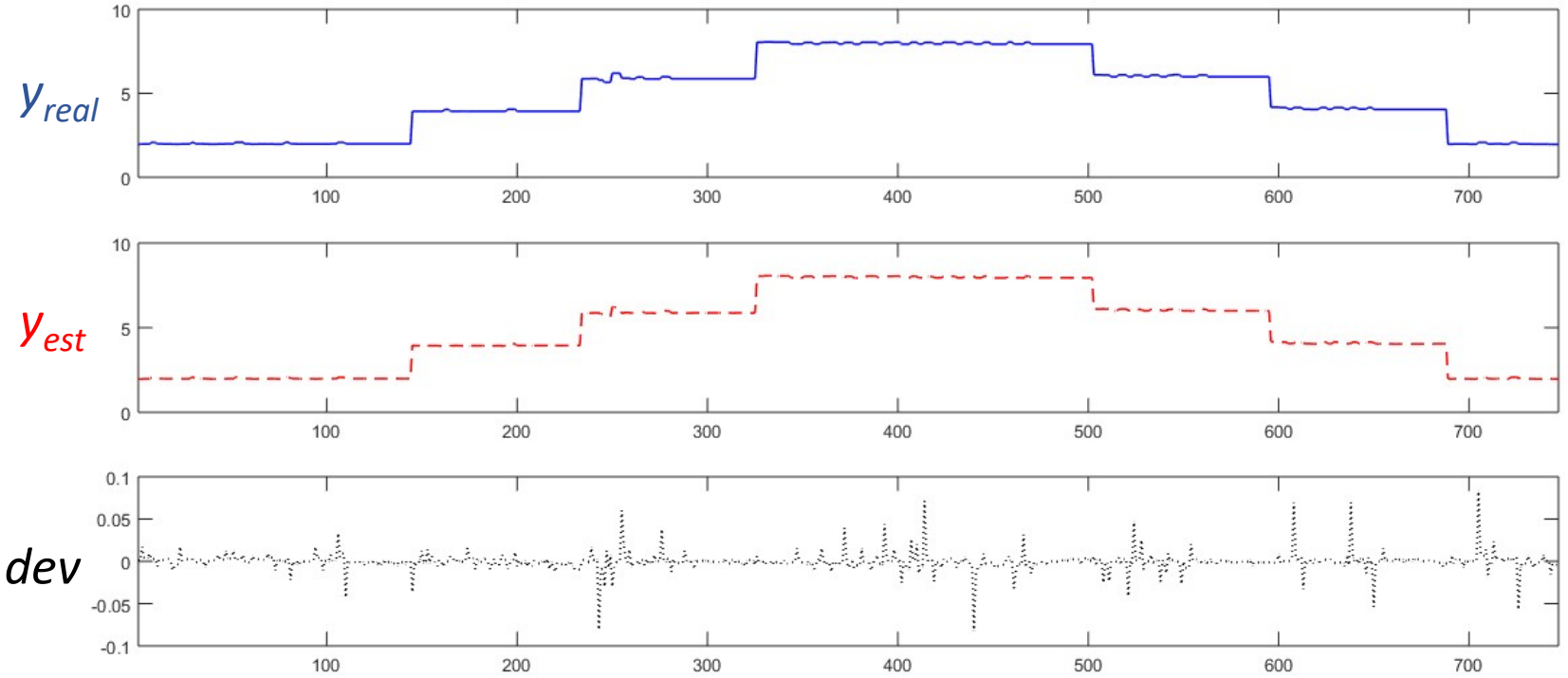
- Experiments and results.
  - Best configuration.
    - 7 clusters.
    - MSE = $0{,}131 \cdot 10^{-3}$.

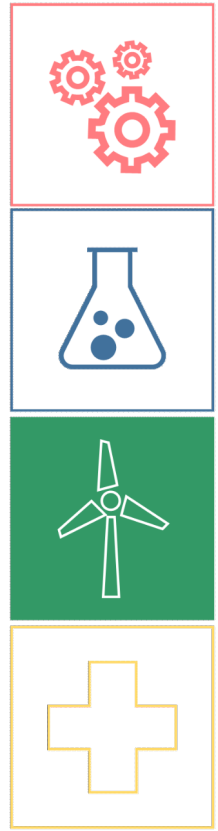
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Technique	ANN-1	ANN-1	ANN-7	ANN-5	ANN-3	ANN-3	ANN-8
MSE	$0.165 \cdot 10^{-3}$	$0.159 \cdot 10^{-3}$	$0.097 \cdot 10^{-3}$	$0.55 \cdot 10^{-3}$	$0.183 \cdot 10^{-3}$	$0.163 \cdot 10^{-3}$	$0.122 \cdot 10^{-3}$



Virtual sensor approach

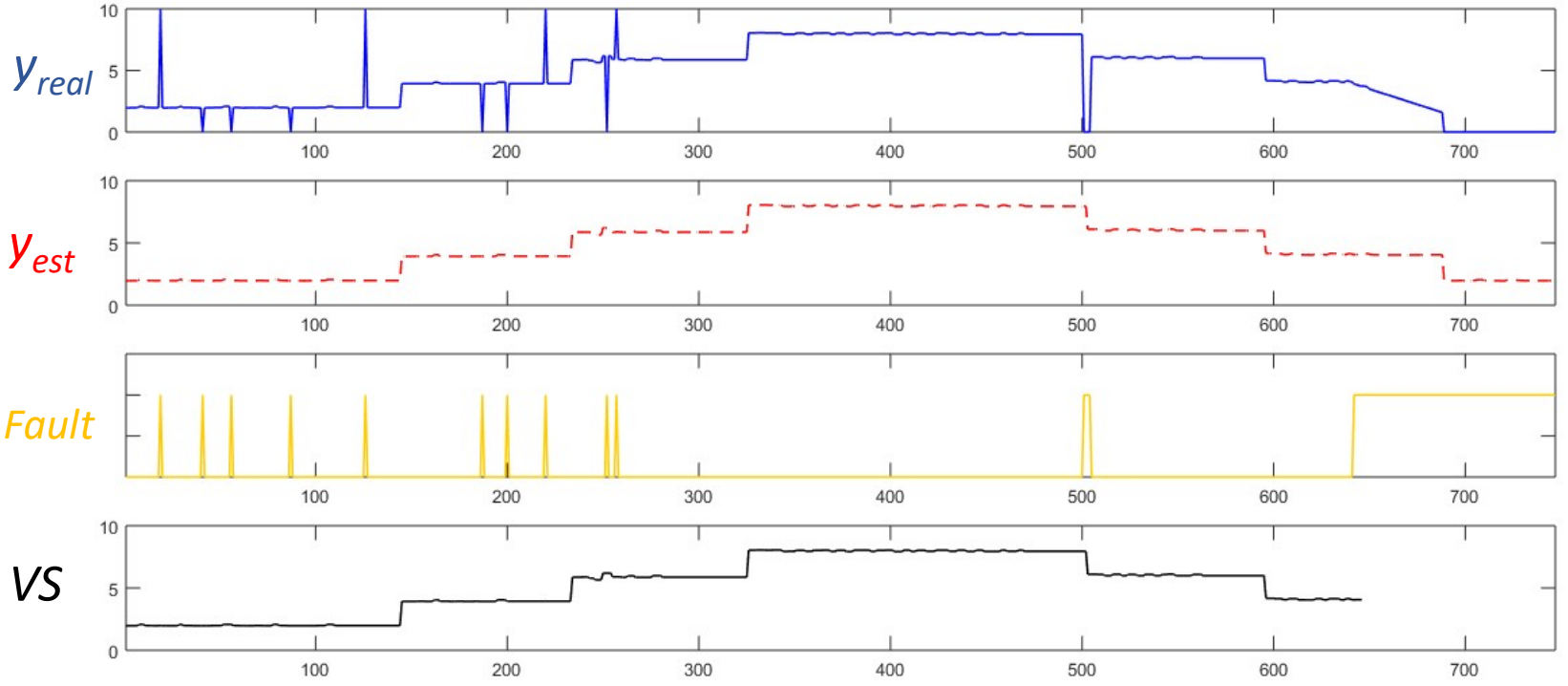
Bicomponent mixing system

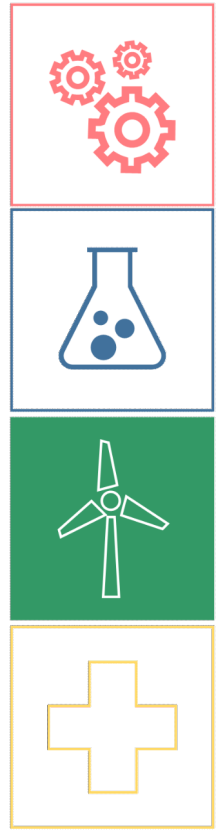




Virtual sensor approach

Bicomponent mixing system

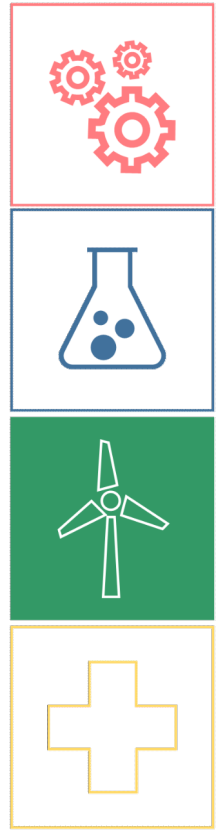




Virtual sensor approach

Bicomponent mixing system

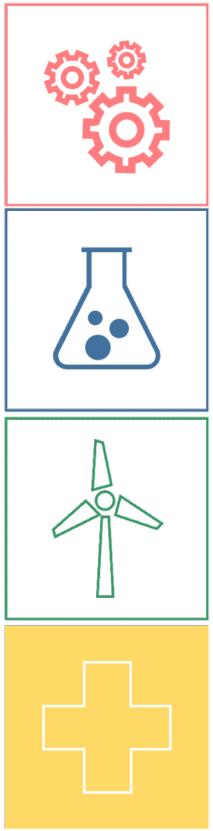
- Conclusions.
  - The virtual sensor is presented as an useful tool.
  - The anomalies are detected, isolated and recovered.
  - Importance of user expertise.
  - Good performance of all models.



Virtual sensor approach

Bispectral Index Sensor

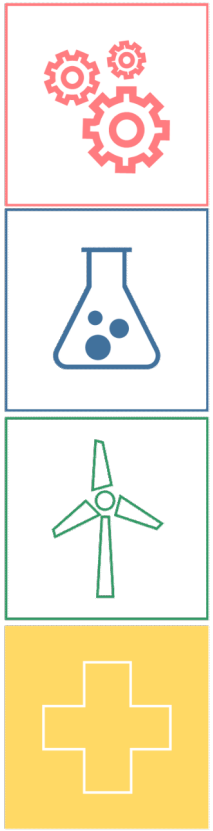
- Article information.
  - **Title:** Hybrid Intelligent System to Perform Fault Detection on BIS Sensor During Surgeries.



Virtual sensor approach

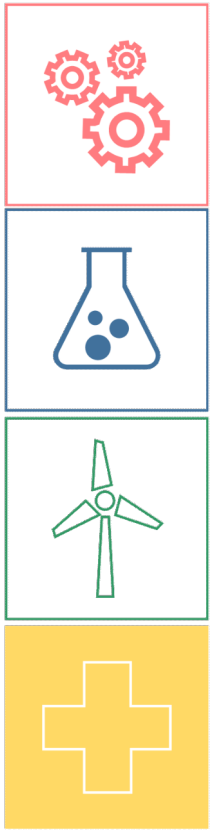
Bispectral Index Sensor

- Monitored parameters:
  - Analgesia.
  - Muscular blockade.
  - Hypnosis.
    - BIS sensor



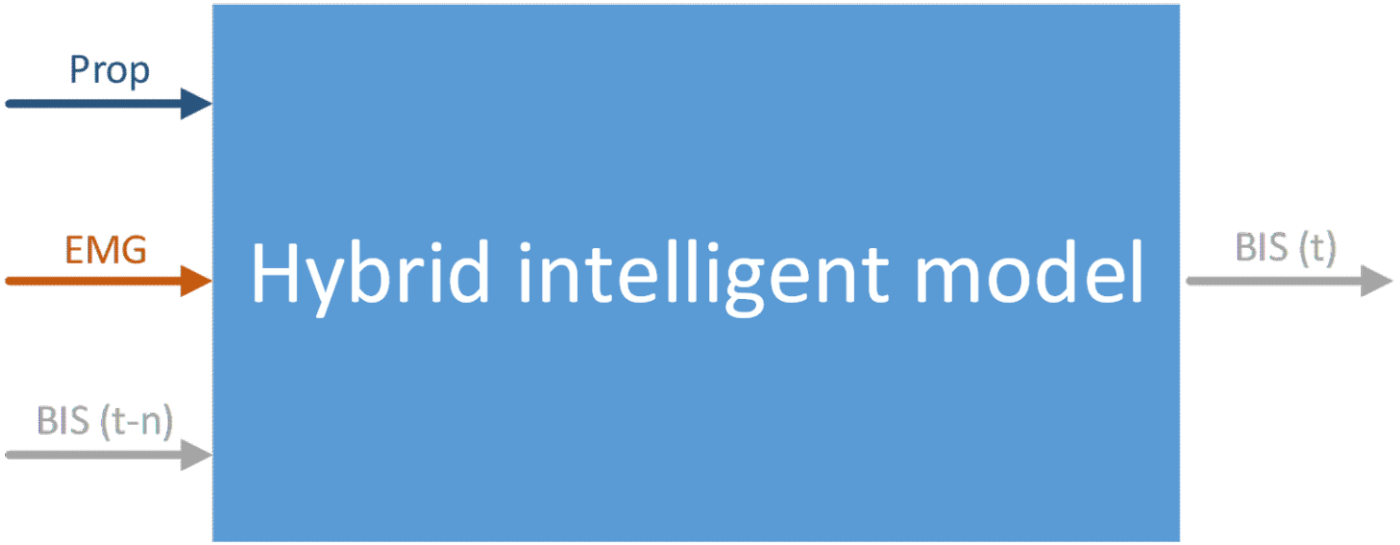
Virtual sensor approach

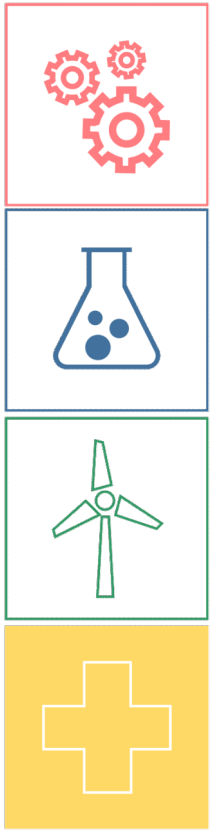
Bispectral Index Sensor



Virtual sensor approach

Bispectral Index Sensor

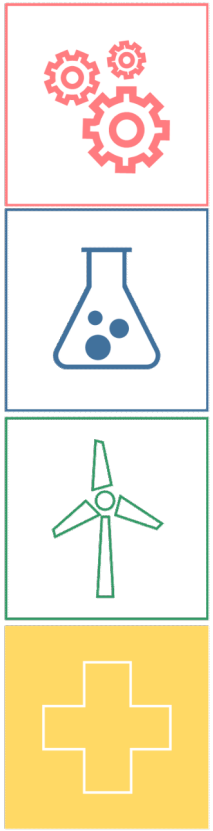




Virtual sensor approach

Modeling anesthetic process

- Model inputs.
  - Propofol dose rate (t, t-1, t-2).
  - EMG signal (t, t-1, t-2).
  - BIS (t-1, t-2).
- Model output.
  - BIS(t).
- Dataset. 50 patients (42.788 samples).

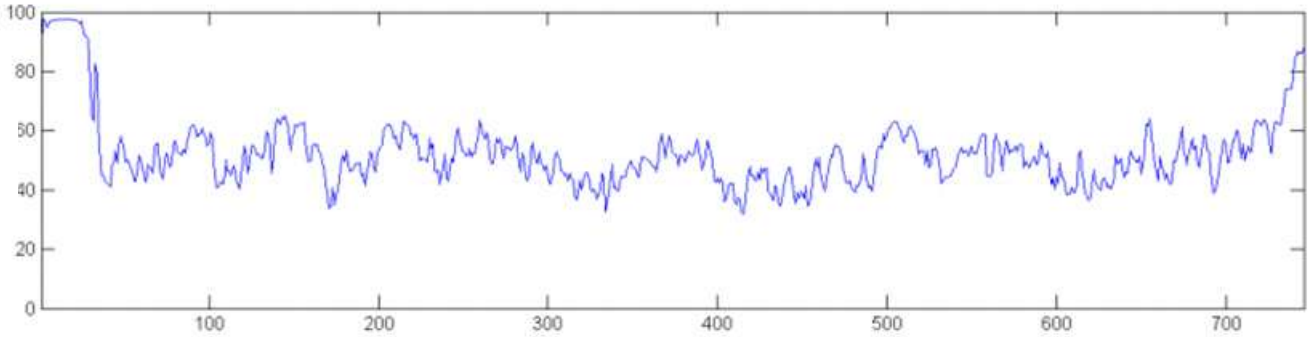


Virtual sensor approach

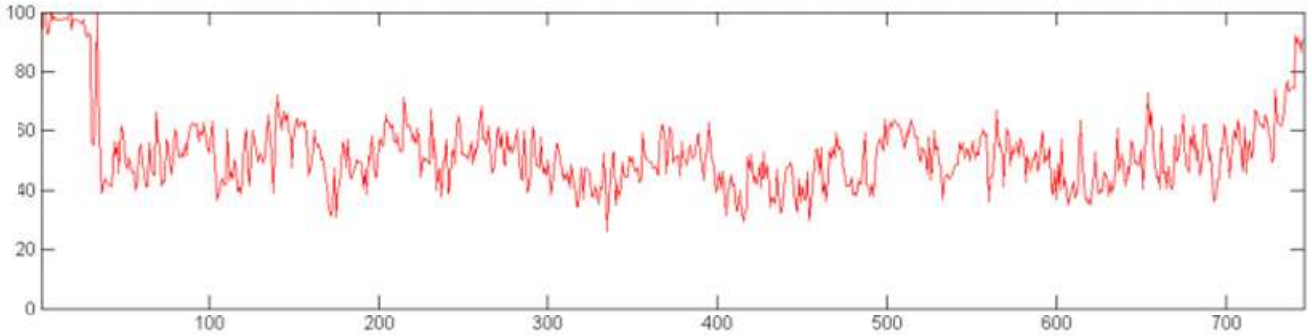
Modeling anesthetic process

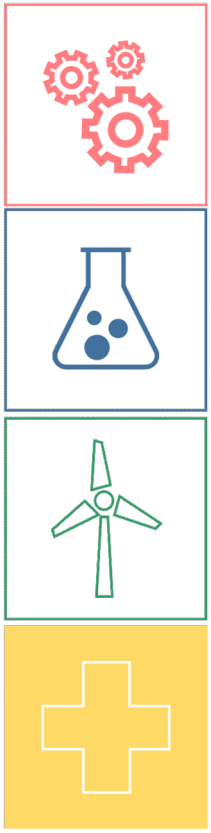
- Results.

BIS_{real}



BIS_{pred}



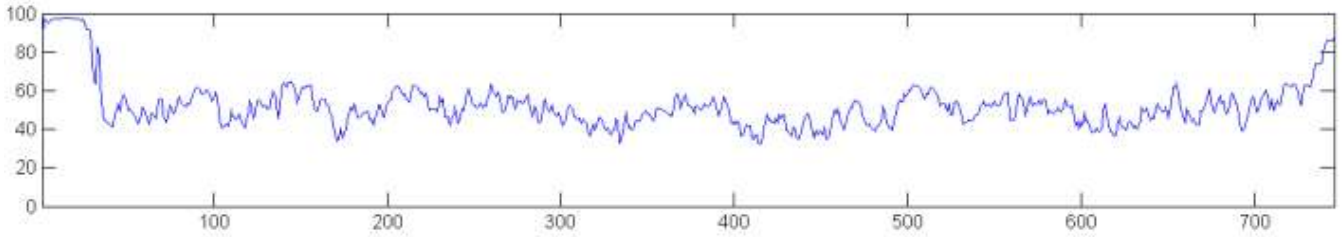


Virtual sensor approach

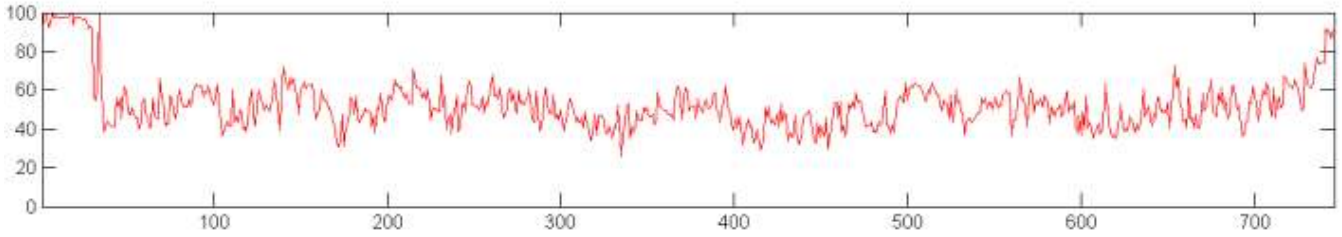
Modeling anesthetic process

- Results.

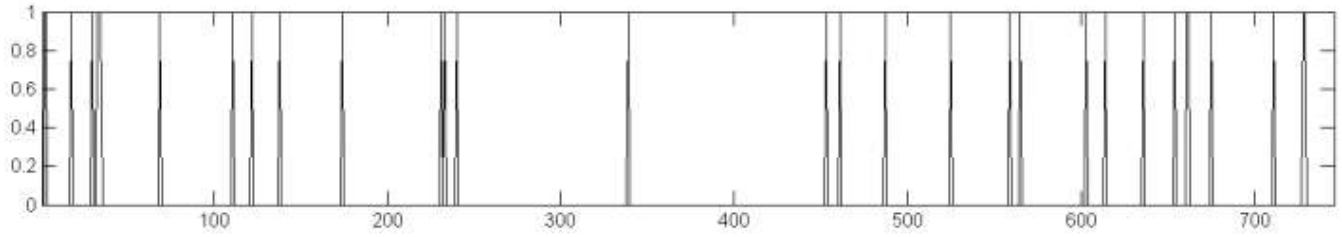
BIS_{real}

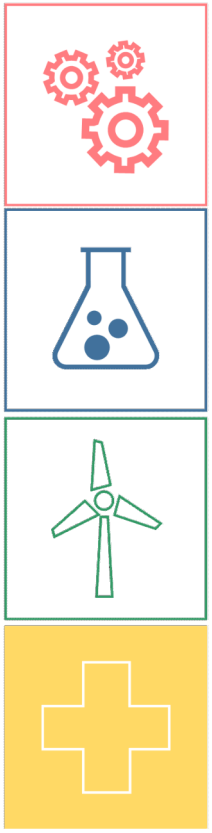


BIS_{pred}



Fault



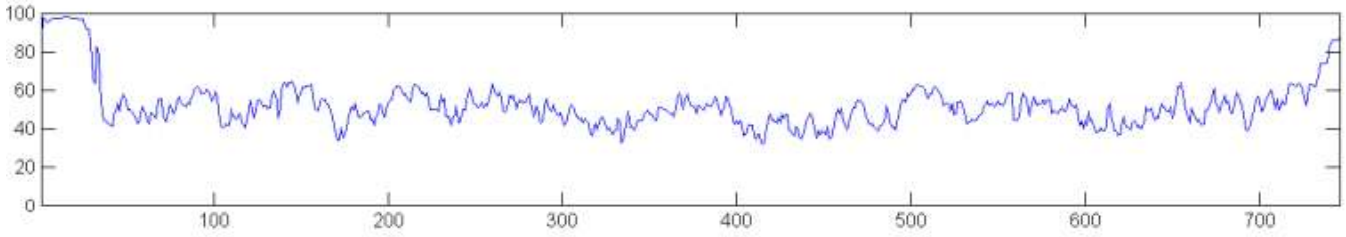


Virtual sensor approach

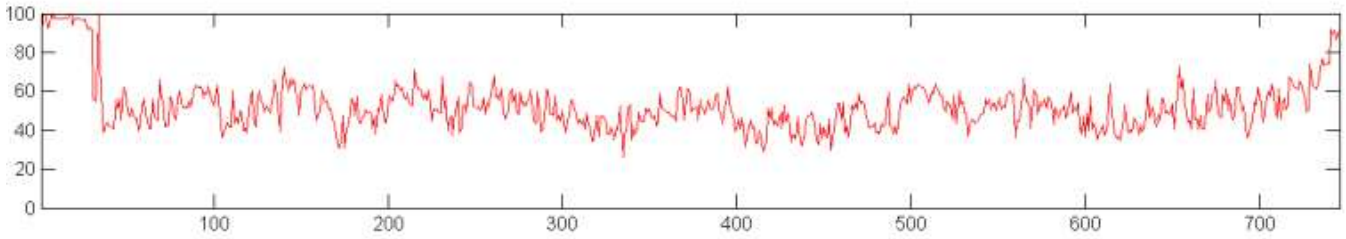
Modeling anesthetic process

- Results.

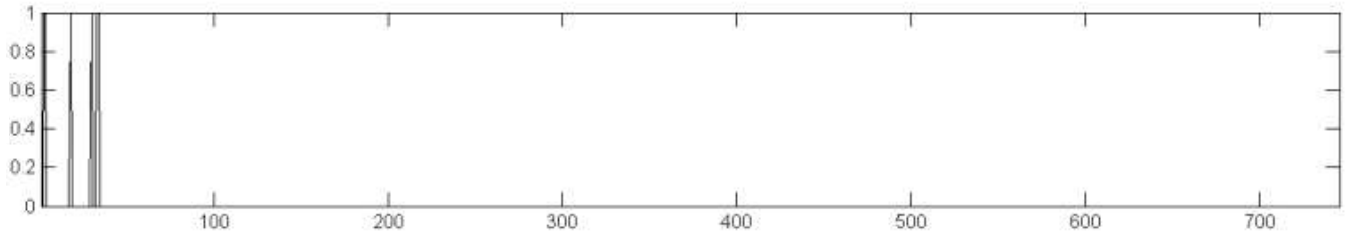
BIS_{real}

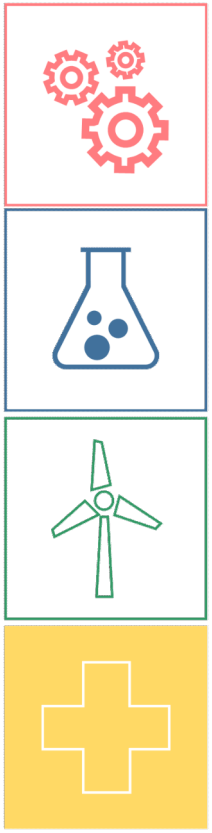


BIS_{pred}



Fault

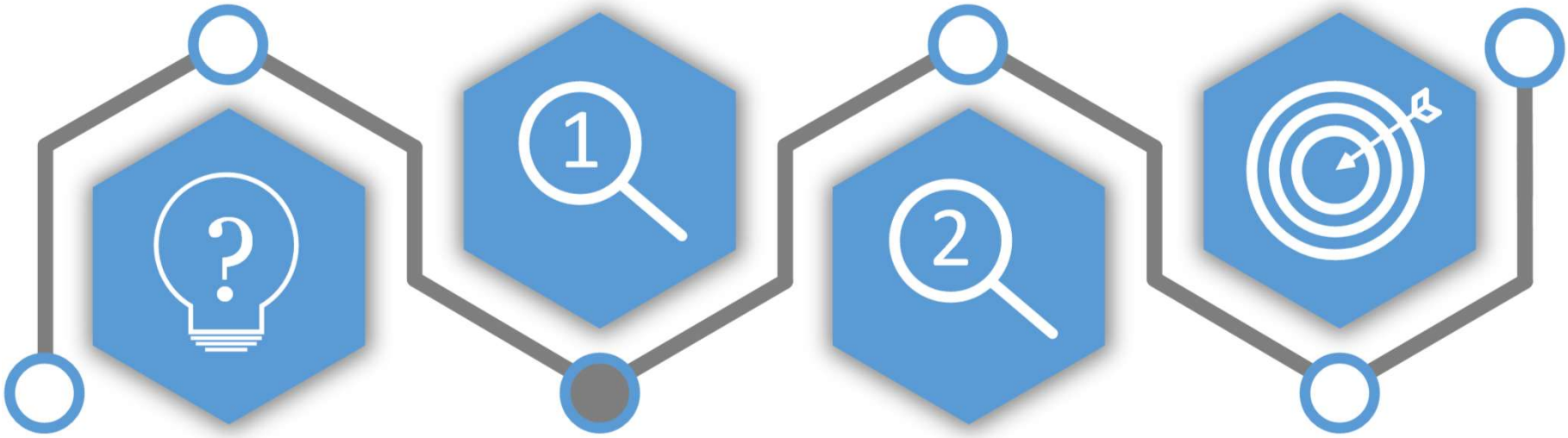




General Index

Introduction

One-class approach



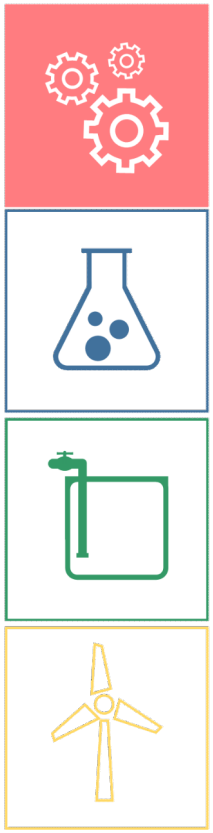
Virtual sensor approach

Other works

One-class approach

Fundamentals

- One-class:
  - Density estimation methods.
  - Reconstruction methods.
  - Boundary methods.



One-class approach

Fundamentals

- One-class:
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  - Reconstruction methods.
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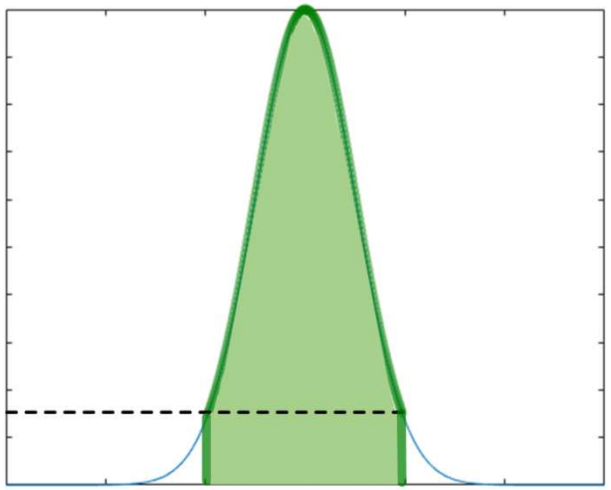
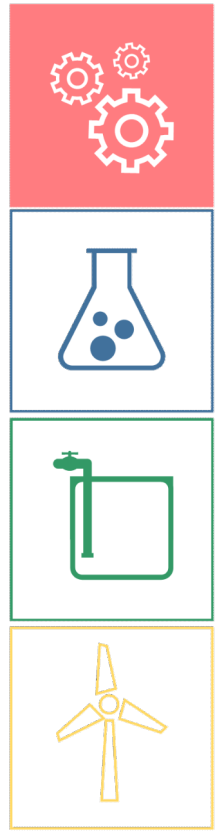
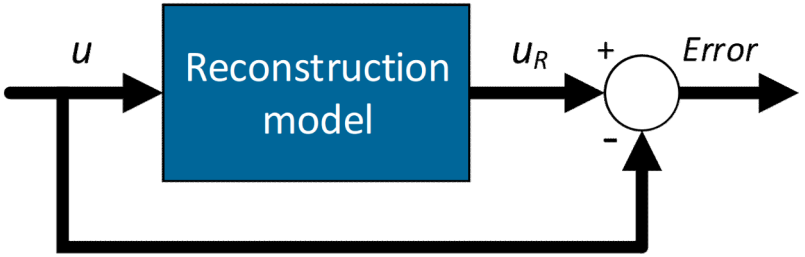


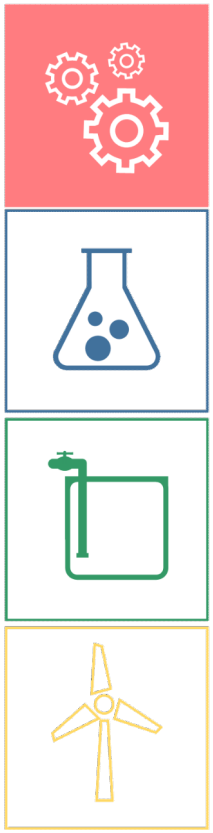


One-class approach

Fundamentals

- One-class:
  - Density estimation methods.
  - **Reconstruction methods.**
  - Boundary methods.





One-class approach

Fundamentals

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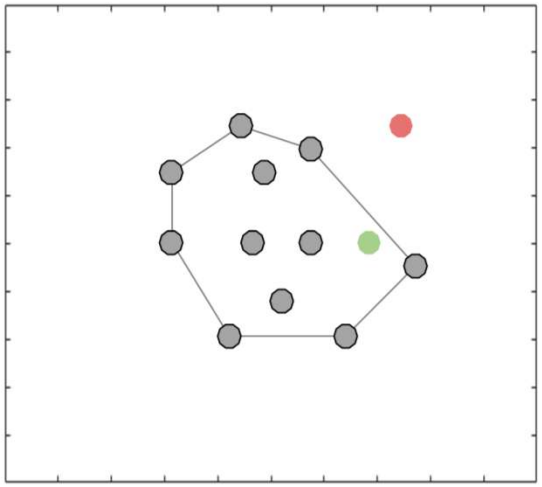
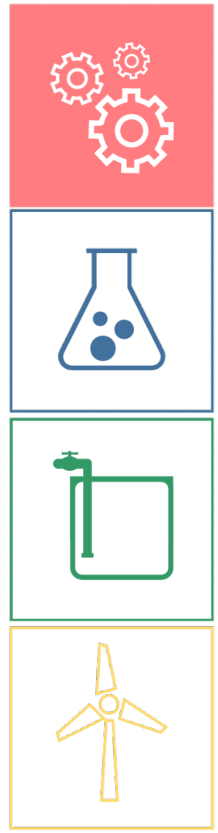
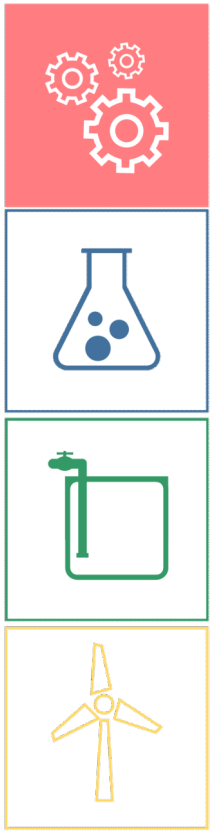




One-class approach

Fundamentals

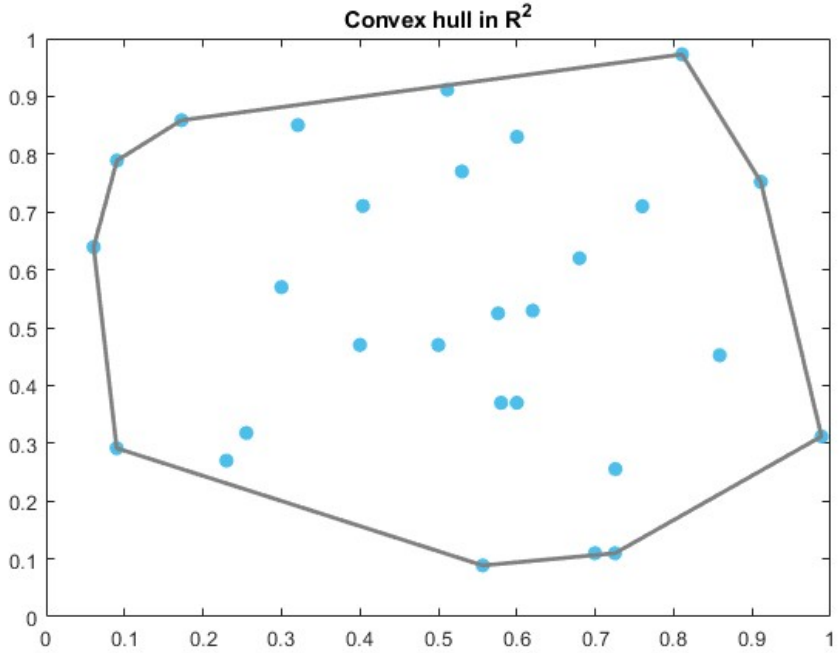


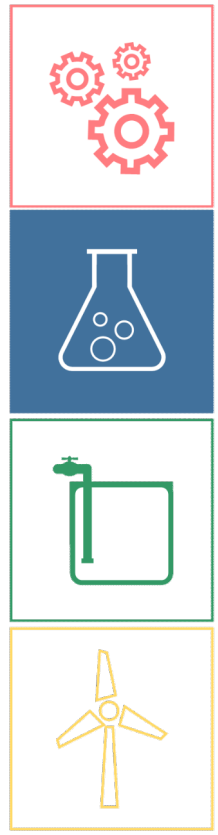
One-class approach

Implementation

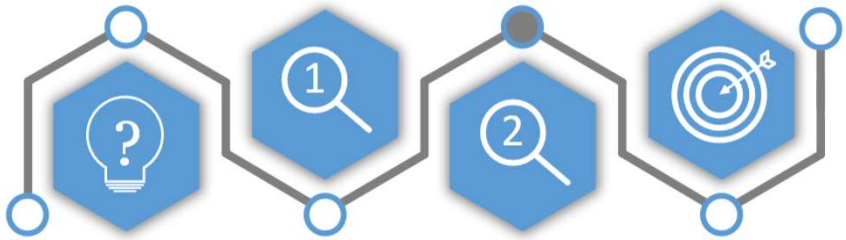
- One-class techniques.
  - **ACH.**

$$CH(X) = \left\{ \sum_{i=1}^{N} \alpha_i xi \| \sum_{i=1}^{N} \alpha_i = 1, 0 \leq \alpha_i \leq 1 \right\}$$





One-class approach



Implementation

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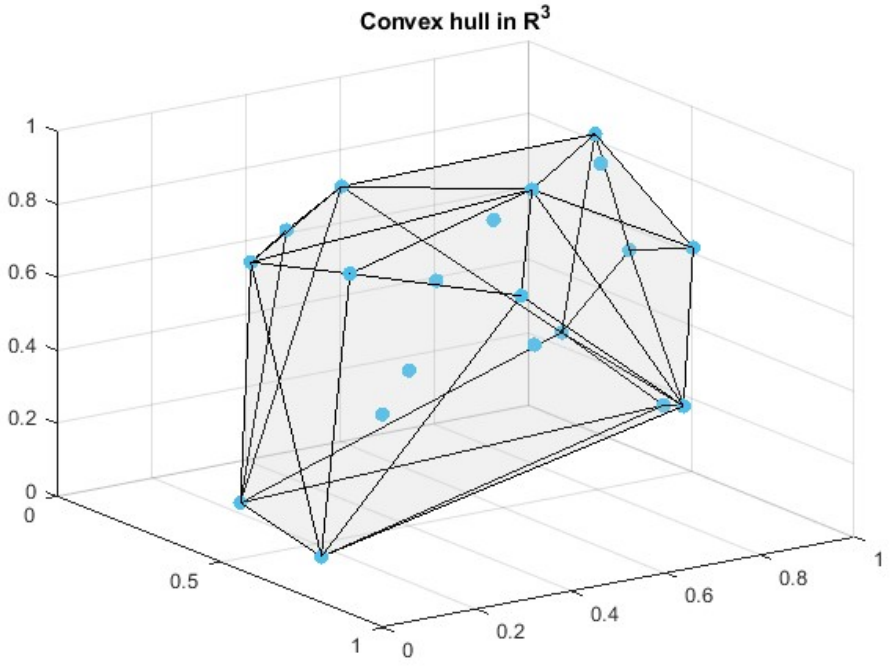

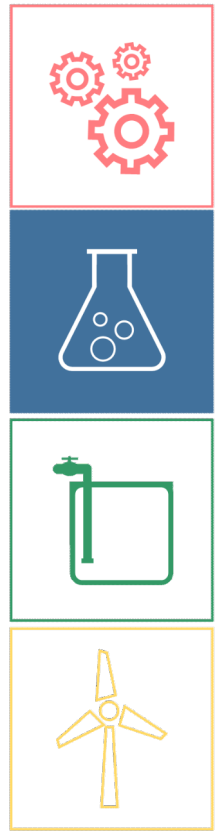

One-class approach

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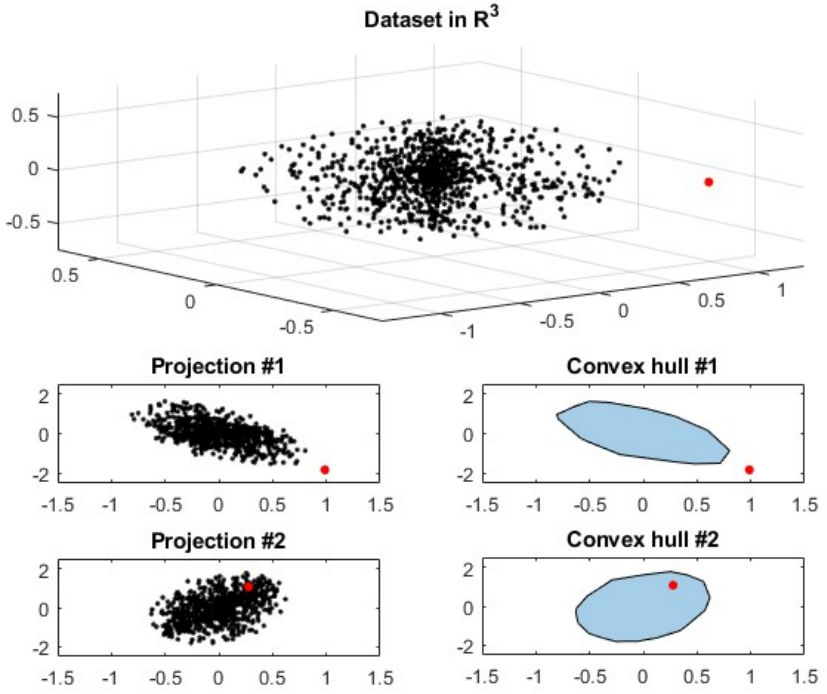
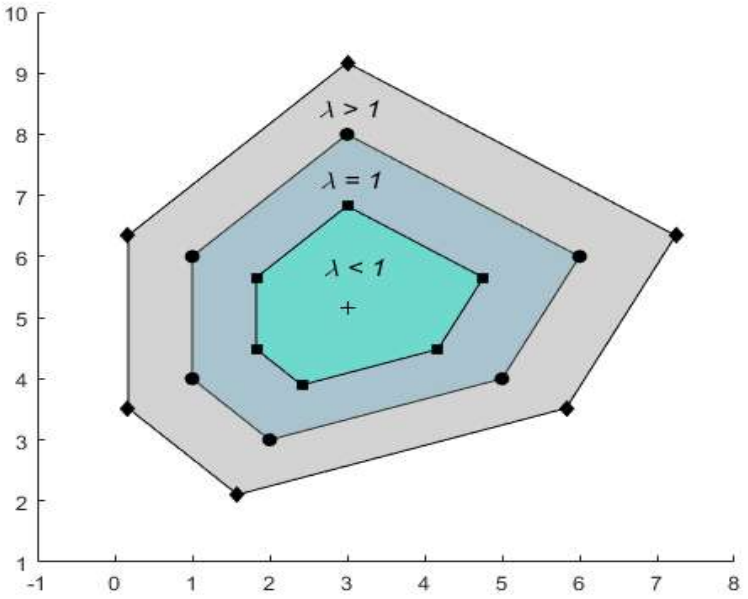


One-class approach

Implementation

- One-class techniques.
  - **ACH.**

$$v^{\lambda} : \{\lambda v + (1-\lambda)c \mid v \in CH(X)\}$$

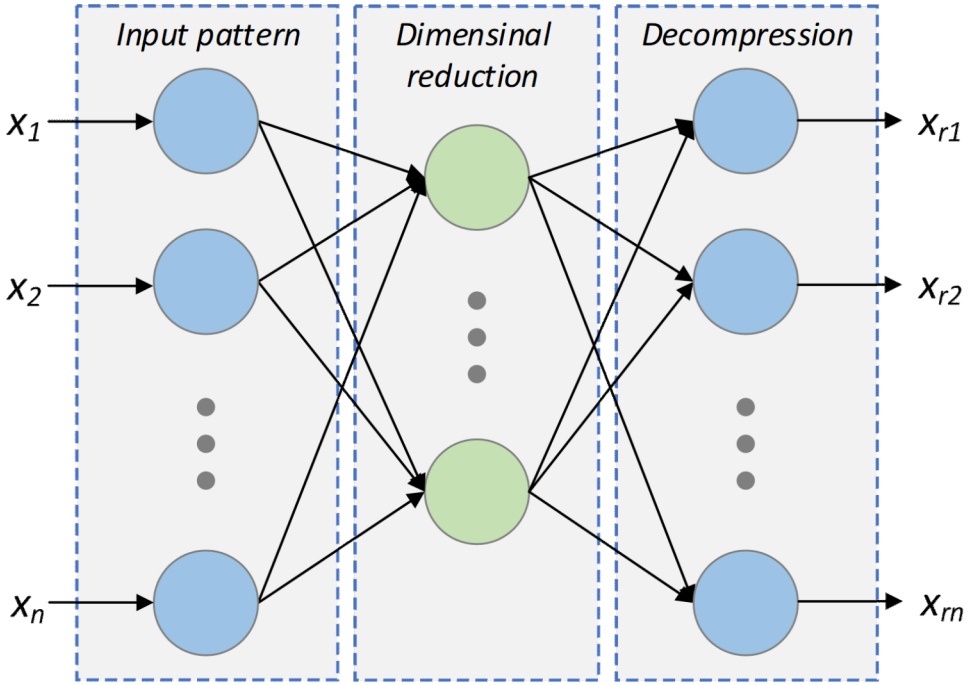


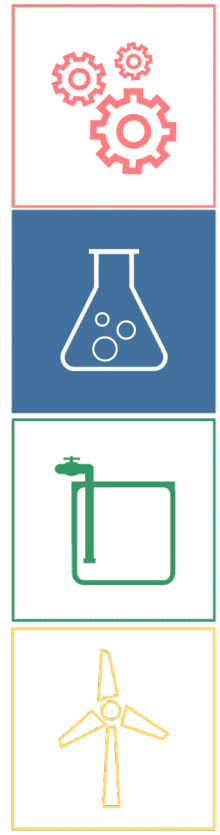
One-class approach

Implementation

- One-class techniques.
  - ACH.
  - **Autoencoder.**

$$v = f_1(W_1 x + b_1)$$
$$x_r = f_2(W_2 v + b_2)$$

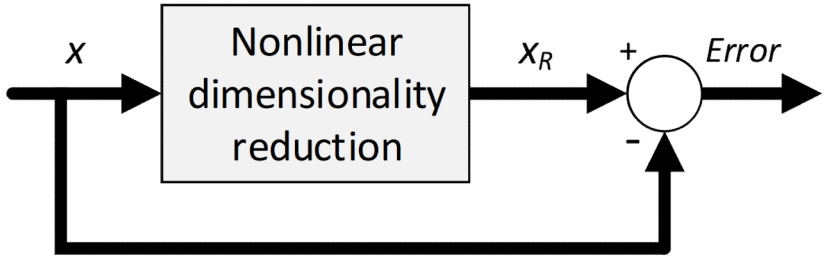




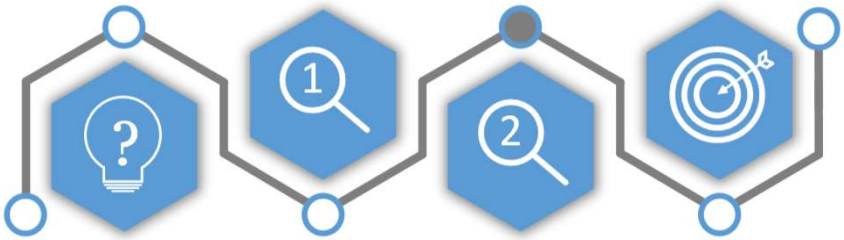
One-class approach

Implementation

- One-class techniques.
  - ACH.
  - **Autoencoder.**



One-class approach

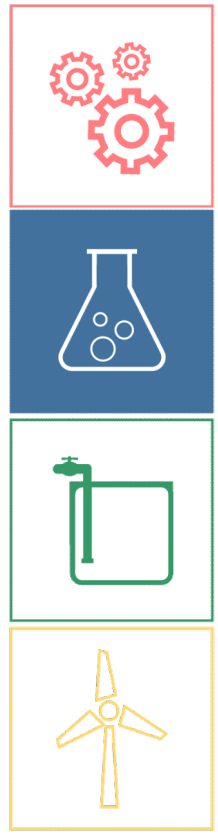


Implementation

- One-class techniques.
  - ACH.
  - Autoencoder.
  - **SVM.**

$$min\left(0.5||w||^2+\frac{1}{\nu l}\sum_{i=1}^{l}\xi_i-b\right)$$

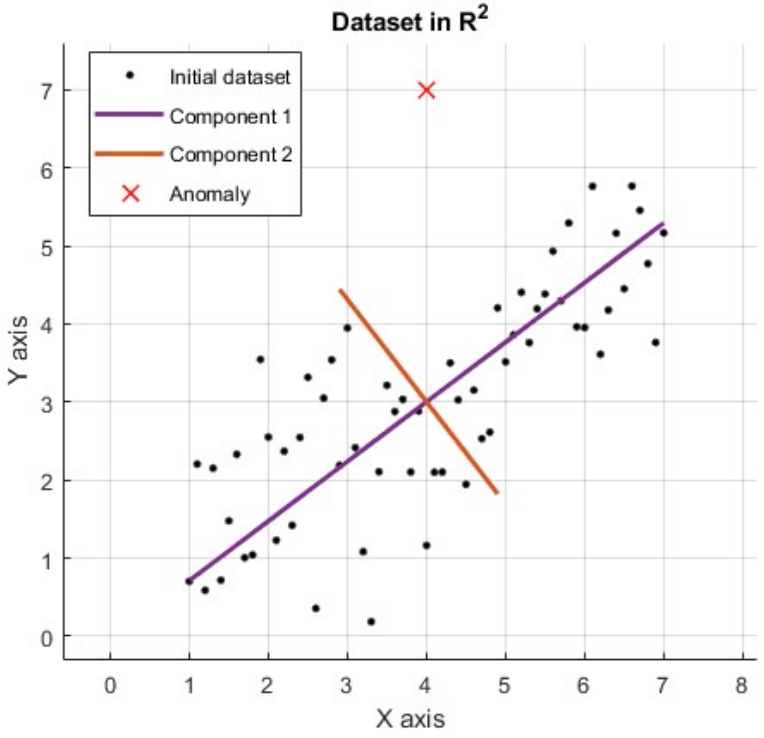
$$(w\cdot\delta(x_i))\geq b-\xi_i),\xi_i\geq 0$$

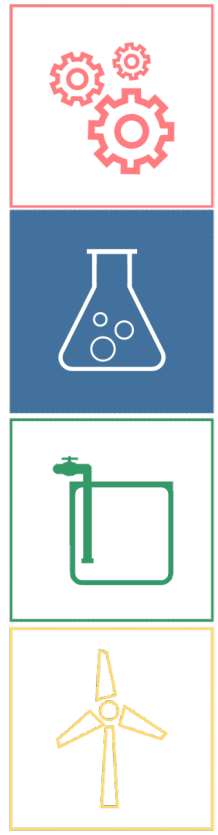


One-class approach

Implementation

- One-class techniques.
  - ACH.
  - Autoencoder.
  - SVM.
  - **PCA.**



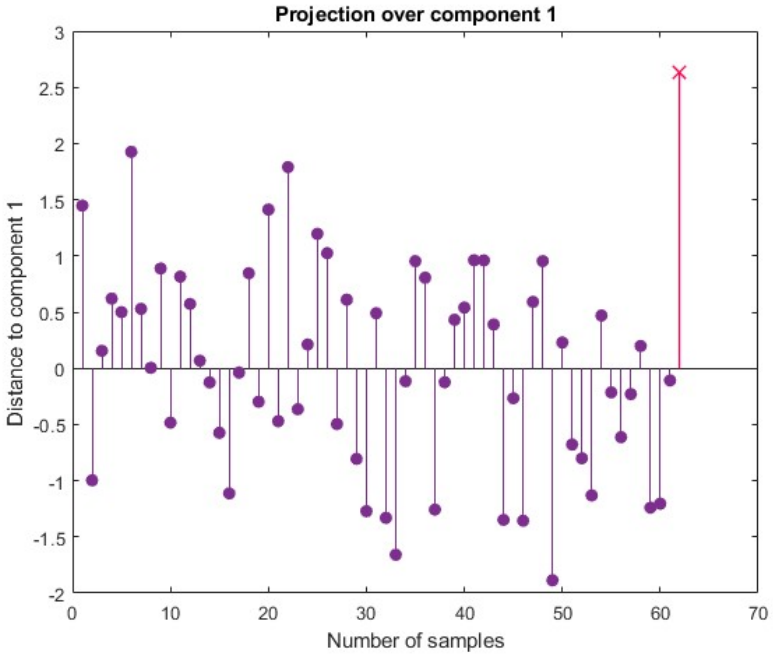


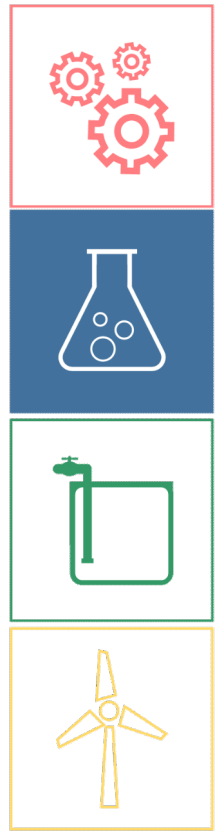
One-class approach

Implementation

- One-class techniques.
  - ACH.
  - Autoencoder.
  - SVM.
  - **PCA.**

$$e(x) = ||x - x_{pr}||$$

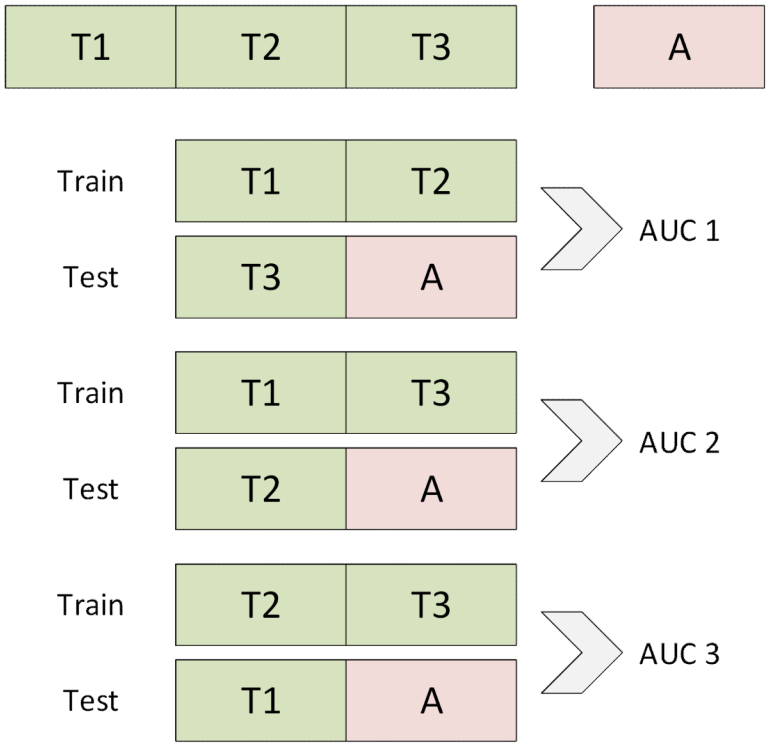


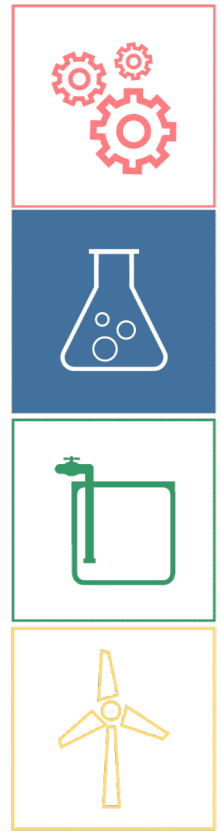


One-class approach

Implementation

- One-class techniques.
  - ACH.
  - Autoencoder.
  - SVM.
  - PCA
- **Validation.**

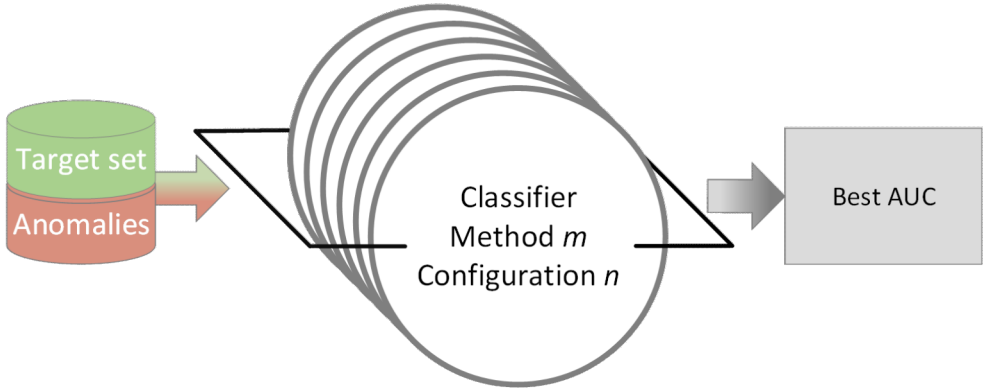


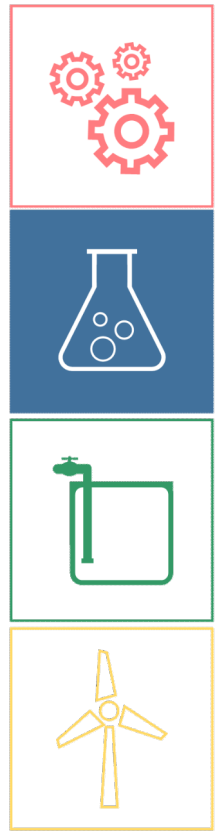


One-class approach

Implementation

- One-class techniques.
  - ACH.
  - Autoencoder.
  - SVM.
  - PCA
- Validation.
- **Best configuration.**

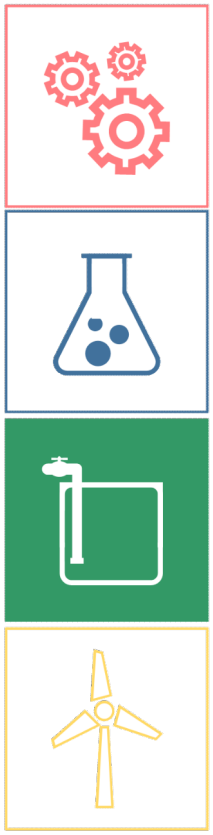




One-class approach

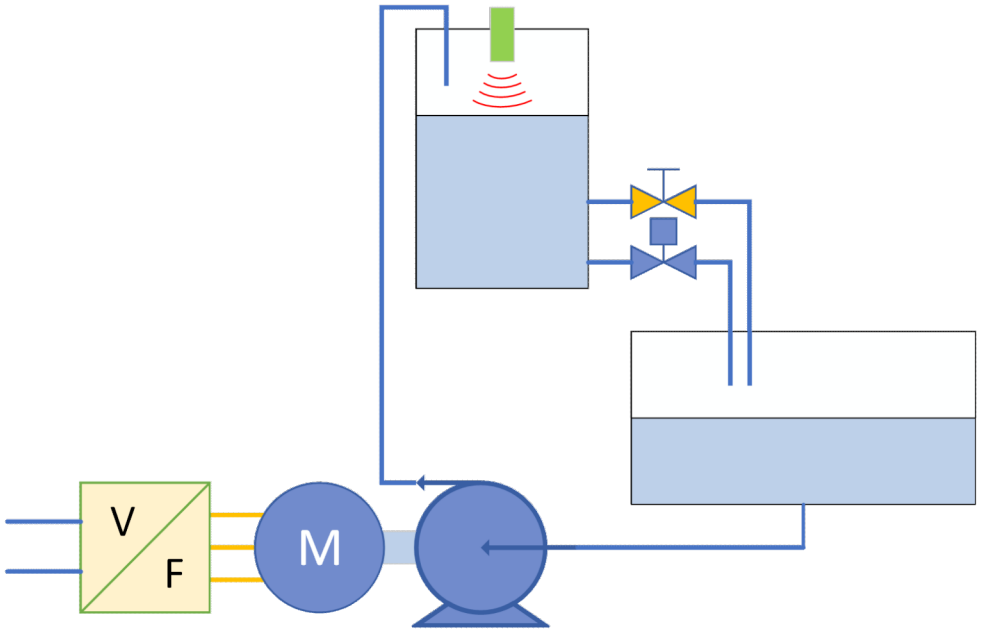
Liquid level control plant

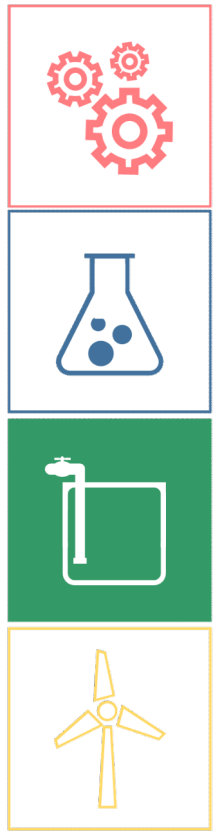
- Article information.
  - **Title:** Anomaly detection based on one-class intelligent techniques over a control level plant.



One-class approach

Liquid level control plant

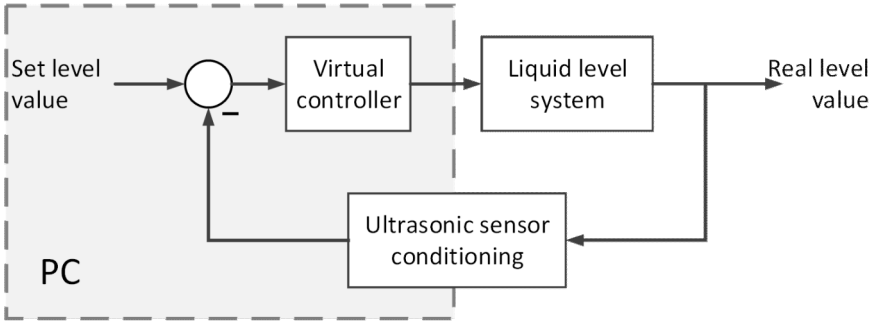


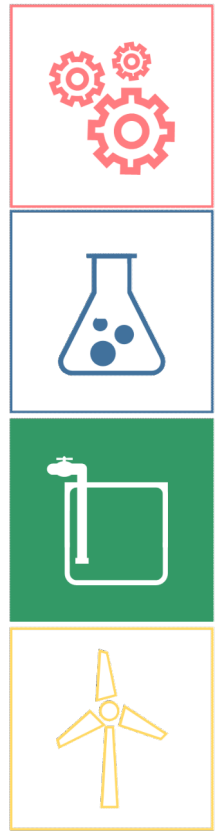


One-class approach

Liquid level control plant

- Monitored variables.
  - Control signal.
  - Error signal.
  - Plant coefficients.
  - Set point.
  - Process value.

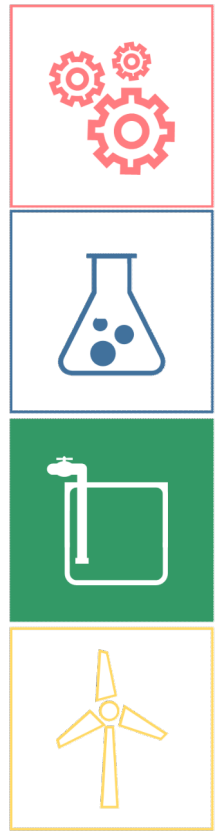




One-class approach

Liquid level control plant

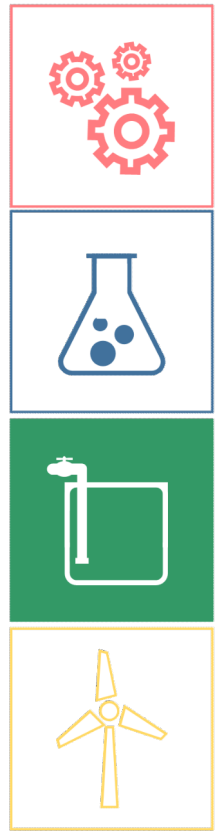
- Dataset.
  - Target set: electric valve closed: 5400 samples.
  - Anomalies.
    - Electric valve open 10 %: 5400 samples.
    - Electric valve open 30 %: 5400 samples.
    - Electric valve open 50 %: 5400 samples.
    - Electric valve open 70 %: 5400 samples.
    - Electric valve open 90 %: 5400 samples.



One-class approach

Liquid level control plant

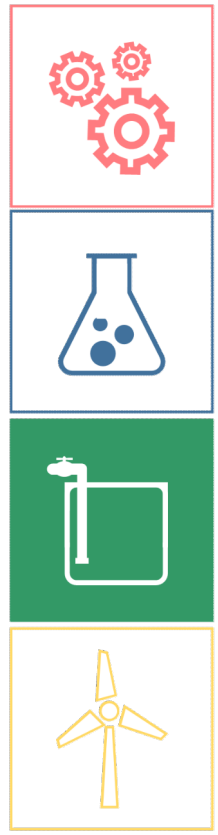
- Experiments and results.
  - Classifier inputs.
    - Control signal.
    - Error.
    - Plant coefficients.
  - Data conditioning.
    - 0 to 1.
    - Z-Score.



One-class approach

Liquid level control plant

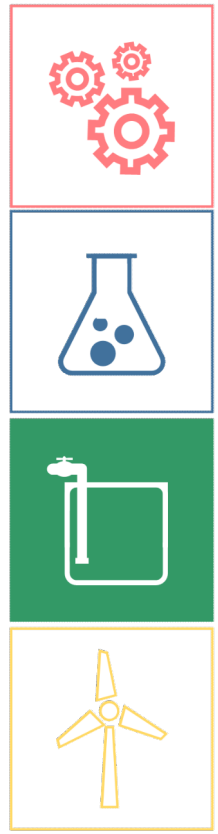
- Experiments and results.
  - ACH.
    - Expansion parameter λ: 0.9, 1, 1.1.
    - Projections: 5, 10, 50, 100, 500, 1000.
  - Autoencoder.
    - Neurons in the hidden layer: 1:1:4.



One-class approach

Liquid level control plant

- Experiments and results.
  - SVM.
    - Outlier percentage: 0:1:10.
    - Kernel function: Gaussian.
  - Tested anomalies. Valve open (%): 10:20:90.



One-class approach

Liquid level control plant

- Experiments and results.
  - ACH.

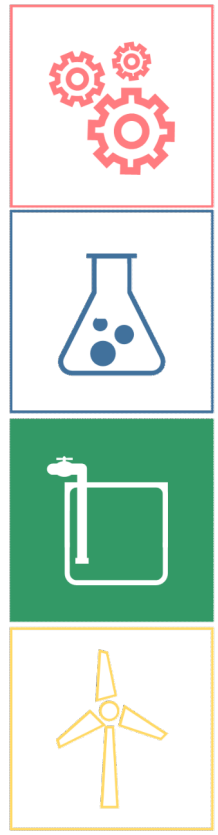
Projections	λ	AUC	Training time (min)
1000	1,1	99,78	13,25

  - Autoencoder.

Hidden layer neurons	Conditioning	AUC	Training time (min)
4	Z-Score	99,49	8,83

  - SVM.

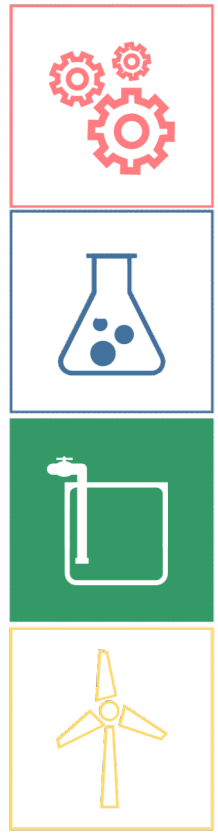
Outlier percentage	Conditioning	AUC	Training time (min)
5	0-1	99,35	1,04



One-class approach

Liquid level control plant

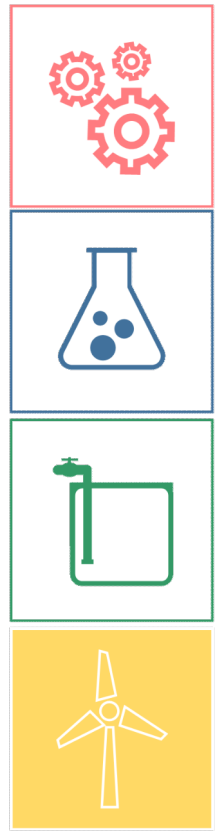
- Conclusions.
  - The approach is validated over a laboratory plant.
  - Successful performance without the need of an expert user.
  - Influence of number of projections and parameter λ.
  - Influence of data conditioning.



One-class approach

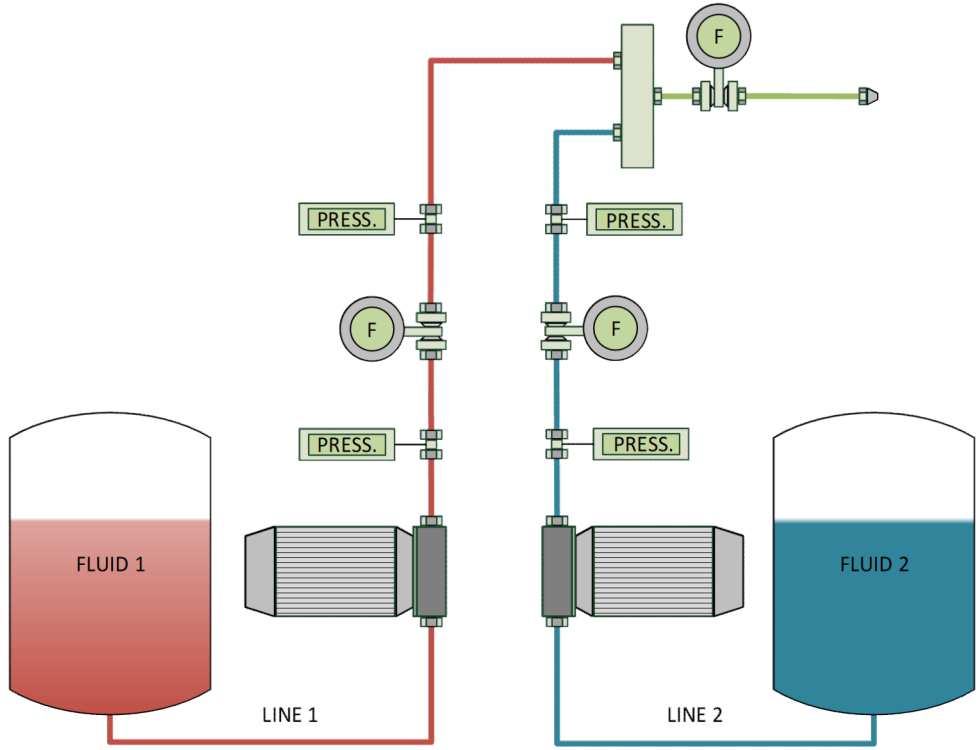
Bicomponent mixing system

- Article information.
  - **Title:** Detección de anomalías basada en técnicas inteligentes de una planta de obtención de material bicomponente empleado en la fabricación de palas de aerogenerador.



One-class approach

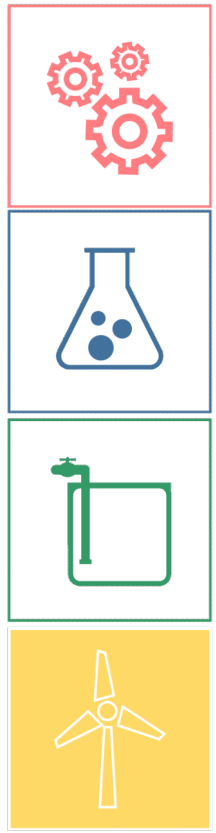
Bicomponent mixing system



One-class approach

Bicomponent mixing system

- Classifier topology.
- One-class techniques.
  - ACH.
  - Autoencoder.
  - SVM.
  - PCA.



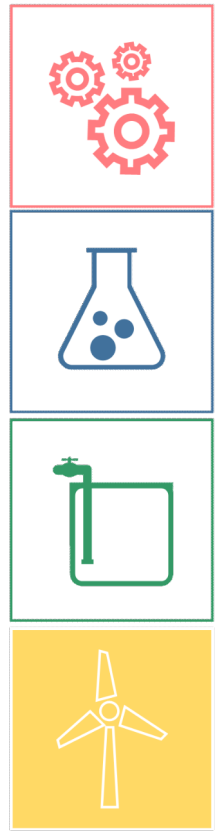
One-class approach

Bicomponent mixing system

- Anomaly generation.

a_{11}	a_{12}	a_{13}
a_{21}	a_{22}	a_{23}
a_{31}	a_{32}	a_{33}
a_{41}	a_{42}	a_{43}

a_{11}	$a_{12}\pm p\%$	a_{13}
a_{21}	a_{22}	$a_{23}\pm p\%$
a_{31}	$a_{32}\pm p\%$	a_{33}
$a_{41}\pm p\%$	a_{42}	a_{43}



One-class approach

Bicomponent mixing system

- Anomaly generation.

One-class approach

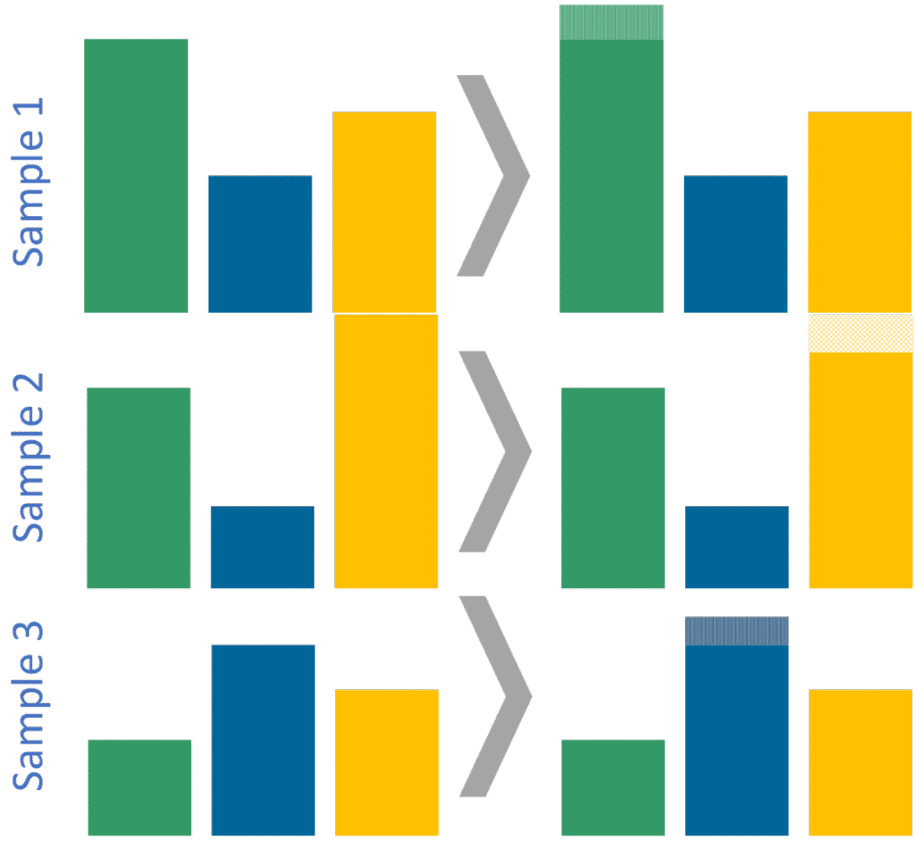
Bicomponent mixing system

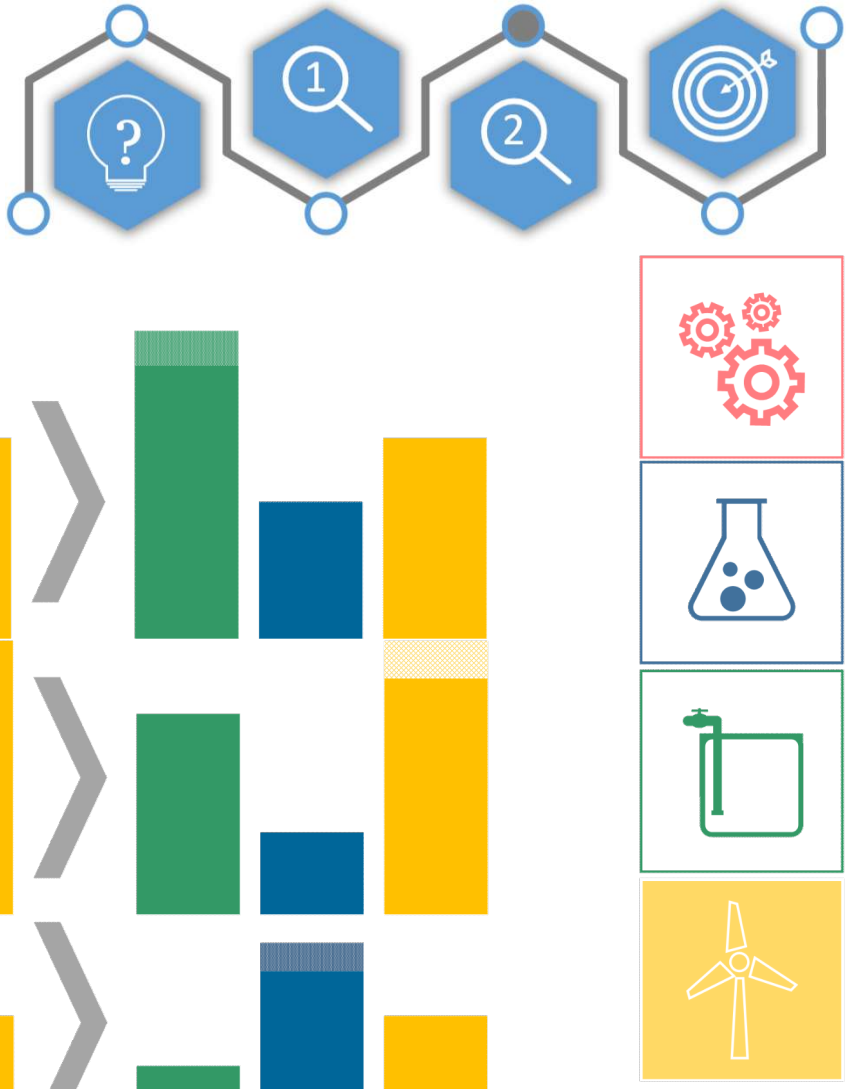
- Anomaly generation.

One-class approach

Bicomponent mixing system

- Anomaly generation.

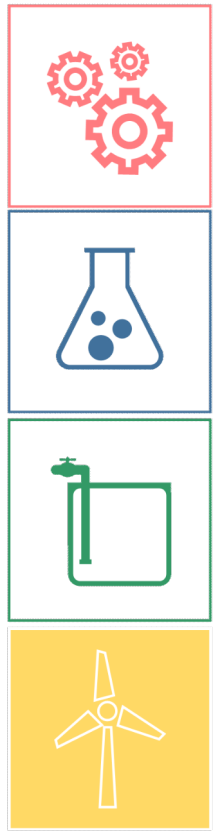




One-class approach

Bicomponent mixing system

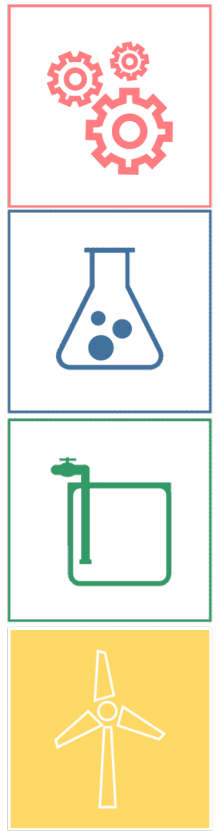
- Experiments and results.
  - Classifier inputs.
    - Four flows.
    - Four pressures.
    - Two pump speeds.
  - Data conditioning.
    - 0 to 1.
    - Z-Score.



One-class approach

Bicomponent mixing system

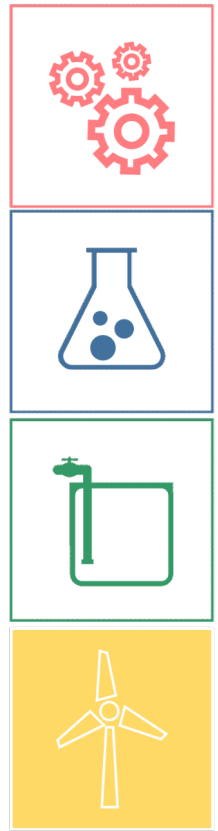
- Experiments and results.
  - ACH.
    - Expansion parameter λ: 0.9, 1, 1.1.
    - Projections: 5, 10, 50, 100, 500, 1000, 5000, 10000
  - Autoencoder.
    - Neurons in the hidden layer: 1:2:9.



One-class approach

Bicomponent mixing system

- Experiments and results.
  - SVM.
    - Outlier percentage: 0:1:5.
    - Kernel function: Gaussian.
  - PCA.
    - Components: 1:1:10
  - Tested anomalies.
    - Selected anomalies: 5 % of the dataset. Deviation: 25 %.



One-class approach

Bicomponent mixing system

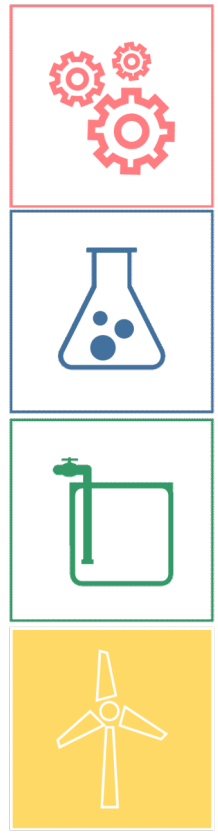
- Experiments and results.
  - ACH.
  - Autoencoder.
  - SVM.
  - PCA.

Projections	λ	AUC	Training time (min)
10000	1	98,15	14,97

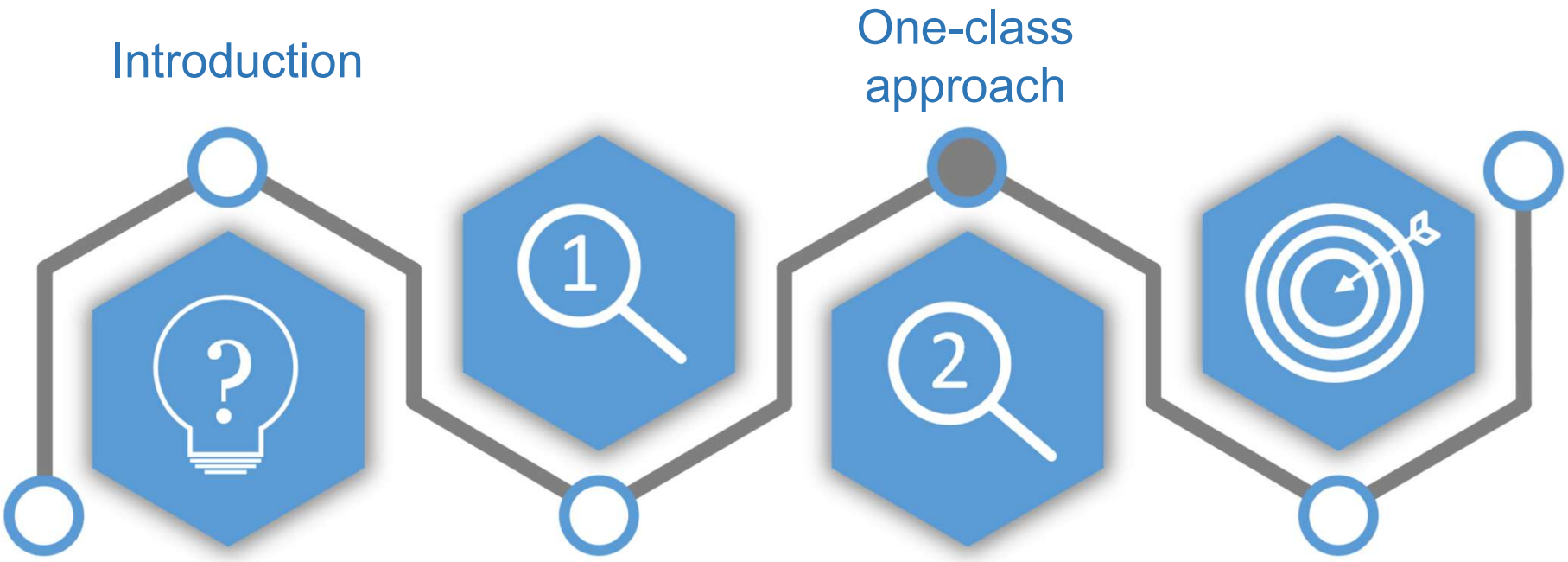
Hidden layer neurons	Conditioning	AUC	Training time (min)
9	Raw	95,81	230,33

Outlier percentage	Conditioning	AUC	Training time (min)
5	0-1	95,55	2,60

Components	Conditioning	AUC	Training time (min)
5	0-1	97,49	0,05

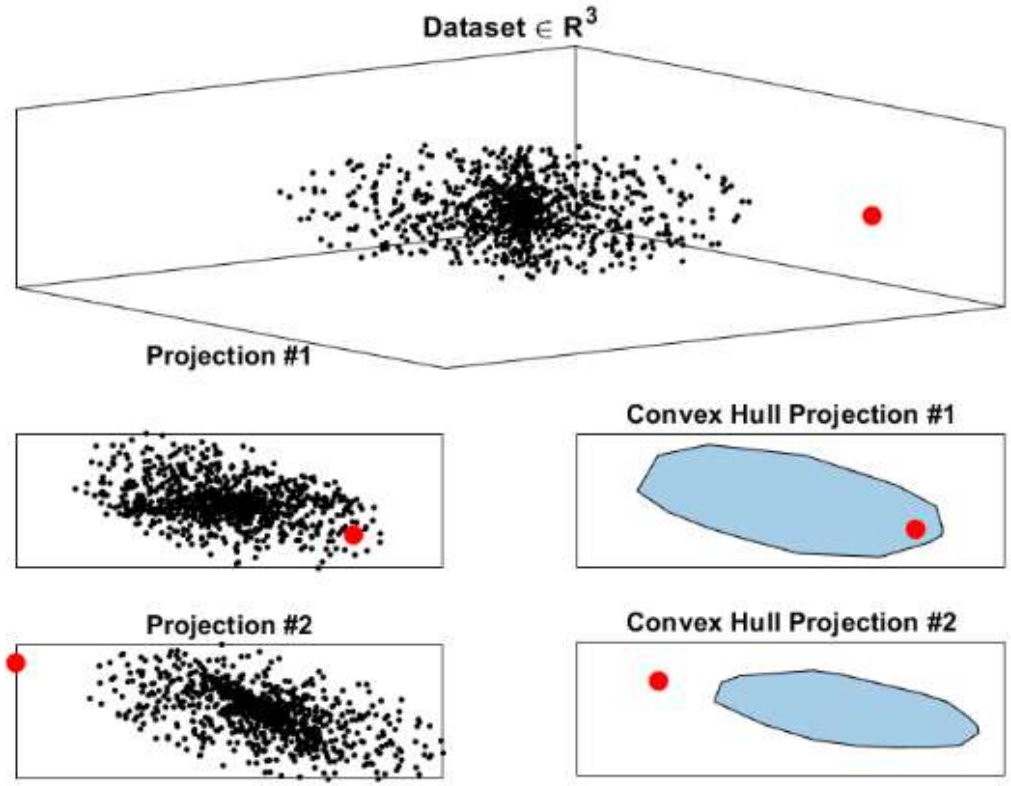


General Index



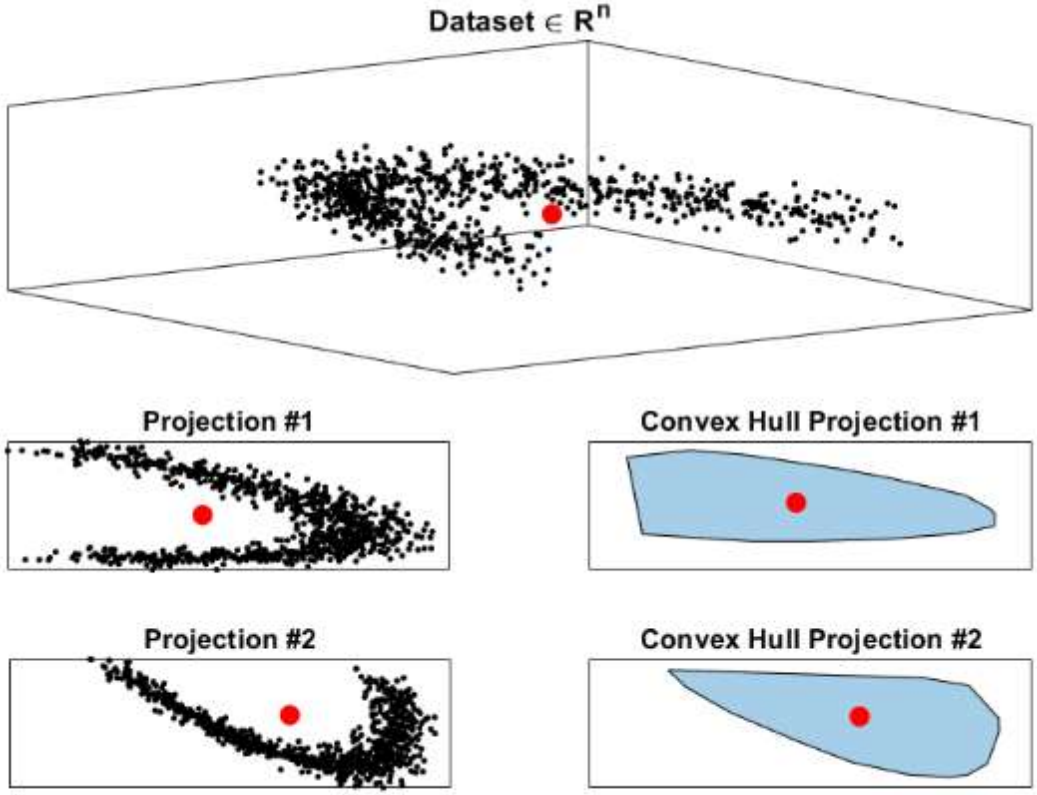
Other Works

New algorithms



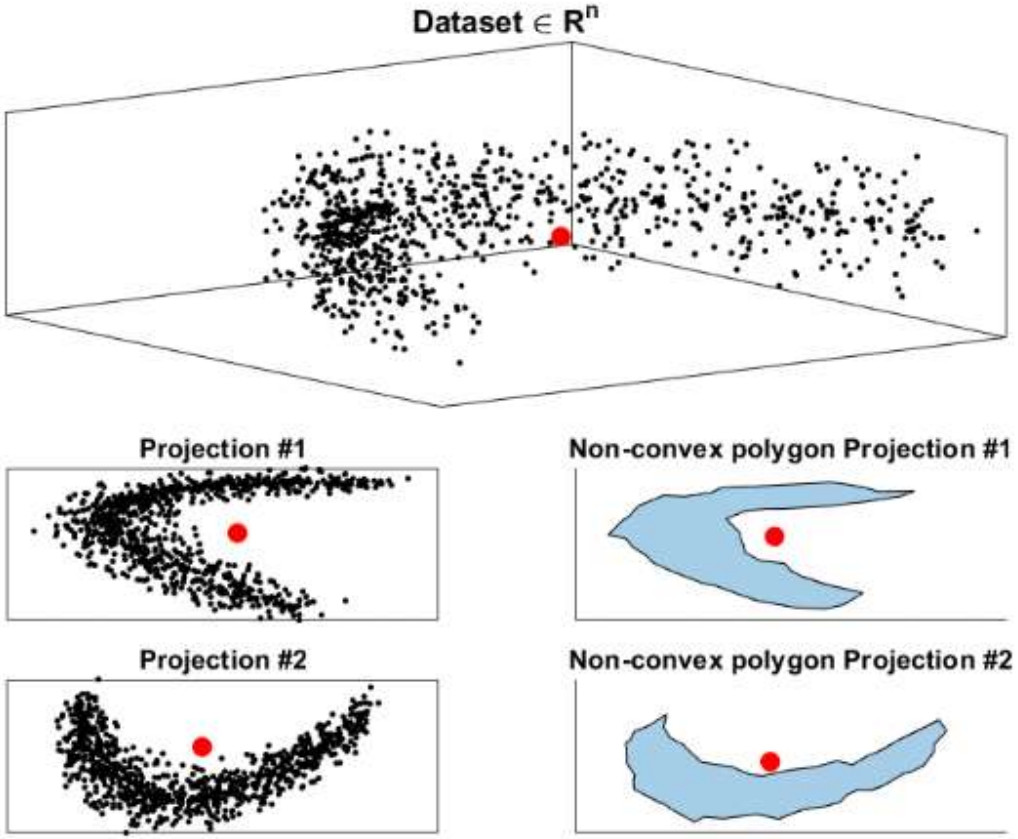
Other Works

New algorithms



Other Works

New algorithms



#ProyectosCiber

Infraestructuras críticas ciberseguras mediante modelado inteligente de ataques, vulnerabilidades y aumento de seguridad de sus dispositivos IoT para el sector de abastecimiento de agua

2024 | 2025

Colabora:

INCIBE - Instituto Nacional de Ciberseguridad
UDC - Universidade da Coruña
CTC - Grupo de Investigación Ciencia y Técnica Cibernética

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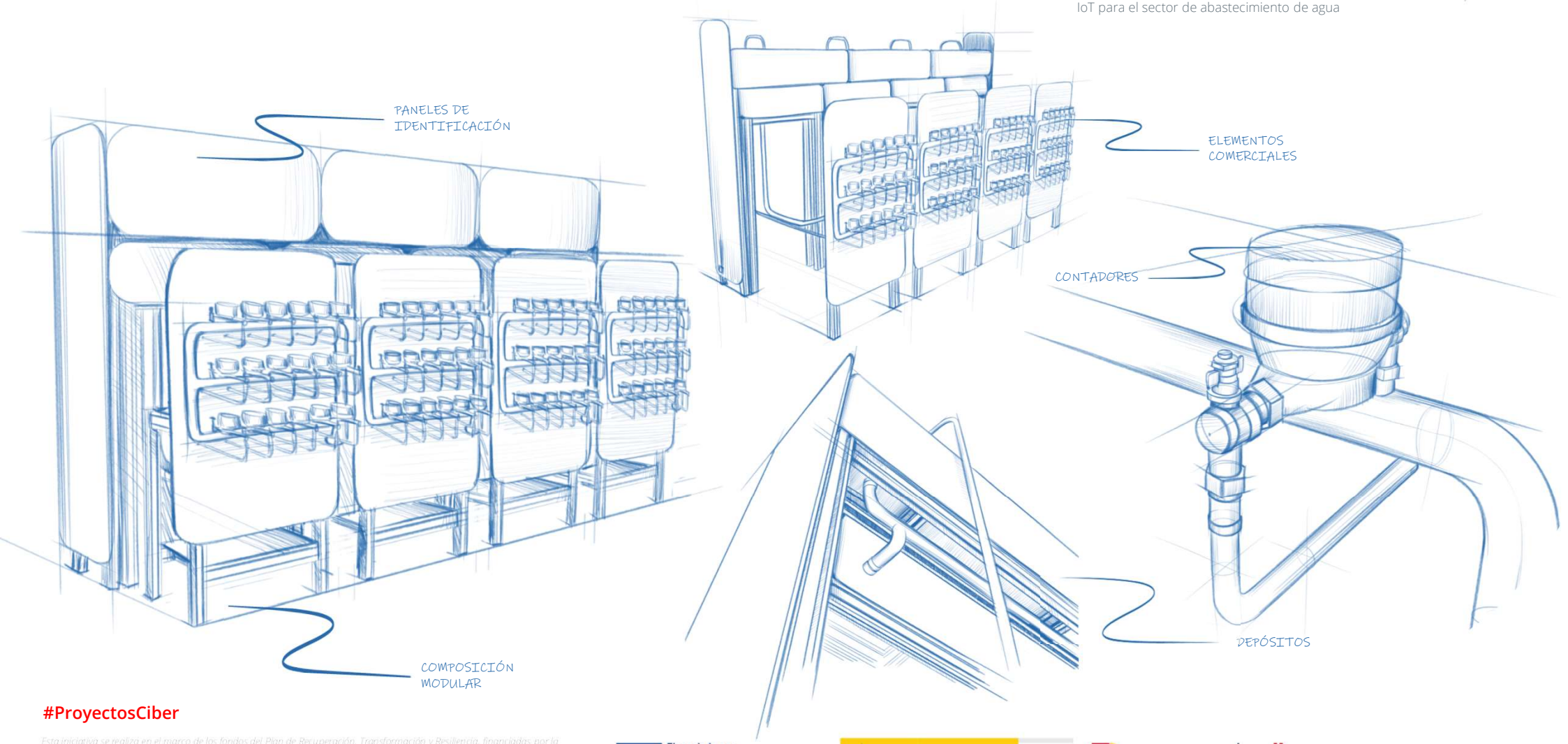
Andrés José Piñón Pazos
María Carmen Meizoso López
Francisco Javier Pérez Castelo
Benigno Antonio Rodríguez Gómez

Financiado por la Unión Europea NextGenerationEU



#ProyectosCiber

Esta iniciativa se realiza en el marco de los fondos del Plan de Recuperación, Transformación y Resiliencia, financiados por la Unión Europea (Next Generation), el proyecto del Gobierno de España que traza la hoja de ruta para la modernización de la economía española, la recuperación del crecimiento económico y la creación de empleo, para la reconstrucción económica sólida, inclusiva y resiliente tras la crisis de la COVID19, y para responder a los retos de la próxima década

Financiado por la Unión Europea NextGenerationEU

GOBIERNO DE ESPAÑA MINISTERIO PARA LA TRANSFORMACIÓN DIGITAL Y DE LA FUNCIÓN PÚBLICA

Plan de Recuperación, Transformación y Resiliencia

incibe_ INSTITUTO NACIONAL DE CIBERSEGURIDAD

UNIVERSIDADE DA CORUÑA

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GOBIERNO DE ESPAÑA MINISTERIO PARA LA TRANSFORMACIÓN DIGITAL Y DE LA FUNCIÓN PÚBLICA

Plan de Recuperación, Transformación y Resiliencia

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UNIVERSIDADE DA CORUÑA

Other Works

More projects

- Score of the probability of suffering from pathologies according to medical examinations.
- Detecting anomalies in retail sector.

Detección de anomalías basadas en sensores virtuales y en técnicas one-class

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