Explicabilidad en Inteligencia Artificial Aplicada en Problemas de Ingeniería

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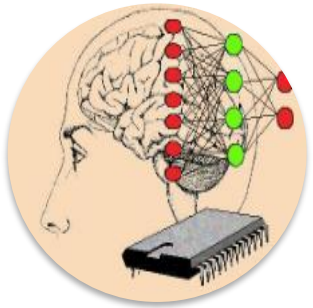
Abril 2024

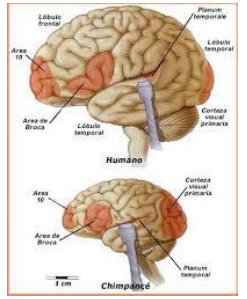
Contenido

- Introducción a la IA
- IA en Educación
- IA en Smart Grid
- IA en Producción
- IA en Telecomunicación
- Futuros retos

¿Qué es Inteligencia …?



El cerebro humano es 3 veces mas grande, con una ***red neuronal mas densa e interconectada***, con más de ***80 millones de neuronas*** que funcionan de manera ***conexionista distribuida,*** siendo la ***base de la inteligencia***



Según el diccionario de la Real Academia Española:

- Capacidad para comprender o entender.
- Capacidad para resolver problemas.
- Conocimiento, acto de comprensión.
- Sentido en el que puede tomarse una proposición, un dicho o una expresión.
- Habilidad, destreza y experiencia

....

Inteligencia: capacidad de adquirir y usar conocimiento

¿Qué es Inteligencia Artificial?

Capacidad de las **computadoras** para **realizar tareas** que normalmente requerirían **inteligencia humana**.

Abarca la **ciencia e ingeniería dedicada a diseñar y programar computadores** que ejecutan **tareas que requieren inteligencia** si la hicieran los seres humanos

Es interdisciplinaria: neurociencias, lógica matemática, psicología, teoría de la información, ciencias de la computación, entre otras.

- **inteligencia artificial estrecha/débil (ANI)**
- **Inteligencia Artificial General (AGI)**
- **Superinteligencia Artificial (ASI)**

La IA generativa es un tipo de IA que permite generar nuevos contenidos en lugar de analizarlos o manipularlos. Esos nuevos contenidos son de tipo texto, fotos, audio o vídeo, y normalmente son indistinguibles de los contenidos creados por humanos.

Los grandes modelos de lenguaje (LLM), que usan los chatbots,son un tipo de IA generativa.

Evolución de IA

Razonamiento:

Resolución de problemas mediante **inferencia:** deductiva, abductiva o inductiva

Aprendizaje Automático:

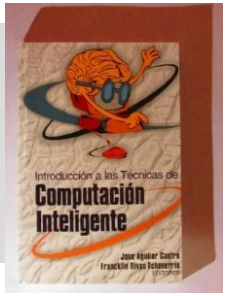
técnicas que que permitan que las computadoras *aprendan* a partir de los **dato**s o **experiencia**.

Procesamiento del lenguaje natural:

procesar información expresada en **lenguaje humano**

Computación Inteligente:

Abarca las tres técnicas mas importantes de la IA: **Redes neuronales artificiales, Lógica difusa, Computación Evolutiva**



Universo de la IA

Visión Artificial:

Comprender y analizar **imágenes y videos**

Planificación:

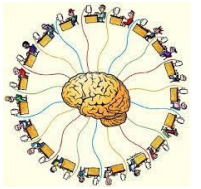
Generar **secuencias de acciones** para alcanzar un objetivo

Búsqueda:

Resolución de problemas mediante el **recorrido** de un espacio de **posibles soluciones (meta-heurísticas, etc.).**

Inteligencia colectiva:

describen los procesos de **aprendizaje grupales**. Muchos bioinspirados como las colonias de insectos: PSO, ACO.



Sistemas auto-organizados y autonómicos

Sistemas que se **auto-regulan** con capacidades que **emergen**

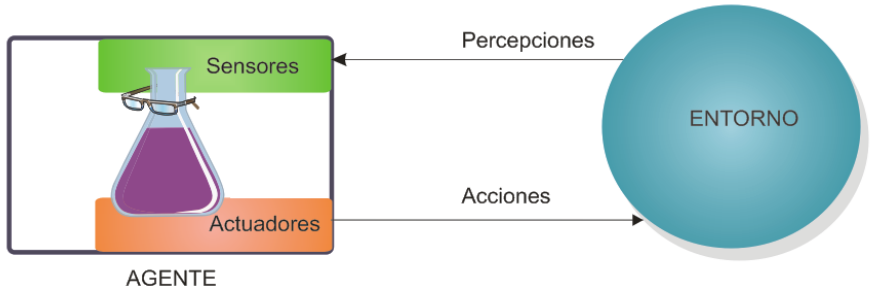
Aplicaciones

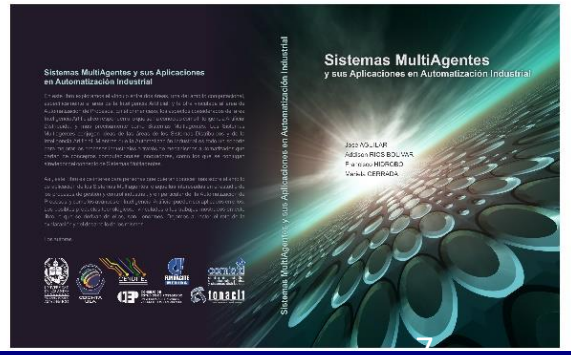
Es inimaginable

En esta década, prácticamente todo software tendrá algo de IA

Concepto de Base: Agentes

Es un sistema (quizas computacional) que está *situado en un entorno*, que es capaz de realizar *acciones autónomas* flexibles en ese entorno para *alcanzar sus objetivos*





Caracterizado por:

–SU ESTRUCTURA (ARQUITECTURA)

–SUS ACCIONES (COMPORTAMIENTO)

Arquitectura+programa

Mecanismos para/de

- **resolver un problema**
- **planificar sus actividades /tareas**
- **representar el conocimiento**
- **razonamiento**
- **aprendizaje**
- **percepción**
- **comunicarse**

Agentes

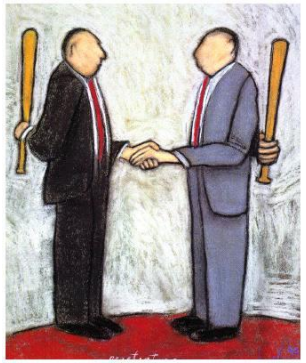
Avatar

https://www.alamy.es/avatar-chica-con-pelo-largo-y-oscuro-avatar-y-rostro-unico-icono-en-el-estilo-de-dibujos-animados-de-simbolos-vectoriales-ilustracion-web-de-stock-image213116418.html

Robots Sociales

Vehículo Autónomo

Sistemas Multiagentes



Es un sistema informático formado por un ***grupo de agentes*** que ***interactúan*** entre sí utilizando protocolos y lenguajes de comunicación de alto nivel, para ***resolver problemas*** que pueden estar más allá de las capacidades o del conocimiento de cada uno.

Enjambre de Robots

Vehículos Autónomos en una ciudad

Vistas como agentes inteligentes!!

Capacidad de las cosas para aprender, razonar e interactuar

IoT e IA

SECTOR INDUSTRIAL

Donde encontramos maquinaria que se encarga de controlar los procesos de fabricación, la temperatura, el control de producción, etc. Todo conectado a Internet.

SECTOR URBANO

Control de semáforos, de puentes, de vías de tren, etc. Cada vez más ciudades utilizan el Internet de las Cosas con el que pueden monitorizar el funcionamiento de sus estructuras así como añadir variaciones ante nuevos eventos.

SECTOR AMBIENTAL

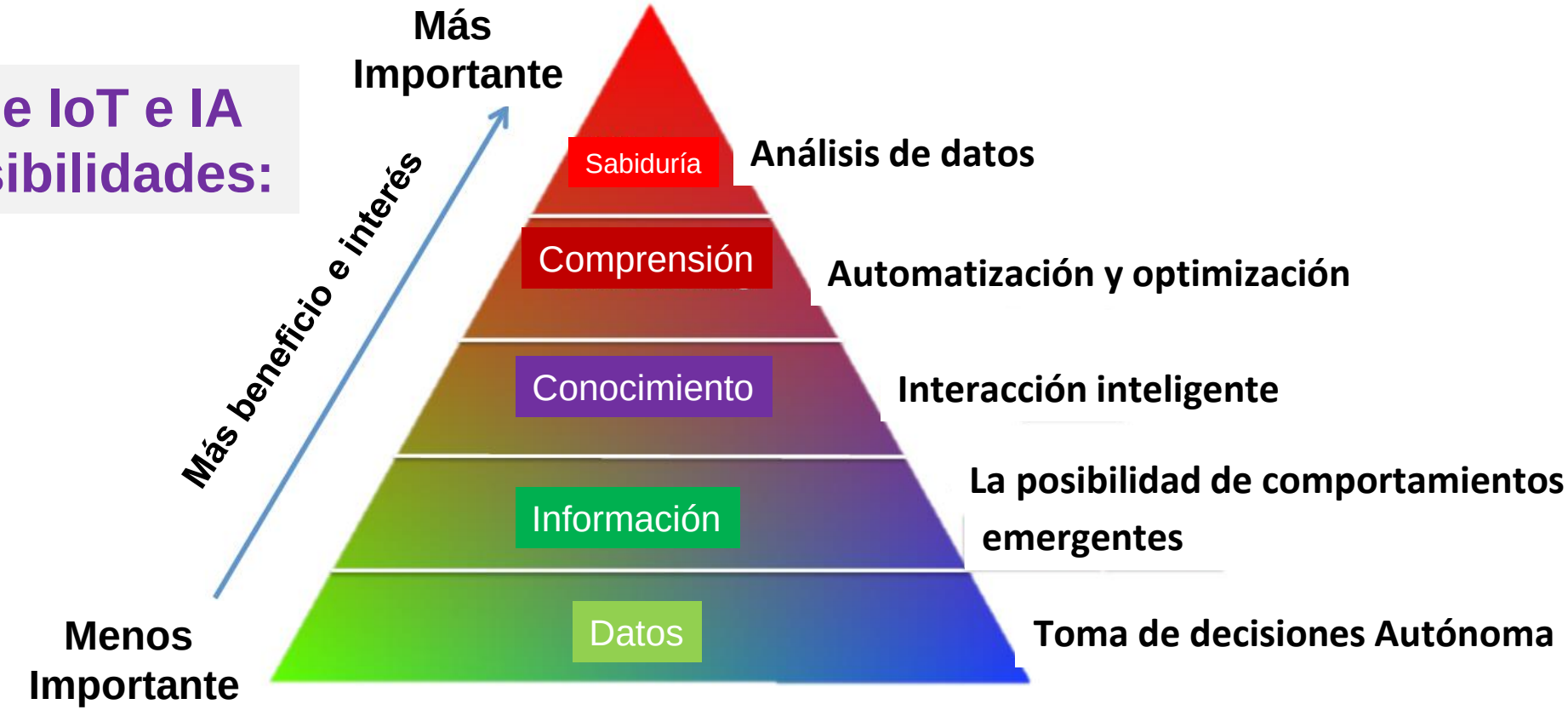
Con el Internet de las Cosas se permite acceder a información de sensores atmosféricos o meteorológicos.

SECTOR SANITARIO

Clínicas y hospitales confían cada vez más en esta tendencia que permite monitorizar a los pacientes sin ser invasivos.

Estos **dispositivos inteligentes** **recopilan datos** útiles con la ayuda de varias tecnologías, y luego procesan y hacen que los datos fluyan de **forma autónoma** a otros dispositivos

La combinación de IoT e IA ofrece muchas posibilidades:

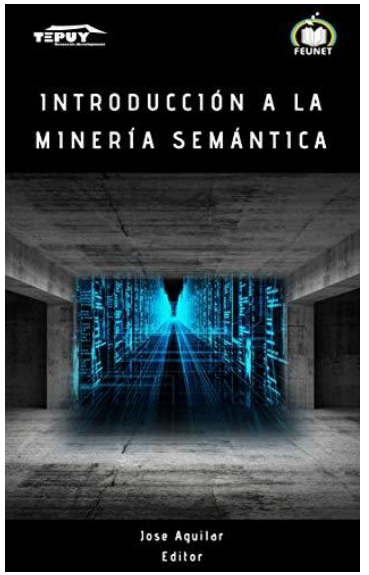


Ciencias de Datos e IA

Minería de Datos

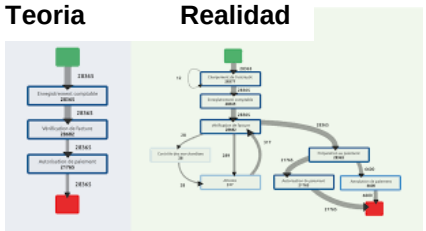
Minería Semántica

Ontológica
De la web
De datos semánticos
Del texto



Minería de Cualquier Cosa:
es la electricidad actual de la economía

Minería de Procesos



Minería de Grafos

Ciencias de Datos e IA

Anális
ciencia qu
bruto c
buscar c
conclu
inform

Pero,
¿Cómo automatizar ese proceso?

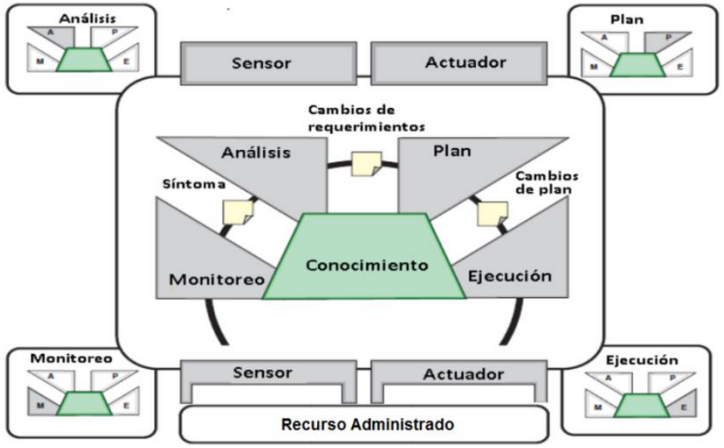
Optimización
Identificación
Diagnóstico
...

Avances actuales de la IA

¿Puede un sistema actuar de forma autónoma?

La respuesta es Si

la IA esta programada para actuar **sin intervención y control humano** y tener la **capacidad auto-adaptativa** de sus propios recursos

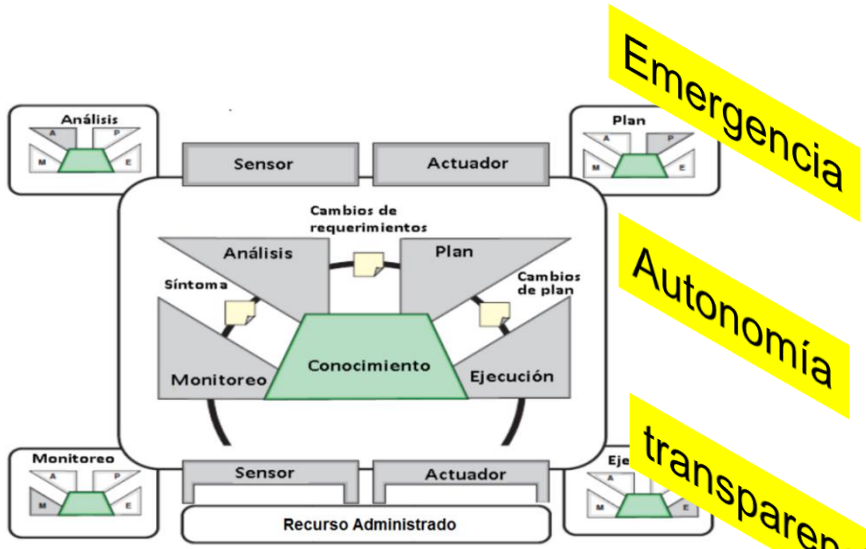


Ejemplos son los **vehículos autónomos**, que combinan varias ramas de la IA para realizar tareas **sin supervisión humana**, e incluso de definir sus objetivos,

Avances actuales de la IA

Sistemas Autónomos

La Inteligencia Artificial permite componer automáticamente servicios complejos a partir de servicios básicos que los dispositivos desplegados en el entorno poseen, para alcanzar un determinado objetivo



Emergencia

Autonomía

transparencia

Las Tecnologías de Información, Comunicación y Automatización (TICAs) se están desplegando por todos lados

Es el conjunto de sistemas que hacen posible la adecuación de un ambiente (salón de clases, museos, casas, etc.)

- Integra todos los dispositivos con capacidad **inteligente y autónoma**, en la dinámica de actividades del entorno
- Dispositivos y software se **auto-organizan**

Analizar:

Interpreta las situaciones que acontecen en el proceso que se está estudiando: detecta, comprende, diagnostica, etc.

Toma de decisiones:

Define **acciones a tomar** sobre el proceso, con el fin de alcanzar el objetivo definido para el ciclo.

Monitoreo:

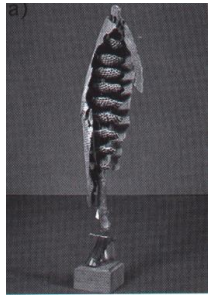
identifica, captura, pre-proces las variables del proceso bajo estudio,

Base de Conocimiento (Modelos)

PROCESO

ACODAT

Emergencia



Comportamiento de un sistema, que "emerge" de las interacciones entre sus componentes, difíciles o imposibles de predecir.

Cerebro y colonia de hormigas son la suma de miles de decisiones de sus componentes interactuando

Hormigas	⟷	Neuronas
feromonas	⟷	Neurotransmisores
Colonia de hormigas	⟷	Cerebro humano

Inteligencia Colectiva o Social

Autonomía vs. Control
Emergente vs. Programado
Distribuido vs. Centralizado

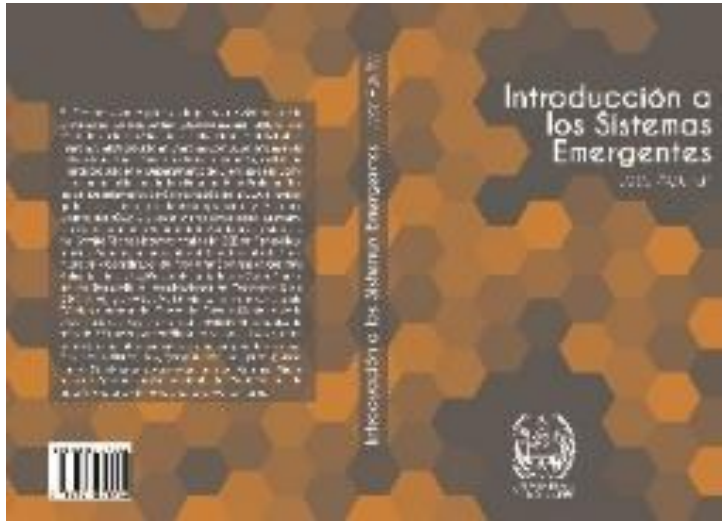
Avances actuales de la IA

Conceptos que coadyuvan a la Emergencia

Lógica del Enjambre

Auto-organización

Auto-poyesis



Estigmergia

Retroalimentación

Inteligencia Colectiva o Social

Sabiduría de la Multitud

COLONIA DE HORMIGAS

BANDADAS DE AVES

COLONIA DE ABEJAS

Sistema Educativo

Sub-sistema Académico

Sub-sistema Científico

Sub-sistema de Aprendizaje

Sub-sistema Institucional

. . .

Sub-sistema de Aprendizaje

Salón de Clases Inteligente (SaCI)

Un sistema multi-agentes

ACODAT para Análisis del Proceso de aprendizaje

ACODATs

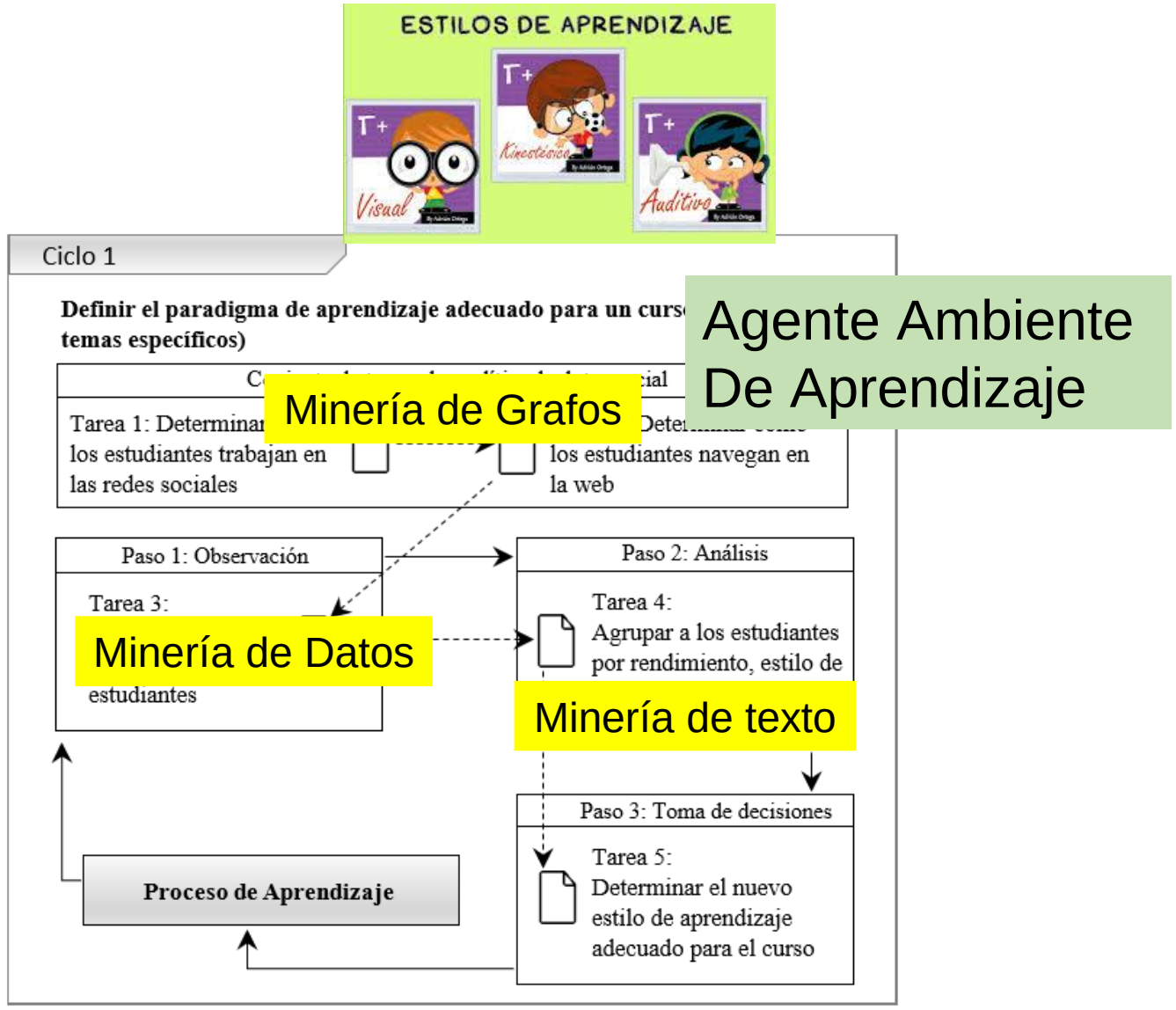
Ciclo 1: Determinar el **paradigma de aprendizaje** adecuado para un curso

Ciclo 2: Determinar los **recursos educativos ideales** para un estudiante.

Ciclo 3: Identificar a los **estudiantes con necesidades específicas**.

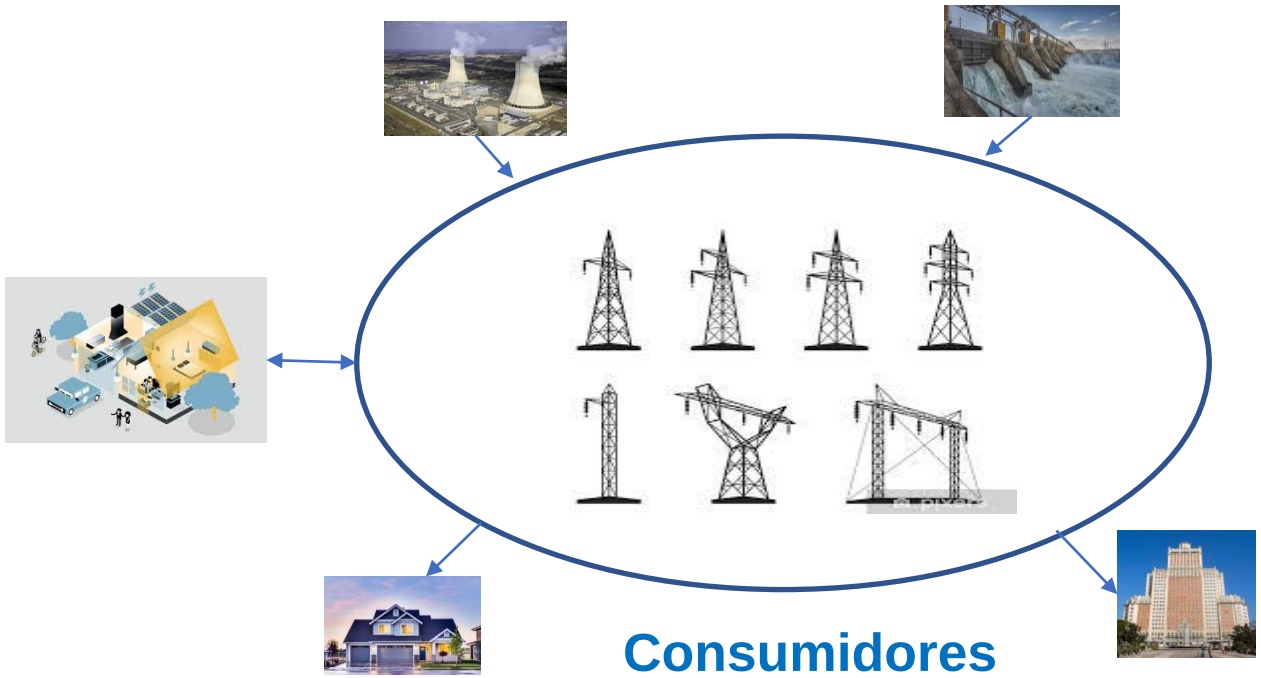
Ciclo 4: **Evitar la deserción** estudiantil.

….



Contexto

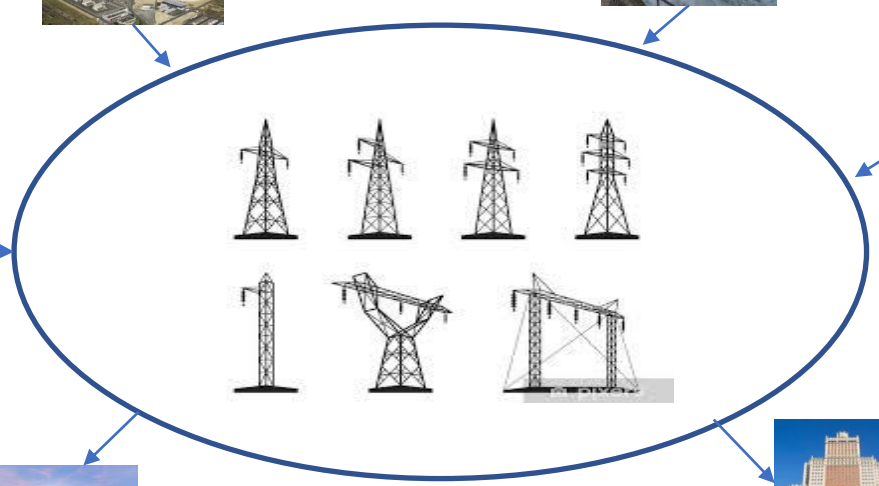
Fuentes de Energía clásicas



Contexto

Fuentes de Energía muy diversas

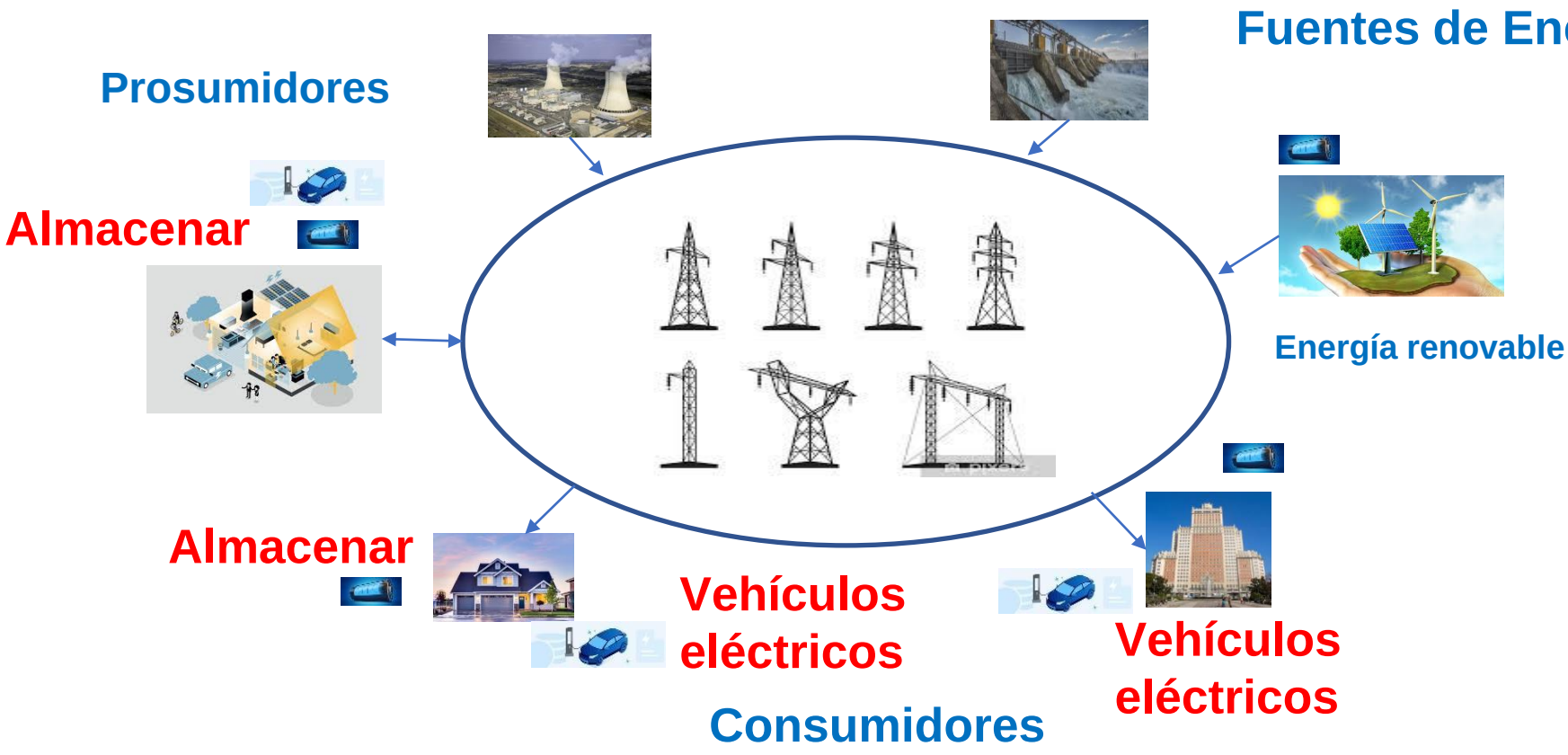
Prosumidores



Energía renovable

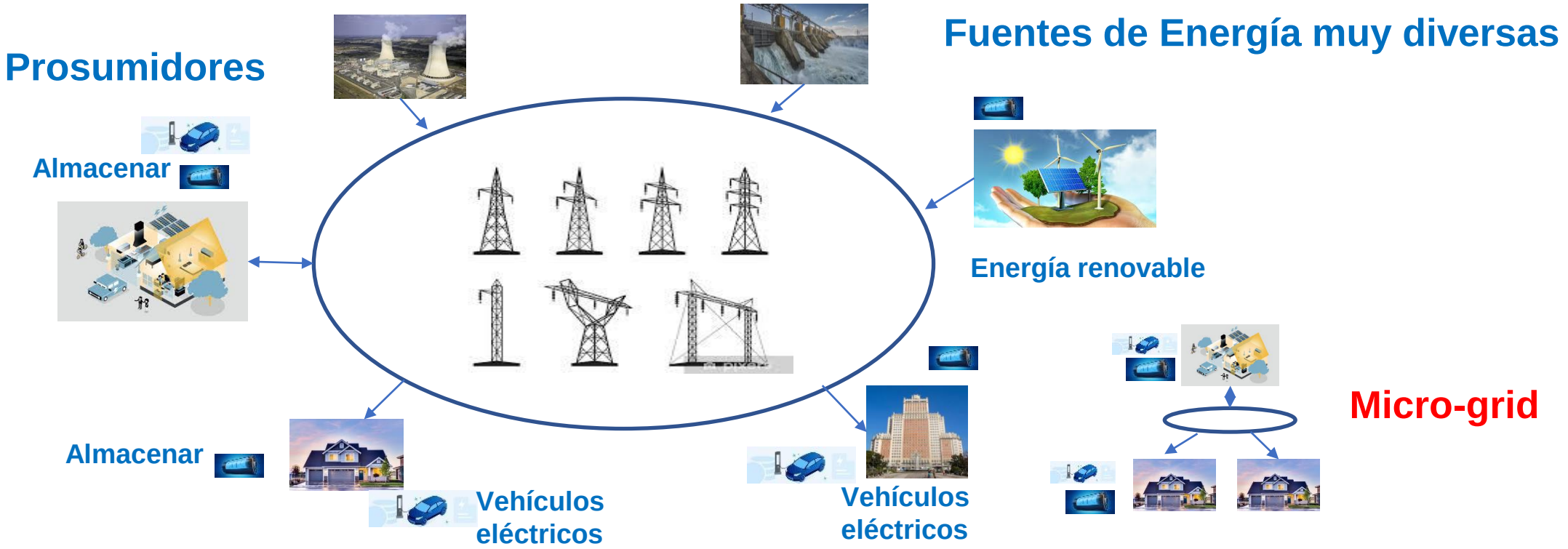
Consumidores

Contexto


Fuentes de Energía muy diversas
Prosumidores
Almacenar
Energía renovable
Almacenar
Vehículos eléctricos
Vehículos eléctricos
Consumidores

Sistema Energético

Contexto



Democratización de la producción

Sistema Energético

Una **red inteligente** energética integra el **comportamiento de sus usuarios** para asegurar un sistema energético **eficiente, sostenible**, de **alta calidad** y **fiabilidad** de suministro.

Energy Management Systems (EMS)

Energía

Intermitente
Distribuida
Se almacena
Móvil
Micro-grid

Variables

- Consumo de energía de los sistemas y equipos conectados.
- Comportamiento de los ocupantes.
- Patrones de uso de energía.
- Costos.
- Factores cíclicos o estacionales.
- Datos del tiempo.
- …

Funciones

- Optimización de las operaciones de edificación.
- Automatización de la gestión energética
- Supervisión de servicios
- Control de servicios y funciones
- Seguimiento del estado del edificio y de las condiciones ambientales.
- …

Energy Management Systems (EMS)

Gestión Sistemas Climatización

Planificación de Cargas Controlables

Almacenar

Energía renovable

Micro-grid

Control Emergente de Micro-redes

Almacenar

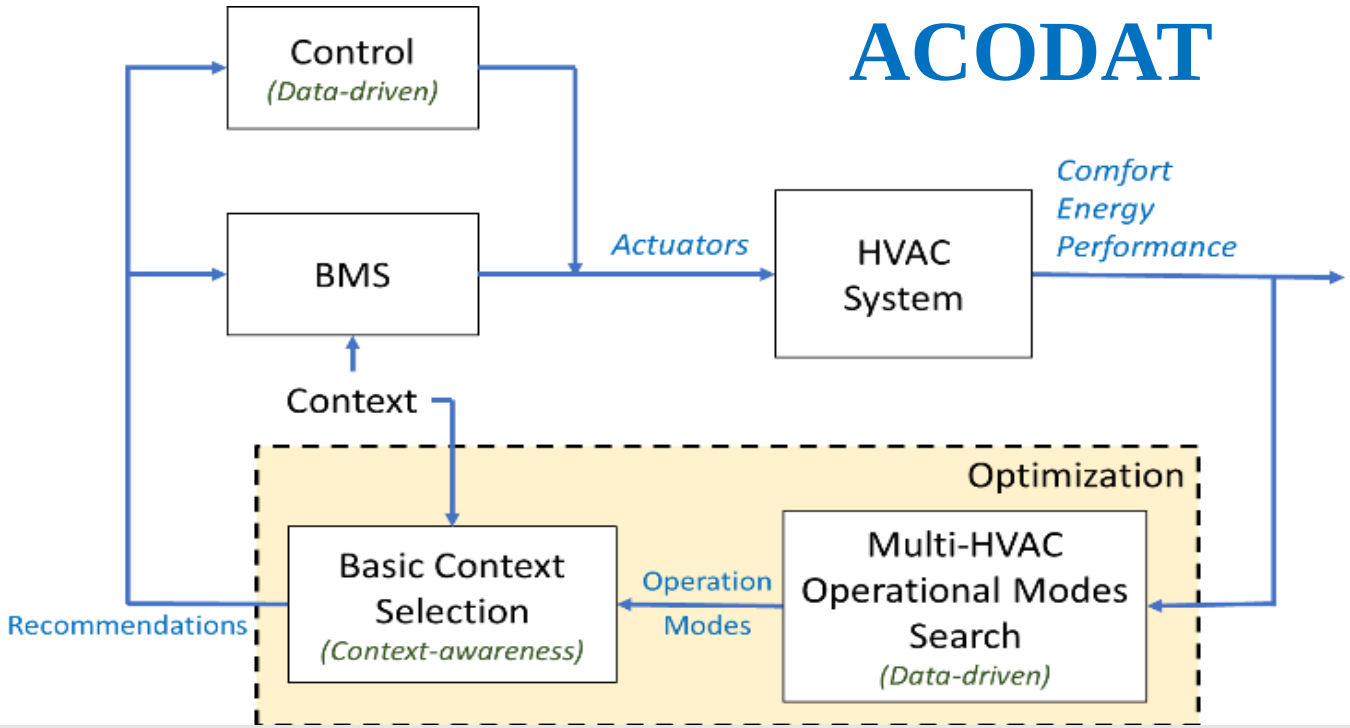
IoT y Energía

Vehículos eléctricos

Análisis de Datos energéticos

Sistema Energético

Arquitectura de gestión autónoma para sistemas de climatización (HVAC) en edificios inteligentes:

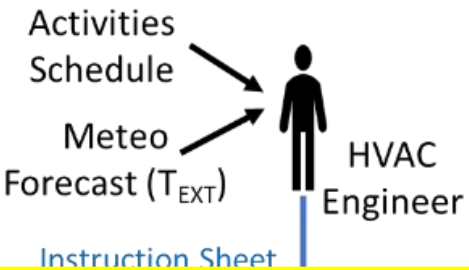


Teatro Real de Madrid

J. Aguilar, A. Garces-Jimenez, N. Gallego-Salvador, J. Gutiérrez de Mesa, J. Gómez-Pulido, A. García-Tejedor "A multi-HVAC system autonomic management architecture for smart buildings", *IEEE Access*, Vol, 7, pp. 123402 – 123415, 2019 (http://bit.do/e7U9L)

Sistema Energético

Arquitectura de gestión autónoma para sistemas de climatización (HVAC) en edificios inteligentes



Una de las tareas de AdD:

Problema multiobjetivo

Min

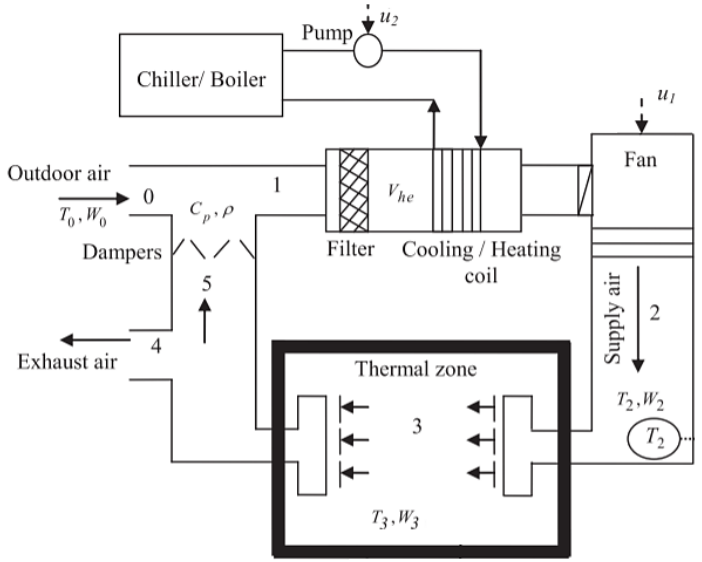
$$Min_{HVAC_{mode},t}\,(P_{consumed}(\mathrm{HVAC_{mode}},t),\ Cost_e(\mathrm{HVAC_{mode}},t),\ COP_{global}(\mathrm{HVAC_{mode}},t),\ \mathbf{Comfort}(\mathrm{HVAC_{mode}},t))$$

Disminuir Costos

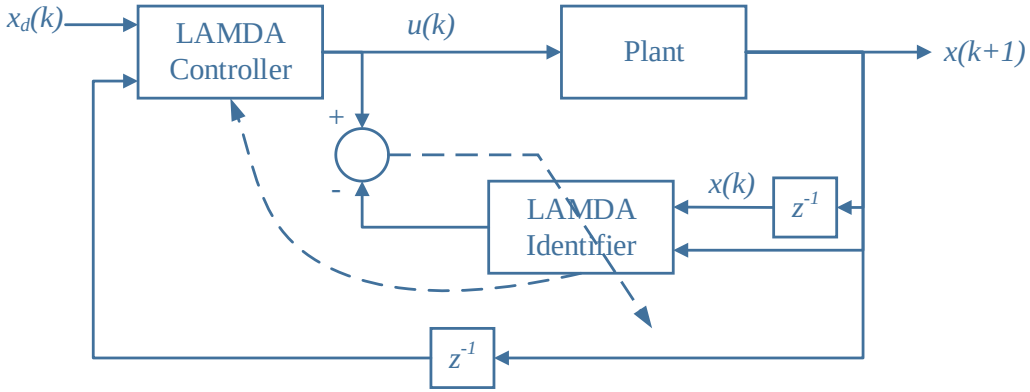
Maximizar Confort

Control inteligente de Sistemas de climatización en edificios inteligentes

Control difuso para un sistema HVAC

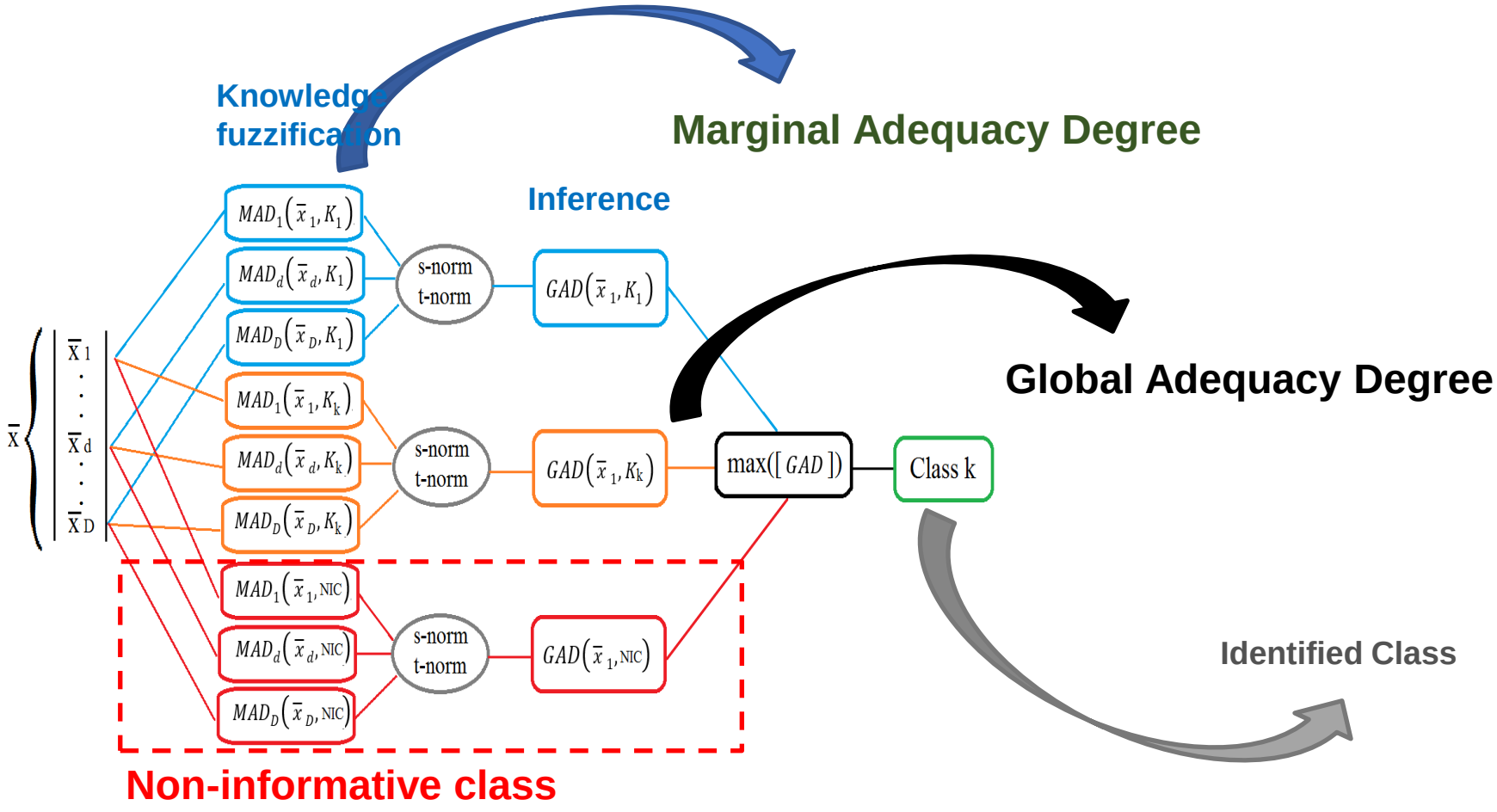


LAMDA como controlador

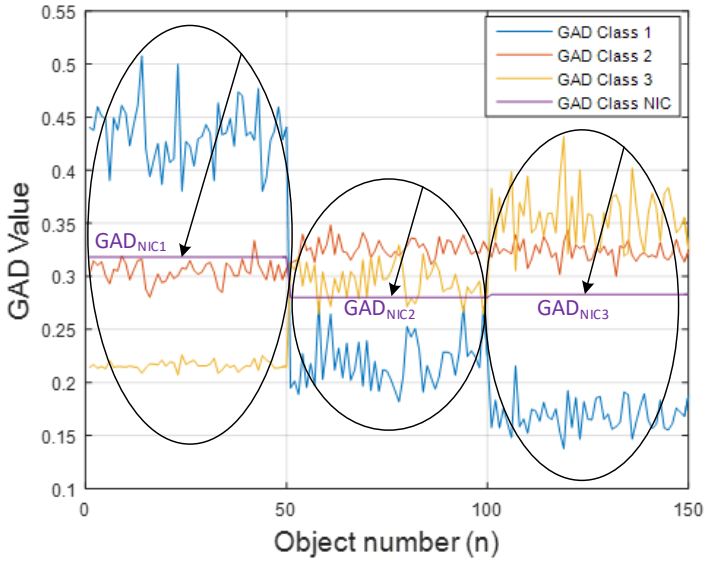


L. Morales, J. Aguilar, A. Garces-Jimenez, J. Gutiérrez de Mesa, J. Gómez-Pulido, Advanced fuzzy-logic-based context-driven control for HVAC management systems in buildings", *IEEE Access*, vol. 8, pp. 16111-16126, 2020. (http://bit.do/fqVhm)

Learning Algorithm for Multivariable Data Analysis (LAMDA)



Control inteligente de Sistemas de climatización en edificios inteligentes



$$R^{(l)}:$$

$$IF\ \{\bar{x}_1\ is\ F_1^i\ and\ \ldots, and\ \ \bar{x}_n\ is\ F_n^k\}\ \ THEN\ \{y_l\ i$$

where $\bar{x_j} \in U_j$. $y_j \in V_j$. F_j^l and G^j are fuzzy sets in U_j and V_j, respectively, $(j = 1,\ldots,n), (l = 1,\ldots,m)$, where n is the number of features and m is the number of rules (known as LAMDA classes).

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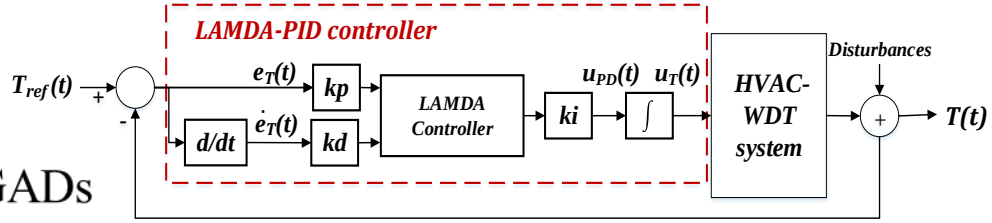


In this case, LAMDA operates with the GADs using the first-order T-S inference method, where $G^j = q^j$:

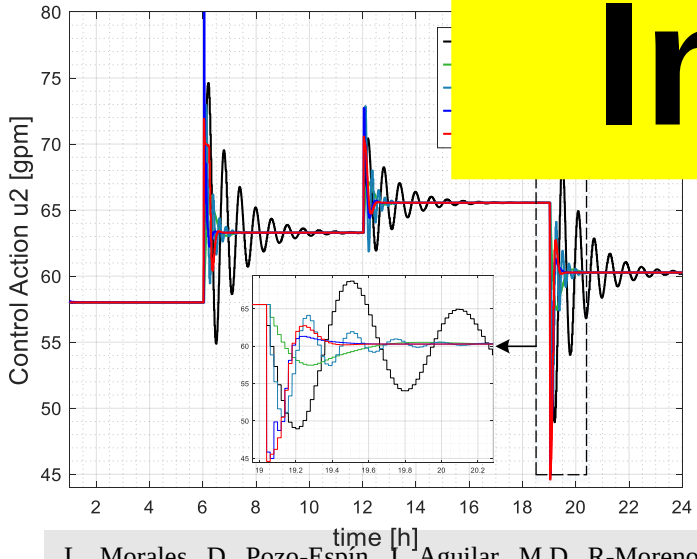
$$u = \beta \sum_{k=1}^{n} q^k GAD_{k,\bar{X}} \qquad \beta = \frac{max(q^k)}{\sum_{k=1}^{n} q^k GAD_{k,max(\bar{X})}}$$

Sistemas de climatización en edificios inteligentes

Enfoques de control inteligente aplicados a la regulación de sistemas HVAC

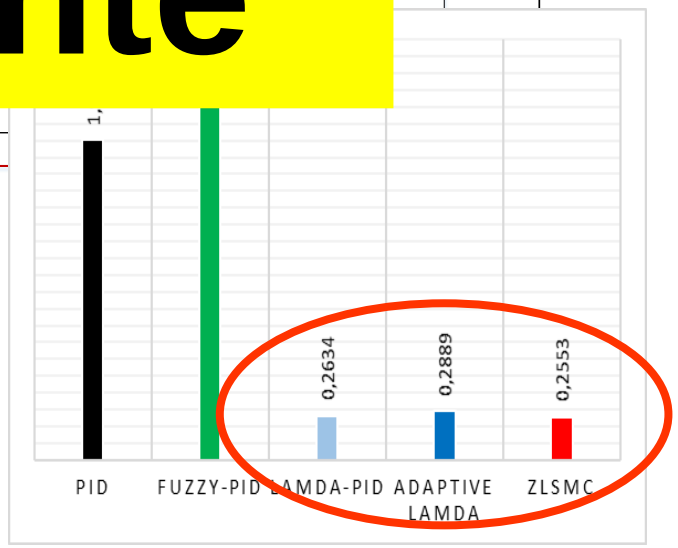
- PID
- Fuzzy-PID
- LAMDA-PID,
- LAMDA-Sliding Mod
  numbers (ZLSMC)
- Adaptive LAMDA

Control Inteligente



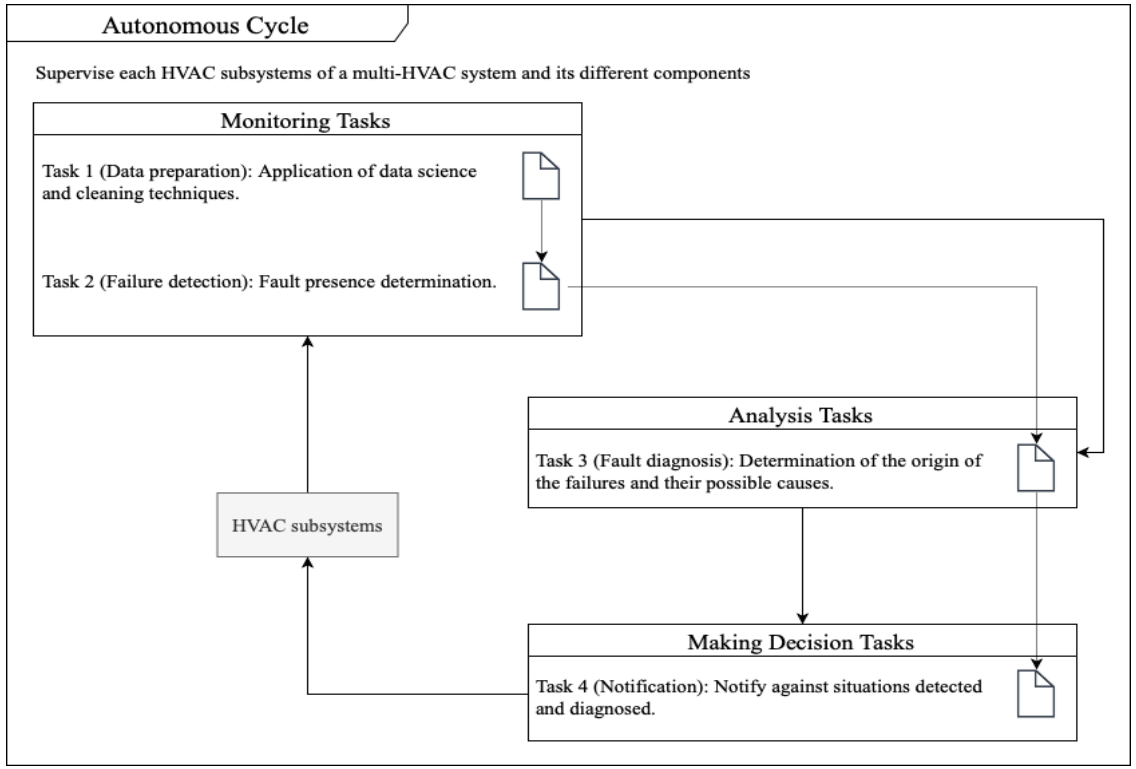
Results of temperature disturbance applied to the MIMO HVAC: (a) control action u_2,

Results of ISE



L. Morales, D. Pozo-Espín, J. Aguilar, M.D. R-Moreno, 'Approaches based on LAMDA control applied to regulate HVAC systems", *Journal of Process Control*, en revisión, 2022

Supervisión de un sistema multi-HVAC



ACODAT

Task 2	Fault Detection
Description:	Failure identification
Data source:	HVAC system Environment
Data analytics type:	Classification
Data analytics technique:	K-neighbors, MLP, …
Knowledge model type:	Classification model
Related data analytics task:	Failure diagnosis
Autonomic cycle type:	Monitoring

Task 3	Fault Diagnosis
Description:	Failure's origin identification Possible causes
Data source:	Previous task
Data analytics type:	Clustering
Data analytics technique:	Kmeans, etc.
Knowledge model type:	Diagnosis model
Related data analytics task:	Failure detection
Autonomic cycle type:	analysis

Supervisión de un sistema multi-HVAC

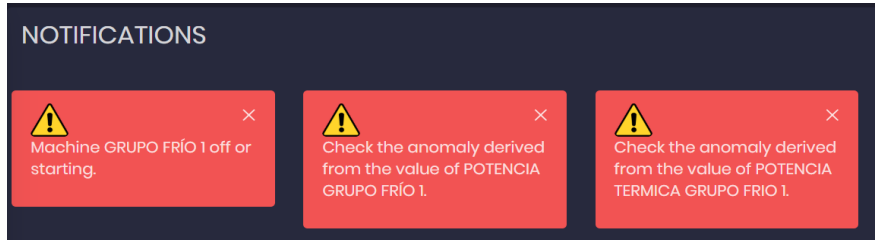
Detección

Variable	Data Model	Accuracy	MSE
COP cold group 1	MLP regressor	70.6%	0.254
	K-neighbors regressor	84.2%	0.138
	gradient boosting regressor		
COP Charles heat pump	MLP regressor		
	K-neighbors regressor		
	gradient boosting regressor		

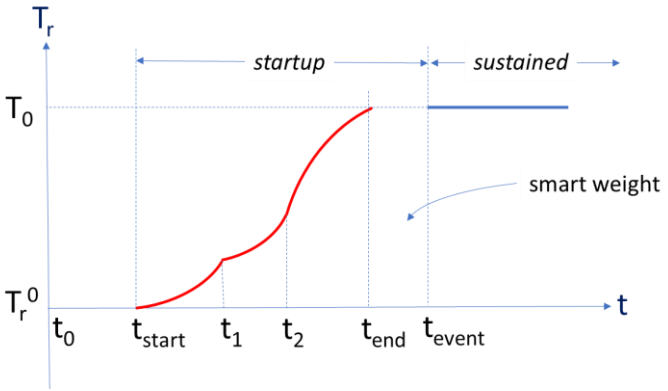
Supervisión inteligente

Diagnóstico

No. Clusters	Silhouette Coefficient
2	0.48
3	0.51
4	0.49
5	0.41

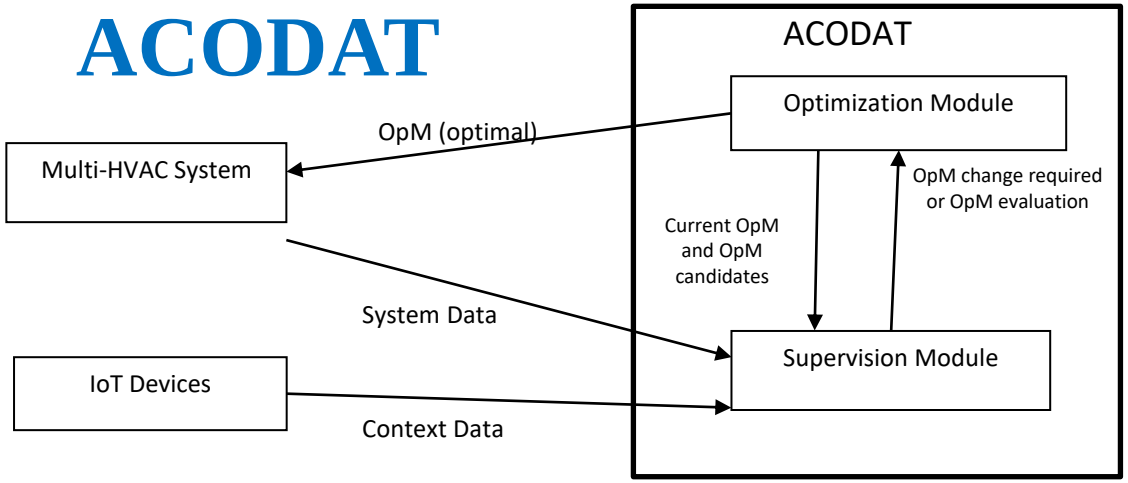


Puesta en marcha del sistema de climatización múltiples



Problema

ACODAT



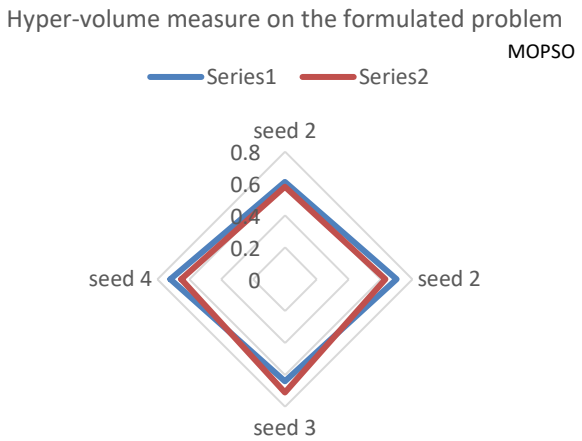
Task 1	Supervision
Description:	Identification of an abnormal situation during the initialization process of the multi-HVAC system
Data source:	Information of the process to reach the setpoint
Data analytics type:	Classification
Possible data analytics techniques:	Random forest, linear regression, etc.

Task 2	Optimization
Description:	Determination of the new configuration of the multi-HVAC system
Data source:	Information about the multi-HVAC system and context
Data analytics type:	Optimization
Possible data analytics techniques	Evolutionary approaches

Puesta en marcha del sistema de climatización múltiples

Detección

Classifier ML Technique	Precision	Accuracy
Logistic regression	0.93	
Random forest	0.91	
SVM	0.83	



Reconfiguración

Arranque inteligente

en uno de los subsistemas de HVAC).
2. Aceleración abrupta del proceso de puesta en marcha
3. Consumo energético excesivo.

Suposiciones del OpM:

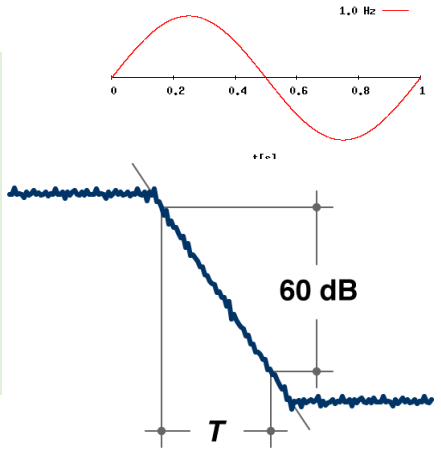
a. Todos los subsistemas HVAC están disponibles.
b. Sólo se utilizan bombas de calor agua-aire.
c. Sólo se utilizan enfriadores de agua por agua.

Conditions	% of correct degradation detections	Individual selected from the Pareto Front ($P_{consumed}$ COP Comfort)
	93%	(33, 6, 0.5)
	94%	(34, 2, 0.09)
	95%	(37.2, 4.1, 0.23)
	96%	(32.3, 3.6, 0.11)
	91%	(41.1, 2.4, 0.02)
2 and c	90%	(41.9, 4.2, 0.6)
3 and a	81%	(62.3, 2.2, 0.08)
3 and b	78%	(61.1, 4.2, 0.4)
3 and c	82%	(61.8, 3.9, 0.06)

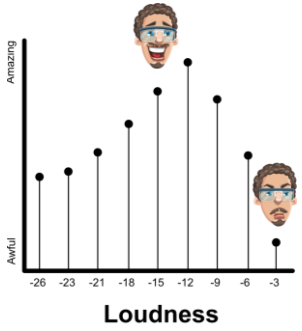
Audio para la estimación de ocupación y actividad en edificios inteligentes

Características acústicas

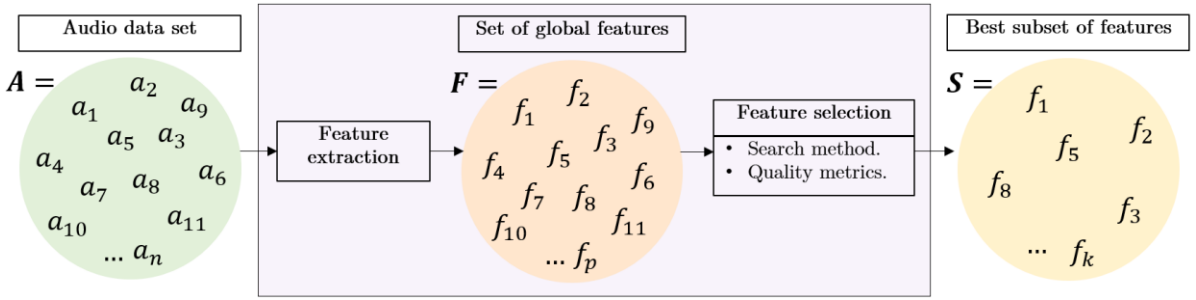
- Frecuencia dominante
- Volumen
- Tiempo de reverberación



3 Tipos descriptores
- Basada en Ingeniera del Sonido
- Basado en estadística
- Basada en Series de Tiempo



Acoustic Features Engineering



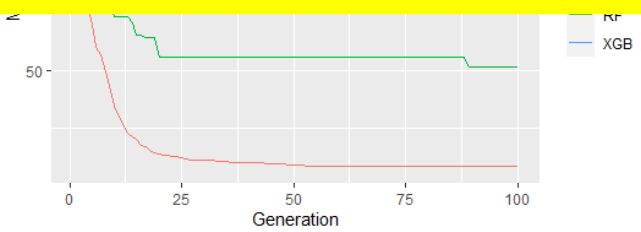
G. Santiago, M. Jiménez, J. Aguilar, E. Montoya, Audio Feature Engineering for Occupancy and Activity Estimation in Smart Buildings, Electronics, MDPI, 2021

Audio para la estimación de ocupación y actividad en edificios inteligentes

Actividad en un entorno académico

Occupancy	Acoustic Fe
Low	Normal leve loudness
Medium	Long reverbe time and low le loudness
High	High domir frequencies an level of loudn
Overcrowded	Medium lev loudness

Estimación de ocupación inteligente

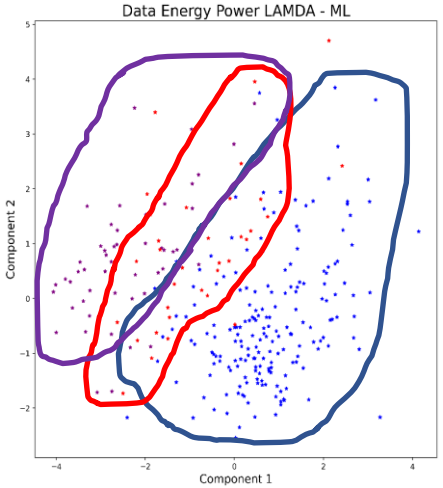


Comparación entre los valores originales y el valor de nuestro modelo con la ocupación y actividad estimadas

	22	44
	22,847	45,090
	0,847	1,090
	Low	Low
	f.med/sfm/stanility/nonlinearity/max-level-shift/ndsi	f.med/sfm/stability/nonlinearity/max-level-shift/ndsi
Activity Estimation	Cleaning and Maintenance	Cleaning and Maintenance

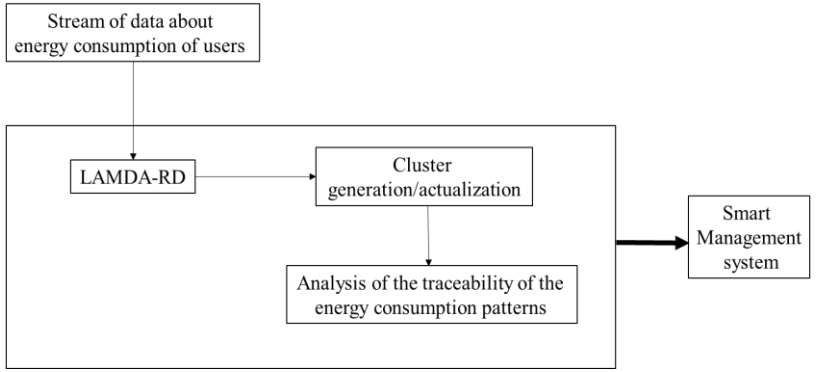
Análisis de datos energéticos

Enfoques de **etiquetas múltiples** para problemas de diagnóstico en sistemas de energía

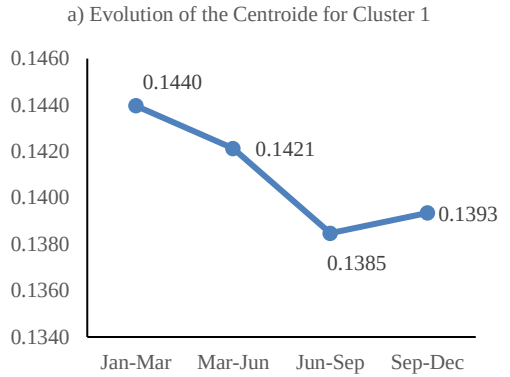


Systems using LAMDA algorithm", *Proc. 2022 IEEE World Congress on Computational Intelligence* (WCCI)

Análisis de los patrones de consumo de energía utilizando técnicas de aprendizaje en línea



Period (by trimester)	Calinski-Harabasz	Silhouette
First	1559	0.65
Second	1675	0.59
Third	2334	0.45
Four	2676	0.38

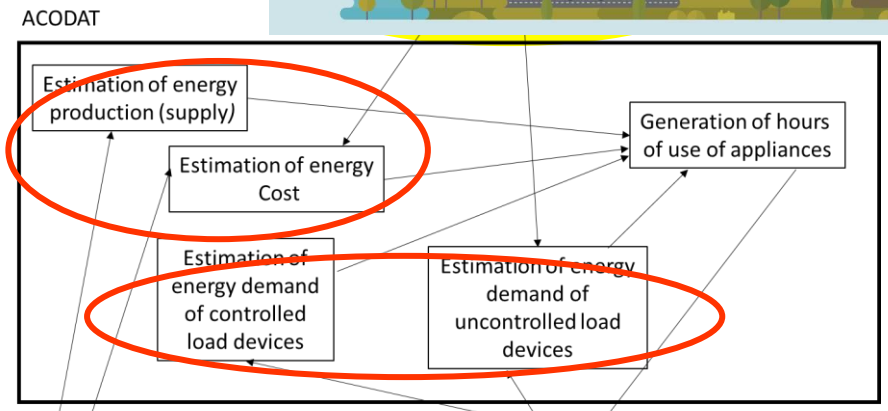


EVOLUTION OF THE ENERGY CONSUMPTION VALUE OF THE CENTROIDE OF THE CLUSTERS DURING A YEAR

Modelos de diagnóstico para sistemas de energía usando enfoques de Aprendizaje Automático en Línea que soporten **información faltante**

Planificación del uso de la Energía

Gestión energética del consumo de energía para dispositivos de carga controlable datos



Redes inteligentes

Hogar

Uncontrolled load devices

HVAC systems (12000 kWh/yr)

DHW (3000 kWh/yr)

Refrigerator (1200 kWh/yr),

home lighting system (1200 kWh/yr).

J. Aguilar, M. D. R-Moreno, Autonomous Cycle of Data Analysis Tasks for Scheduling the Use of Controllable Load Appliances using Renewable Energy, Proc. International Conference on Computational Science and Computational Intelligence, 2021

Planificación del uso de la Energía

Tarea de estimación de demanda de energía

Predicción de la energía solar producida

Technique	Number of layers	Number of epoch	SME	MAPE	R^2
RF			0.07	0.07	0.90
BNN	3	50	0.09	0.10	0.74
	4	50	0.08	0.06	0.88
	5	100	0.08	0.04	0.89

Variables

- distance-to-solar-noon (in radians),
- temperature (daily average temperature, in degrees Celsius),
- wind-direction (daily average wind direction, in degrees, 0-360),
- wind-speed (daily average wind speed, in meters per second),
- sky-cover (in a five-step scale, from 0 to 4, being 0 totally clear and 4 completely covered, visibility (in kilometers),
- …

Predicción de la energía eólica producida …

Tarea de estimación de oferta de energía

Electrodomésticos asociados a cada actividad

Activity	Associated Appliances
Cook	Dishwasher, electric pressure cooker
Eat	Dishwasher
Party	Vacuum cleaner
Enter home, Personal hygiene	Washing machine, tumble dryer,

Predicción de la demanda de energía del lavavajillas

Technique	Number of layers	Number of epoch	SME	MAPE	R^2
RF			0.04	0.03	0.92
BNN	3	50	0.1	0.13	0.83
	4	50	0.1	0.06	0.90
	5	100	0.08	0.04	0.91

Predicción de la demanda de energía de la lavadora …

Tarea para programar el uso de dispositivos de carga controlable

$$\min(R + \alpha F)$$

$$R = \sum_{j=1}^{I*24} \gamma_j \left(a\left|\sum_{i=1}^{N} A_{ij} - \left(\left(\sum_{r=1}^{D} P_{rj}^{k} + \sum_{b=1}^{B} BAT_{bj}\right) - ULD_j\right)\right| * C_j\right)\Big/$$

Uso energía renovable

Asignación
rga requerida

Planificación Inteligente para un hogar

Casos de carga control

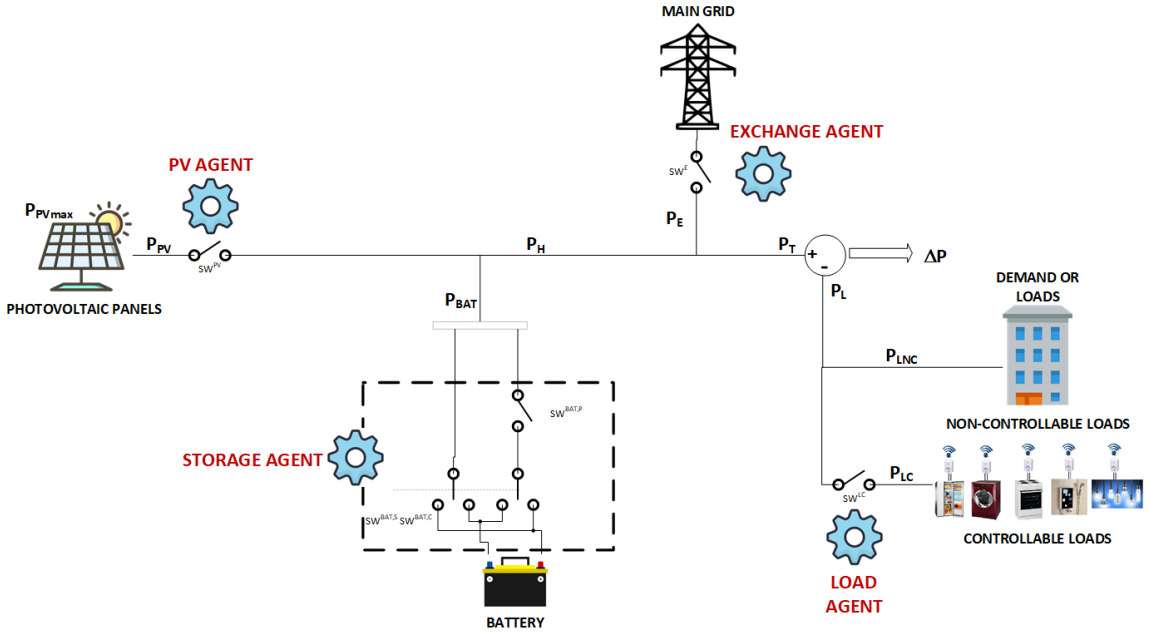
and $\beta = 10$

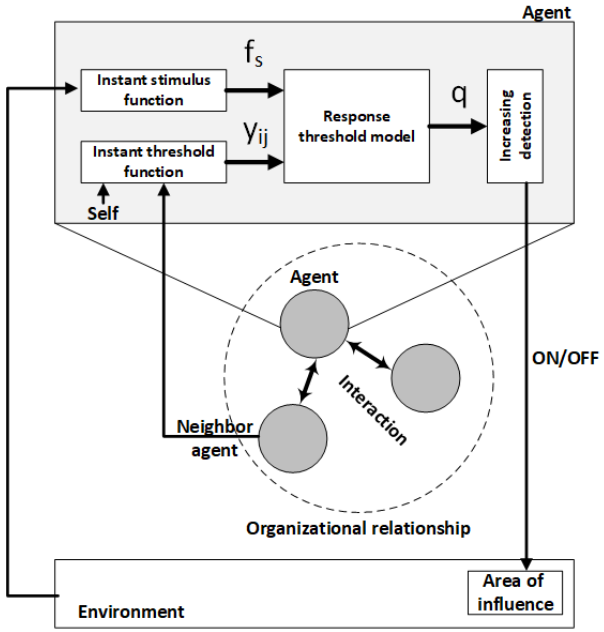
Case	Ap
1	Washing machine, Dis
2	Washing machine, Dis
3	Washing machine, Dishwasher, Tumble dryer, Electric pressure cooker, Vacuum cleaner,

Case					15	
				er	Value	Gener.
1	0	26	0	31	0.2	41
2	0	28	0.4	41	0.5	53
3	3.2	52	3.5	57	5.1	82

Planificación del uso de la Energía

Control Emergente basado en el Modelo de Umbral de Respuesta para una Micro-red





Photovoltaic agent

$$q_{PV}(t) = \frac{s_{PV}(t)^2}{s_{PV}(t)^2 + \theta_{PV}(t)^2},$$

$$s_{PV}(t+1) = s_{PV}(t) + w_{PV}\left(P_{PVmax}(P_L + (1 - Soc)Q_{CAP})\right)$$

Modelo de Umbral de Respuesta

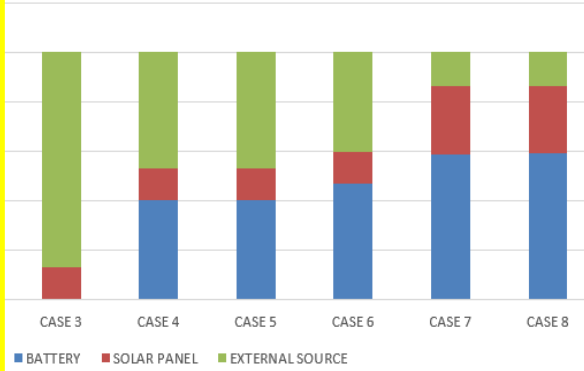
$$\theta_{PV}(t+1) = \theta_{PV}(t) - \beta_{PV}\frac{P_{PV}}{P_L}\Delta t + \gamma_{PV}\left(1 - \frac{P_{PV}}{P_L}\right)\Delta$$

M. Garcia, J. Aguilar M. R-Moreno, “Emergent Control based on the Response Threshold Model for a Microgrid”, en revision, *Applied Energy* , 2022

Control Emergente basado en el Modelo de Umbral de Respuesta para una Micro-red

Normal operation of the microgrid with constant demand

Control emergente en una microgrid



Configuración de sensores óptimo para una gestión de energía tolerante a fallas para edificios inteligente

Definición 1: Diagnosticabilidad. sistema que puede

Definición 4: La matriz de firmas de

Defini
residu
propie
estruct

		f_5
		1
		0
		1
		1

De

MinHV

mode,t))

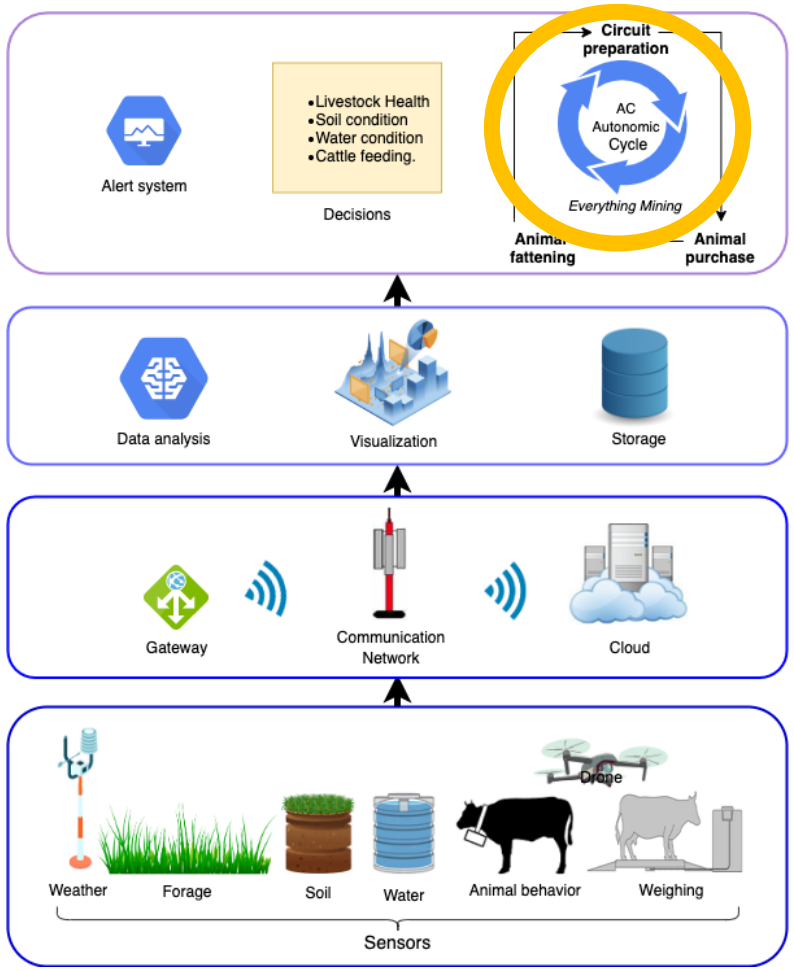
- $P_{consumed}$ ($HVAC_{mode}$,t): Q_{fluid}(t), ρ_{fluid}, y ΔT_{HVAC}(t).
- Cost($HVAC_{mode}$, t): TE_i.
- Comfort($HVAC_{mode}$, t): sensores para la temperatura ambiente actual en cada zona.

Fallas:

- f_1: Fallas en el HVAC.
- f_2 to f_5 : fallas 4 sensores en el HVAC .
- f_6 to f_z : fallas en los sensores de temperatura en cada zona.

Configuración inteligente de sensores para garantizar confort y minimizar energía consumida

Architecture for precision farming



Reflective

4. Business: This layer is in charge to improve the beef-production process using ACODAT for decision-making.

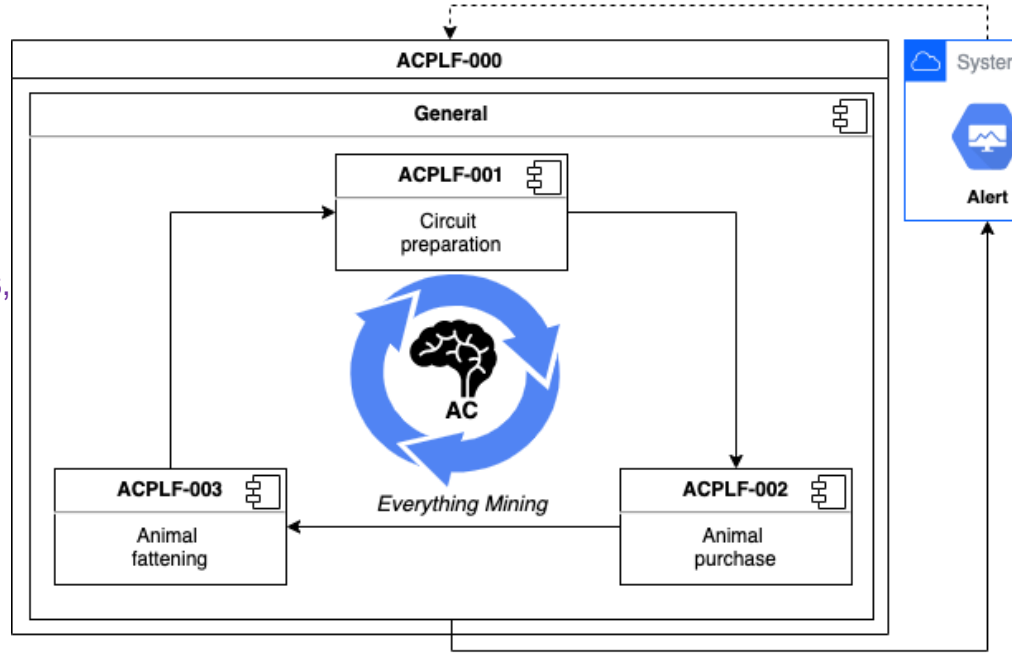
3. Data management: This layer stores, verifies, pre-processes, and protects data. These data will be made available to the beef farmer.

Base

2. Network: This layer is in charge of communication between the sensors and the server in the cloud.

1. Monitoring: This layer captures soil, water, animal behavior and climate variables through IoT-based sensors.

ACODAT in beef production

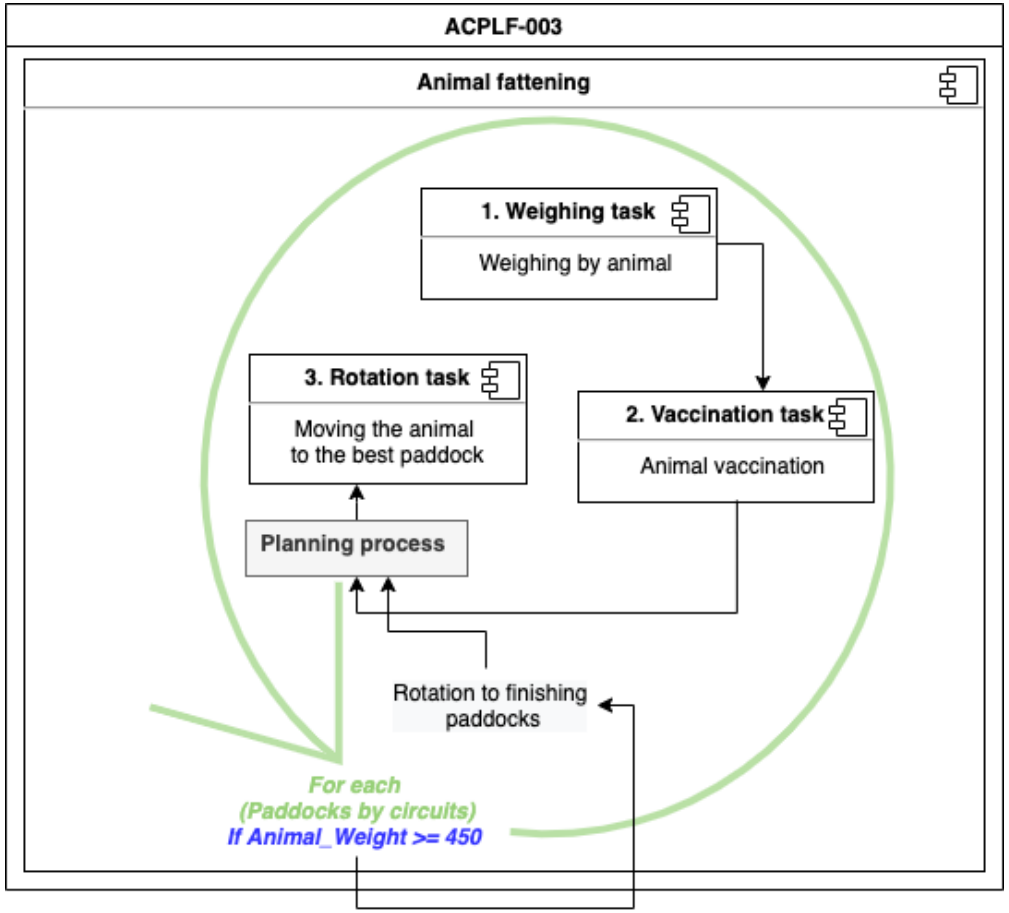


ACPLF-001 (Circuit preparation): This is in charge to prepare paddocks.

ACPLF-002 (Animal purchase): This is in charge (i) to select the best supplier and (ii) to select the animal lot with the best characteristics.

ACPLF-003 (Animal fattening): This is in charge to manage the animal's fattening process.

Architecture for precision farming



ACPLF-003

Predictions generated by the weighting task

Lot Id	Animal Id	Age	Weight	Predicted weight
L20-034	00733	1,6	320	319
L20-034	00734	1,6	300	325
L20-034	00735	1,4	340	338

Prescription generated by the vaccination task

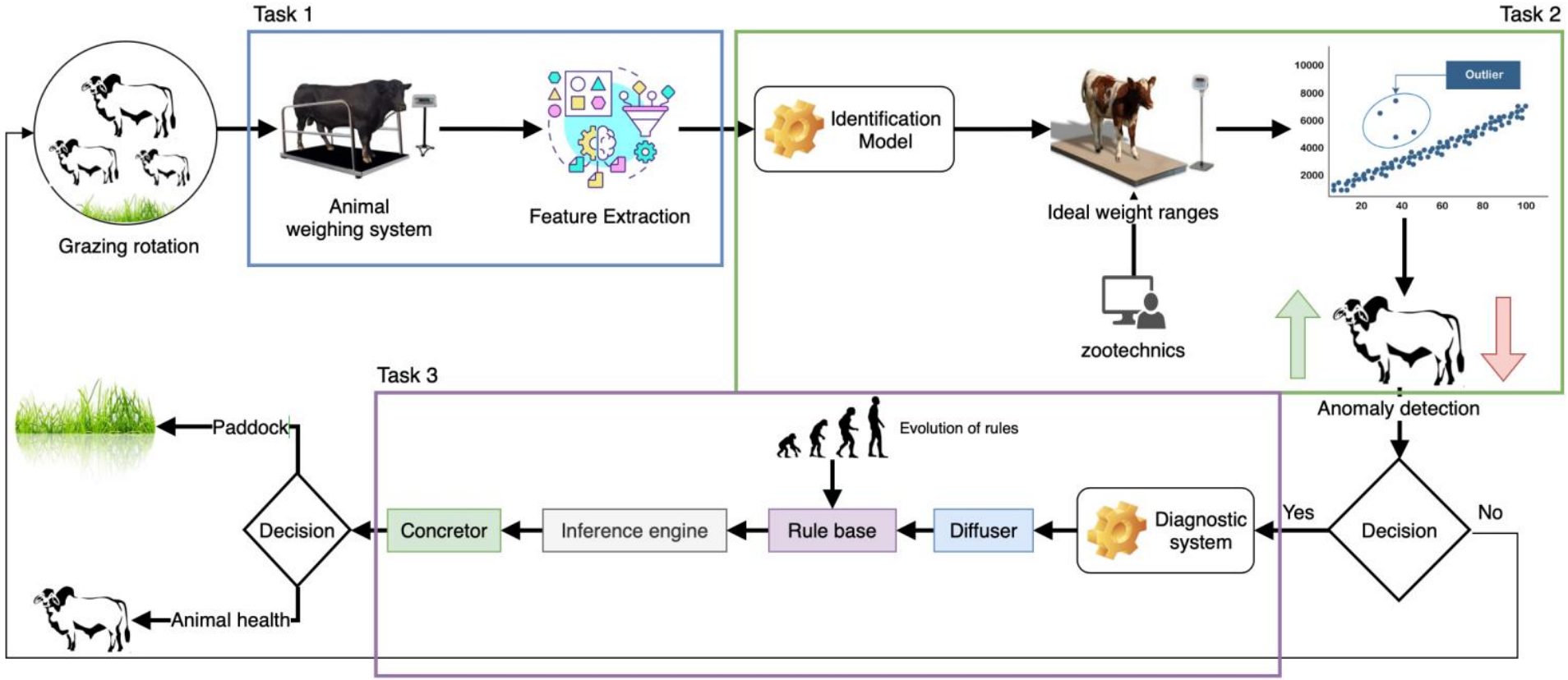
Lot Id	Animal Id	Prescription
L20-034	00734	Anti-partisan
L20-034	00734	Genabilic acid
L20-034	00734	Mineralized salt

Assignment model generated by the rotation task

Lot ID	Quantity of animals	Average weight	Date in	Date out	Paddock	Occupancy time	Resting time
L20-034	28	300	4/01/20	8/01/20	P045	4	45
L20-034	28	303,6	8/01/20	12/01/20	P048	4	35
L20-034	28	305,4	12/01/20	14/01/20	P049	2	36
L20-034	28	307,2	14/01/20	16/01/20	P050	2	37
L20-034	28	309,9	16/01/20	19/01/20	P055	3	38
L20-034	28	311,7	19/01/20	21/01/20	P052	2	39
L20-034	28	314,4	21/01/20	24/01/20	P059	3	45
L20-034	28	316,2	24/01/20	26/01/20	P060	2	30
L20-034	28	318	26/01/20	28/01/20	P065	2	35

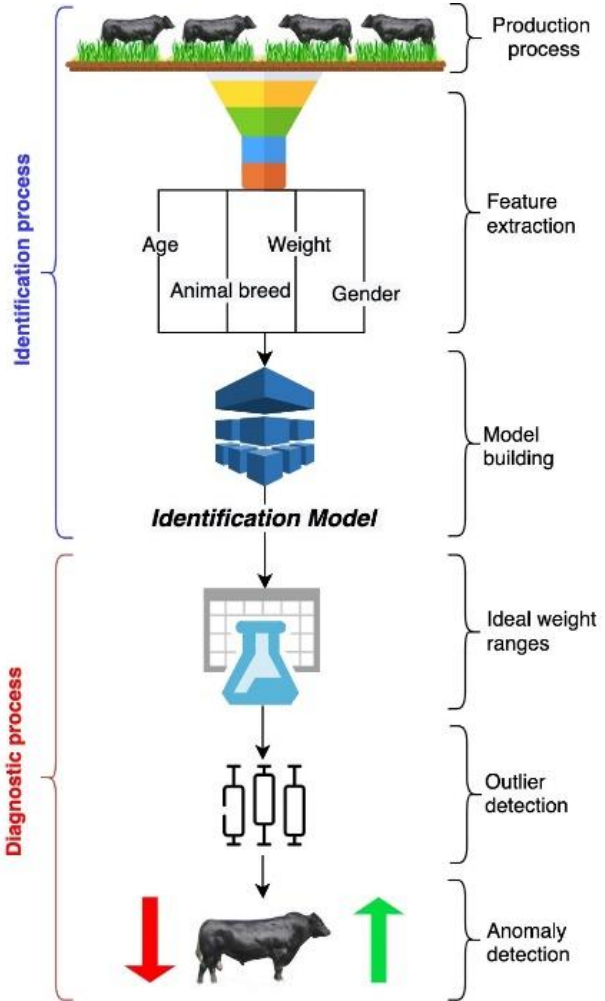
Architecture for precision farming

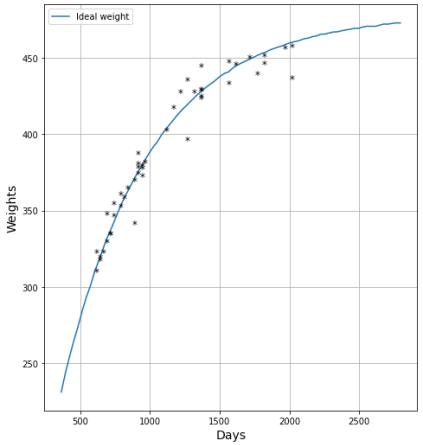
Self-supervisión: Identification + diagnosis



Architecture for precision farming

Anomaly Identification in a beef production process.





Ideal weight-curve versus real weight in AC breed, female

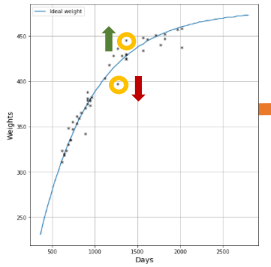
EXAMPLE OF ANOMALOUS DATA DETECTION.

Days	Actual Weight	Breed	Gender	Example ideal Weights	State
600	361	AC	F	[332, 368, ..., 373, 387, ...]	normal
600	259	BAC	F	[309, 374, ..., 344, 368, ...]	abnormal
600	285	AC	M	[311, 363, ..., 387, 373, ...]	abnormal
678	421	BC	F	[325, 412, ..., 402, 382, ...]	abnormal

Angus x Zebu (AC); Bon x Zebu (BC); Zebu x Angus x Zebu (CAC); Zebu x Zebu (CC); Holstein x Zebu (HC); Bon x Angus x Zebu (BAC);

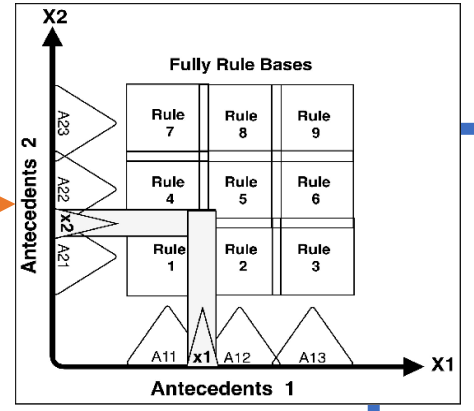
Models for precision farming: Diagnosis model

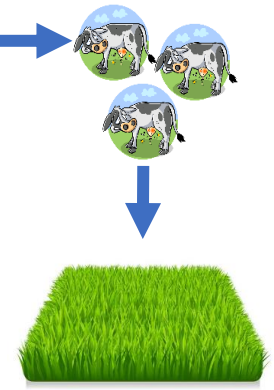
Fuzzy classifier capable of diagnosing the causes of weight loss or gain in rotational grazing cattle.



Ideal weight-curve versus real weight in AC breed, female

Input

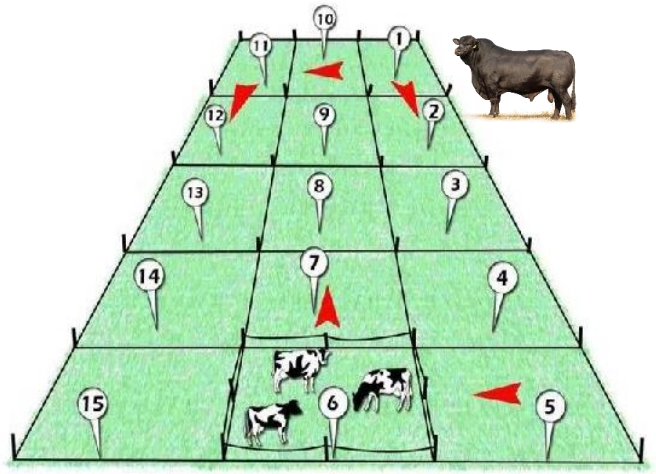




Metrics	Values
Accuracy	95%
Certainty of rules	R1:0.88, R2:0.75, R3:0.89, R4:0.85, R5:0.85, R6:0.75
AUC	1

Architecture for precision farming

A Many-Objective Optimization Approach for Weight Gain and Animal Welfare in Rotational Grazing of Cattle.



$$Max\ z_1 = \sum_{i=1}^{n}\sum_{i=1}^{m} G_{ij}^{t} x_{ij}^{t}$$

$$Min\ z_3 = \sum_{i=1}^{n}\sum_{j=1}^{m} D_{ij}^{t} x_{ij}^{t}$$

Maximizes weight

Minimizes distance

- ✔ Forage quality
- ✔ Percentage of nutritional need
- ✔ Maximizes weight gain
- ✔ Minimizes distance

Number of days simulated	Average Weight Gain Our model	Average Weight Gain Traditional
121	55.75 (0.061)	41.9 (0.05)
242	141.58 (0.031)	112.5 (0.09)
365	215.52 (0.119)	173 (0.11)

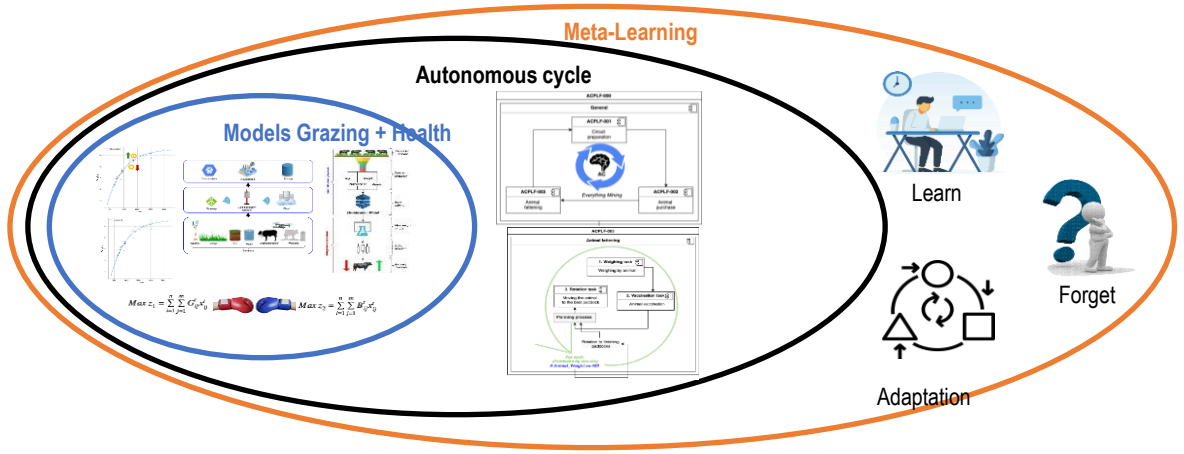
Many-objective

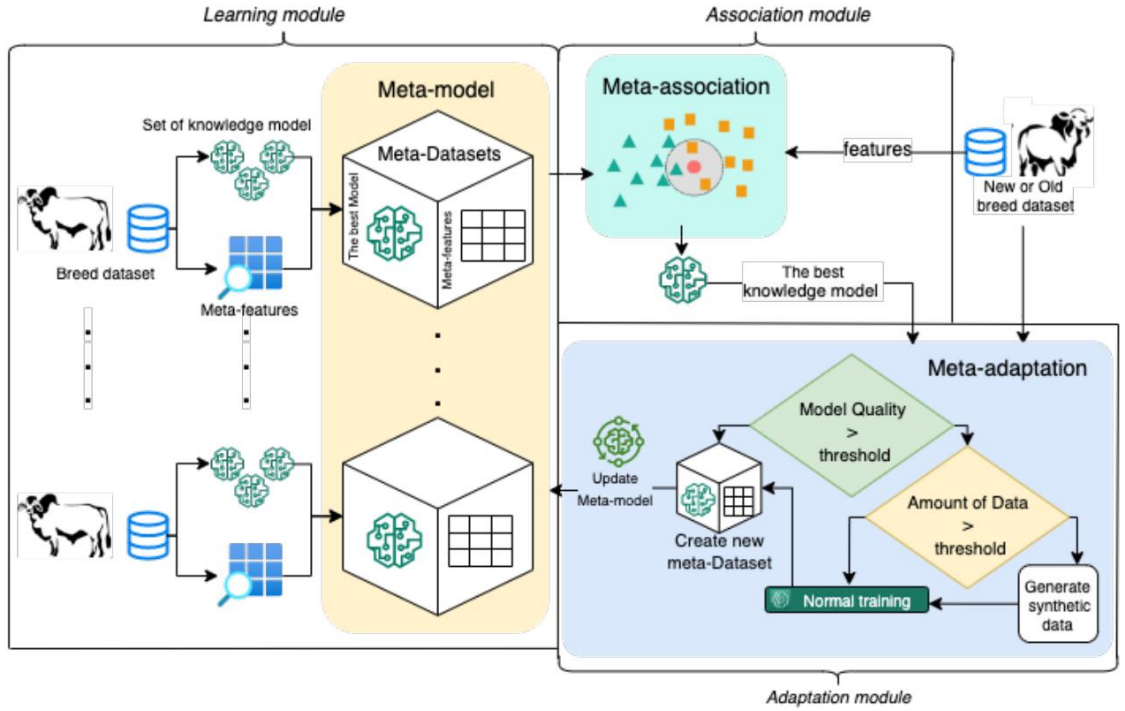
- ✔ Satisfied water
- ✔ Forage satisfied daily
- ✔ Percentage of the lot's need for hydration
- ✔ Percentage of Noise in a paddock
- ✔ Area free of animal movement
- ✔ Shaded area
- ✔ Average paddock temperature
- ✔ Maximum temperature allowed in an animal

Architecture for precision farming

Meta-intelligent model for precision farming

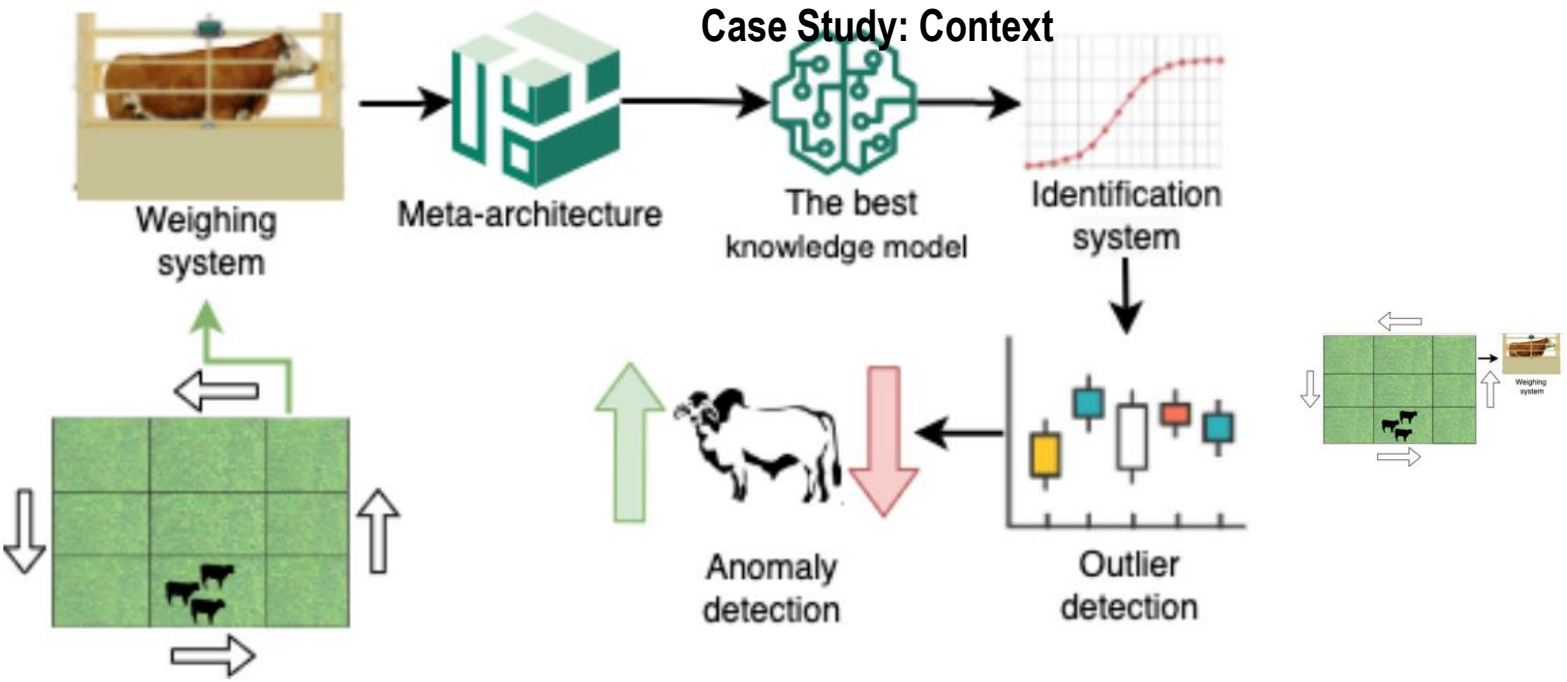
Meta-Lerrning (MTL)





Architecture for precision farming

Case Study: Context



Instantiation of the MTL architecture for PLF

Table 1: Meta-Model

knowledge			*Meta-features*							
Breed	Model	Best params	R^2	Median	Mean	Std	Var	Kurtosis	Entropy	Variation
AC	GB	learningrate:0.1 maxdepth:5 minsamplessp:5 nestimators:40	92	451.6	427.8	64.6	4175.25	1.20	10.62	0.15
BAC	RF	maxdepth:20 maxfeatures:3 maxleafnodes:25 nestimators:40	89	430.24	410.0	57.1	3262.80	1.49	10.62	0.13
CAC	GB	learningrate:0.1 maxdepth:5 minsamplessp:5 nestimators:40	93	470.04	442.6	72.5	5265.85	0.86	10.62	0.16
BC	GB	learningrate:0.1 maxdepth:5 minsamplessp:5 nestimators:40	95	492.2	459.9	87.5	7658.87	0.33	10.62	0.19

Architecture for precision farming

Good quality of the model

Table 2: Meta-model in the case of a breed known by the knowledge model

Breed	Model	Best params	R^2	Median	Mean	Std	Var	Kurtosis	Entropy	Variation
AC	GB	learningrate:0.1 maxdepth:5 minsamplessp:5 nestimators:40	92	451.6	427.8	64.6	4175.25	1.20	10.62	0.15

Decision metrics with good values

Breed	Model	R^2
AC	GB	92.5

Reuse model

Bad quality of the model

Table 4: Decision metrics with bad values

Breed	Model	R^2
AC	GB	57.2

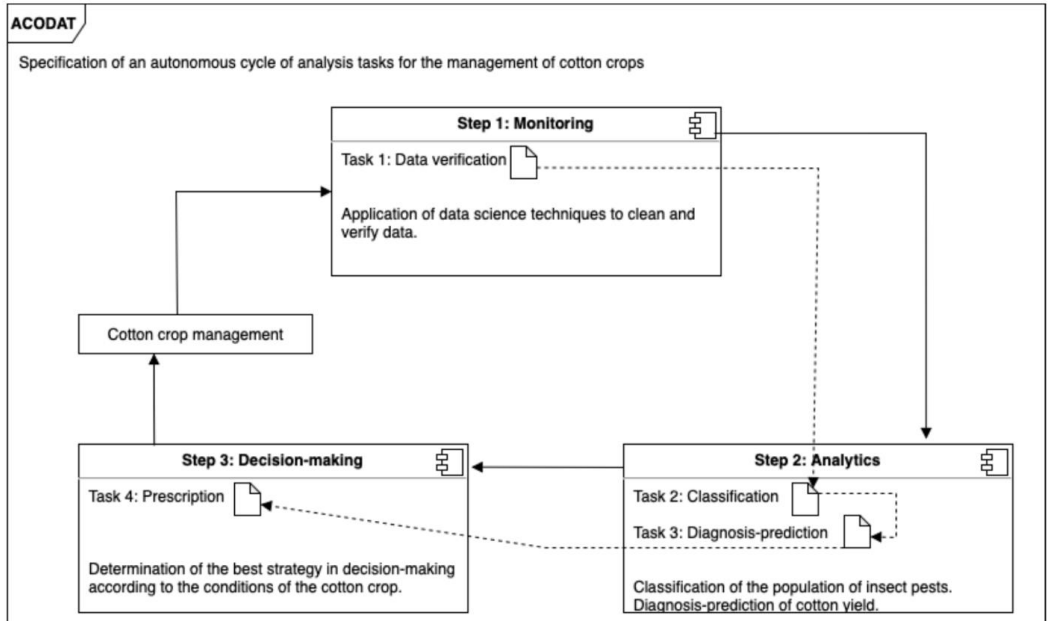
Table 5: Improved decision metrics

Breed	Model	R^2
AC	GB	87.5

Reuse parameters

Smart Insect-Pest Management for Cotton Crops

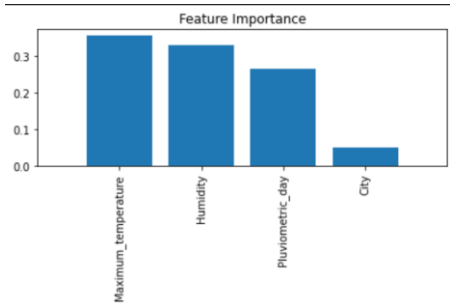
Autonomous Cycle



Classify the population of the boll weevil in cotton

City	Total
Cereté	6,015
Lorica	1,800
Ciénaga de oro	985
Montería	1,162
Cotorra	1,928
Valencia	1,693
Total in Córdoba	13,585

Pheromone trap → boll weevil



Class	Red boll weevils	Black boll weevils
Low (0 to 4),	6,456	4,701
Medium (5 to 20)	304	1,244
High (> 20).	83	808

Architecture for precision farming

Classify the population of the boll weevil in cotton

Córdoba

Results of five classification models using rainfall, humidity, and temperature data

Model	Red boll weevils				Black boll weevils			
	Accuracy		*F1-Score*		*Accuracy*		*F1-Score*	
	Training	*Test*	*Training*	*Test*	*Training*	*Test*	*Training*	*Test*
XGBoost	0.82	**0.82**	0.82	**0.82**	0.60	**0.60**	0.59	**0.59**
SVM	0.80	0.80	0.80	0.80	0.51	0.51	0.51	0.51
ANN	0.70	0.70	0.70	0.70	0.47	0.47	0.47	0.47
RF	0.81	0.81	0.81	0.81	0.58	0.58	0.58	0.58
DT	0.81	0.81	0.81	0.81	0.58	0.58	0.58	0.58

Abbreviations: XGBoost = Extreme Gradient Boosting (trees), RF = Random Forest, SVM = Support Vector Machines, ANN = Artificial Neural Networks, DT = Decision Trees.

TABLE VII. XGBOOST MODELS FOR CLASSIFICATION USING MAXIMUM TEMPERATURE, RAINFALL AND HUMIDITY

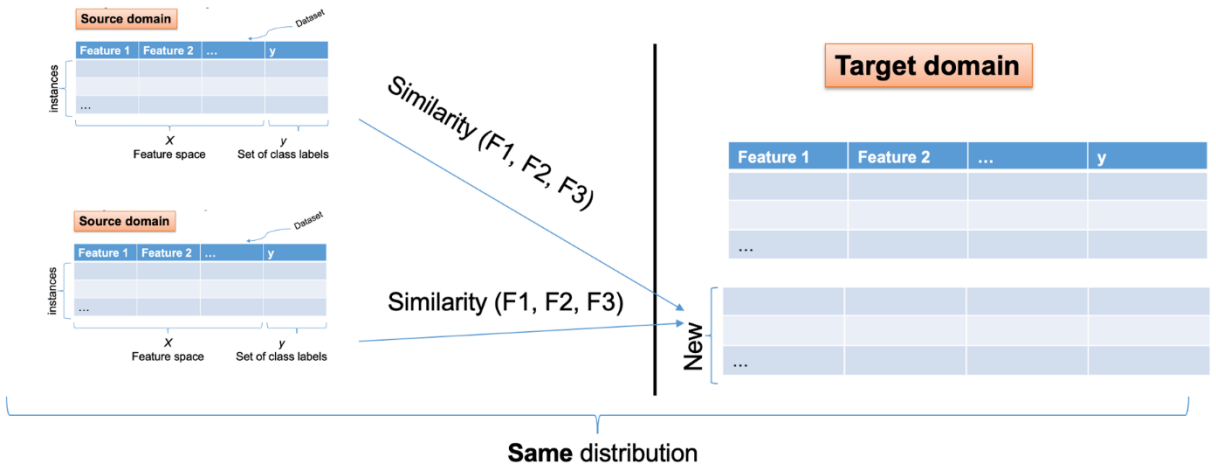
Model	Red boll weevil				Black boll weevil			
	Accuracy		*F1-Score*		*Accuracy*		*F1-Score*	
	Train	*Test*	*Train*	*Test*	*Train*	*Test*	*Train*	*Test*
*Córdoba	0.82	0.82	0.82	0.82	0.60	0.60	0.59	0.59
Cereté	0.78	0.77	0.78	0.77	0.57	0.52	0.57	0.52
Lorica	0.88	**0.88**	0.88	0.88	0.66	0.58	0.66	0.58
Ciénaga de Oro	FoO	FoO	FoO	FoO	0.71	**0.69**	0.71	0.69
Monteria	NH	NH	NH	NH	NH	NH	NH	NH

*Córdoba (included Cereté, Lorica, and Ciénaga de Oro). Abbreviations: XGBoost = Extreme Gradient Boosting, FoO = Fail on oversample, NH = No humidity.

Architecture for precision farming

Transfer Learning in tasks of classification of insect pests in cotton.

Instance-based TL



Similarity 75% - 99.9%

$$S(i) = \left[1 - \frac{|X^i_{source}| - X^i_{target}}{max(X_{target})}\right]$$

Table 5. Increase of new instances in the target domain.

Class	S-L	T-C-O	T-C-TL		
	Instances	*Instances*	*A*	*B*	*C*
0	1668	946	2614	2591	2544
1	95	36	129	127	113
2	12	3	11	8	8
Total	1775	985	2754	2726	2665
Increase of new instances:			1769	1741	1680
Percentage increase:			179.59%	176.75%	**170.56%**

Similarity between source and target domains: A: 75%, B: 90%, C: 95%.
Abbreviations: S-L= Source Lorica, T-C-O: Target - Ciénaga de Oro - Original, T-C-TL: Target - Ciénaga de Oro - Processed with TL.

Results for the set of testing using the target domain to Ciénaga de Oro and three source domains.

Source domains	A		B		C	
	Accuracy	*F1-Score*	*Accuracy*	*F1-Score*	*Accuracy*	*F1-Score*
Cereté	0.8329	0.8329	0.8821	0.8821	FoO	
Lorica	0.9018	0.9018	0.9074	0.9074	**0.9079**	**0.9079**
Lorica + Cereté	0.8982	0.8982	0.8862	0.8862	0.8875	0.8875

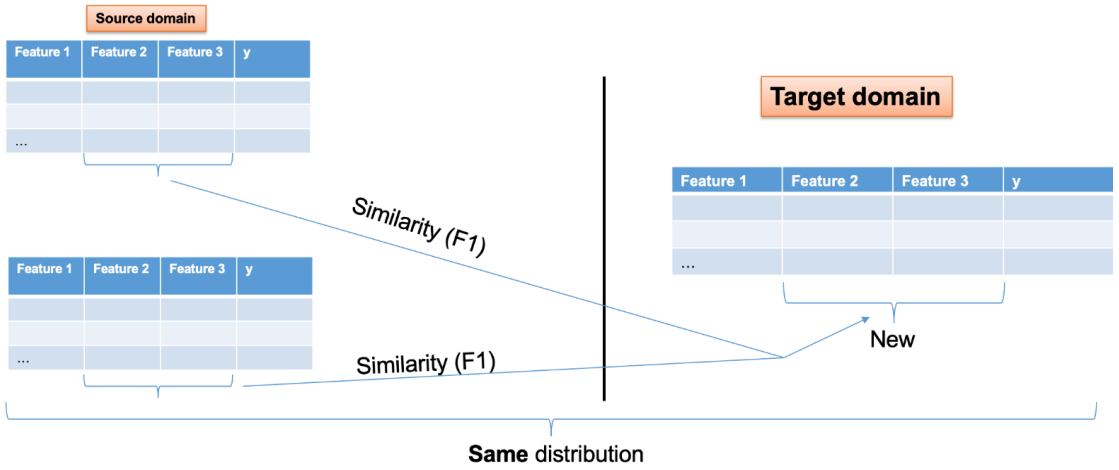
Similarity between source and target domains: A: 75%, B: 90%, C: 95%

Ciénaga de Oro 68% (Before) – 90.79%

Architecture for precision farming

Transfer Learning in tasks of classification of insect pests in cotton.

Feature-based TL



Lorica, Cereté → Montería

Table 4. Target domain and source domains with their instances and features.

City	Domain	Instances	Features		
			Temperature	*Humidity*	*Rainfall*
Montería	Target	1052	✓		
Lorica	Source	1775	✓	✓	✓
Cereté	Source	4083	✓	✓	✓

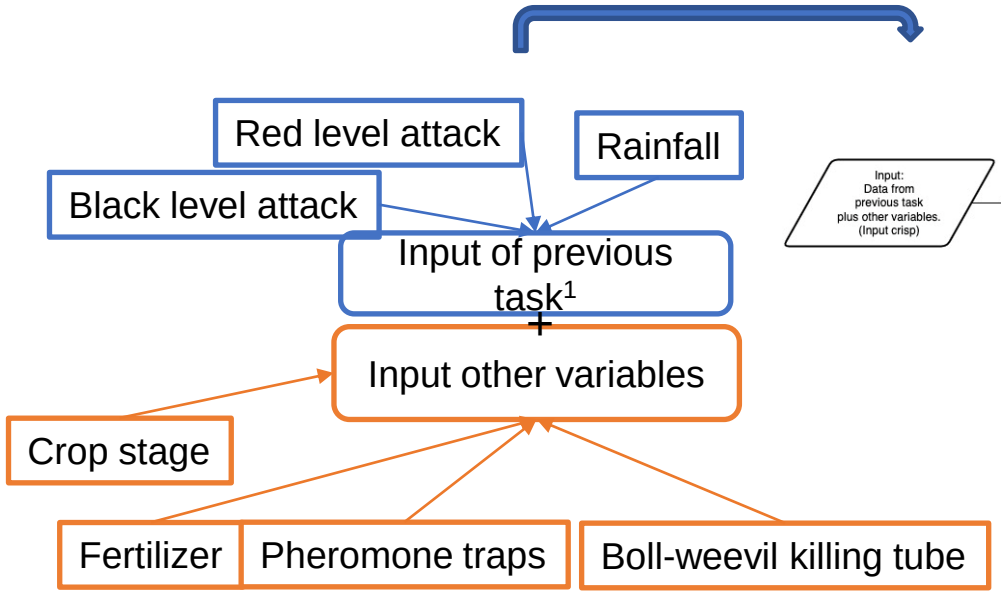
Table 9. Results for the set of testing using the target domain to Montería and four experiments source domains.

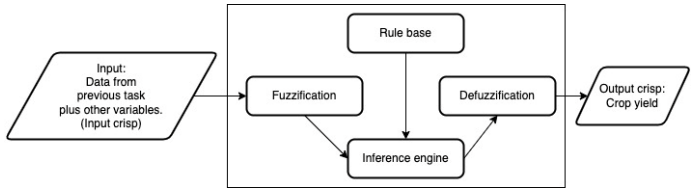
Experiment	A		B		C	
	Accuracy	*F1-Score*	*Accuracy*	*F1-Score*	*Accuracy*	*F1-Score*
First (SMOTE)	0.9442	0.9442	0.93	0.93	**0.9628**	**0.9628**
Second (Hybrid: Manual + SMOTE)	0.9256	0.9256	0.9344	0.9344	0.9584	0.9584
Third (Pure)	FoO	FoO	FoO	FoO	FoO	FoO
Fourth (Automatic hybrid)	0.887	0.887	0.8928	0.8928	0.8836	0.8836

Similarity between source and target domains: A: 75%, B: 90%, C: 95%. Abbreviation: FoO = Fail on oversample.

Architecture for precision farming

Diagnosis





	If							Then
	1-Red attack	2-Black attack	3-Crop stage	4-Rainf	5-Fertiliz	6-Pheromon	7-Boll-weevil	Crop yield
Rule 1	Null	Null	1-Vegetat	Mediu	High	Adequate	Adequate	High
Rule 2	High	High	1-Vegetat	High	Low	Absent	Absent	Low
Rule 3	Medium	Medium	1-Vegetat	High	Low	Absent	Absent	Low
Rule 4	Medium	Medium	1-Vegetat	Low	Low	Absent	Absent	Low
Rule 6	Low	Low	1-Vegetat	High	Low	Absent	Absent	Low
Rule 7	Low	Low	1-Vegetat	Low	Low	Absent	Absent	Low
Rule 8	Low	Low	1-Vegetat	Low	Mediun	Adequate	Adequate	Medium
Rule 9	Low	Low	1-Vegetat	Low	High	Adequate	Adequate	Medium
Rule 10	Low	Low	1-Vegetat	High	Mediun	Adequate	Adequate	Medium
Rule 11	Medium	Medium	1-Vegetat	Low	High	Adequate	Adequate	Medium
Rule 12	Medium	Medium	1-Vegetat	Low	Mediun	Adequate	Adequate	Medium
Rule 13	Medium	Medium	1-Vegetat	High	Mediun	Adequate	Adequate	Medium
Rule 14	High	High	1-Vegetat	Low	High	Adequate	Adequate	Medium
Rule 15	High	High	1-Vegetat	Low	Mediun	Adequate	Adequate	Medium
Rule 16	High	High	1-Vegetat	High	Mediun	Adequate	Adequate	Medium

Gaussian

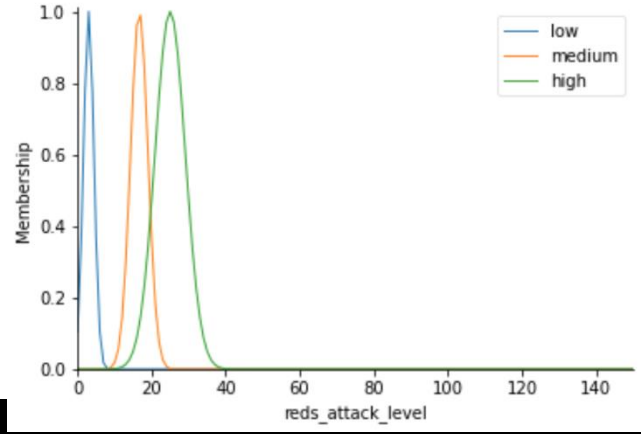
38 rules of type if-then rules

ANTECEDENT → **CONSEQUENT**

Survey Results: Experts' Assessments

Variable	Low		Medium		High	
	Mean	Std	Mean	Std	Mean	Std
Attack level of the red boll weevil	3	1.41	16.66	2.35	25	4.08
Attack level of the black boll weevil	2.66	1.69	15	4.08	25	7.07
Rainfall	2.66	0.47	6	0.81	12.33	1.69
Fertilizer	1.66	0.94	5	2.16	10.33	2.35
Crop yield	1.16	0.23	2.33	0.23	3.83	0.23

Abbreviation: Std= standard deviation



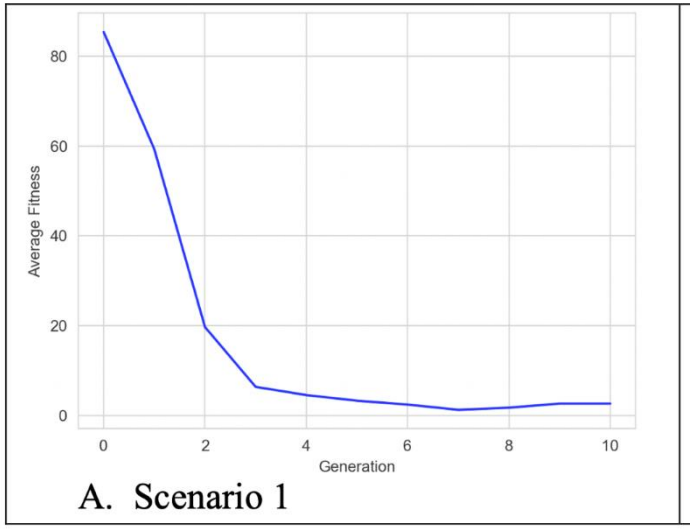
Architecture for precision farming

Prescription

Genetic Algorithm

$$C1 = A_9 * 100 + A_{10} * 100 + A_{11} * 100 + A_{12} * 100$$

$$C2 = A_7 * 100 + A_8 * 100$$



Mnimization of the fitness function (with 10 generations)

Table 16
Activity configurations of the best recommendation.

Position on chromosome	Gene	Activity
1	1	The cotton crop should be monitored more frequently.
2	1	The area where the boll weevils were found should be marked, according to the last inspection.
3	1	The cotton buds (squares) of the cotton plants that have fallen to the ground must be collected daily.
4	1	The bolls of the cotton plants that have been affected by the boll weevil must be collected to prevent the boll weevil from feeding and spreading.
5	1	The previously demarcated area should be fumigated.
6	1	Excessive rain must be evacuated using adequate drainage channels.
7	0	The irrigation system should NOT be implemented.
8	1	Soil analysis should be performed.
9	1	The necessary amounts of fertilizer should be applied according to soil analysis and agronomist recommendations.
10	0	Pheromone traps must NOT be placed.
11	0	DO NOT move the pheromone traps frequently.
12	1	Boll-weevil killing tubes should be installed.
13	1	Boll-weevil killing tubes should be moved frequently.

Table 14
Summary of the scenarios.

Scenario	A	B	Crop stage	Rainfall	Fertilizer	C	D	Crop yield
1	Low	Low	Vegetative	High	Medium	Adequate	Adequate	Medium
2	Medium	Medium	Fruiting	Low	NA	NA	NA	Low

Abbreviations: A = Attack level of red boll weevils, B = Attack level of black boll weevils, C = Pheromone trap, D = Boll-weevil killing tube, NA = The farmer did not use this item.

Architecture for precision farming

Scenario 1

temperature, humidity and rainfall,
low attack level of red boll weevils,
low attack level of black boll weevils,

vegetative stage, the rainfall was high (17 mm),
5 packages of fertilizer (medium),
used pheromone traps, and a boll-weevil killing tube.
yield was medium (2.88 ton/ha)

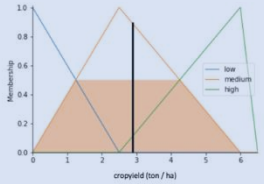


Fig. 9. Defuzzification of the output variable (crop yield with 2.88 tons/ha).

1	1	1	1	1	1	0	1	1	0	0	1	1

Fig. 10 Best individual for the first scenario.

Table 16
Activity configurations of the best recommendation.

Position on chromosome	Gene	Activity
1	1	The cotton crop should be monitored more frequently.
2	1	The area where the boll weevils were found should be marked, according to the last inspection.
3	1	The cotton buds (squares) of the cotton plants that have fallen to the ground must be collected daily.
4	1	The bolls of the cotton plants that have been affected by the boll weevil must be collected to prevent the boll weevil from feeding and spreading.
5	1	The previously demarcated area should be fumigated.
6	1	Excessive rain must be evacuated using adequate drainage channels.
7	0	The irrigation system should NOT be implemented.
8	1	Soil analysis should be performed.
9	1	The necessary amounts of fertilizer should be applied according to soil analysis and agronomist recommendations.
10	0	Pheromone traps must NOT be placed.
11	0	DO NOT move the pheromone traps frequently.
12	1	Boll-weevil killing tubes should be installed.
13	1	Boll-weevil killing tubes should be moved frequently.

Table 15
Example scenarios and their results.

Scenario	The best prescription	N generations	Error	Crop yield
1	100%	7	0	Medium
2	100%	7	0	Low
3	100%	7	0	Medium
4	100%	8	0	Medium
5	100%	8	0	Low
6	100%	8	0	Low
7	100%	7	0	Low

Sistemas de Comunicación 5G

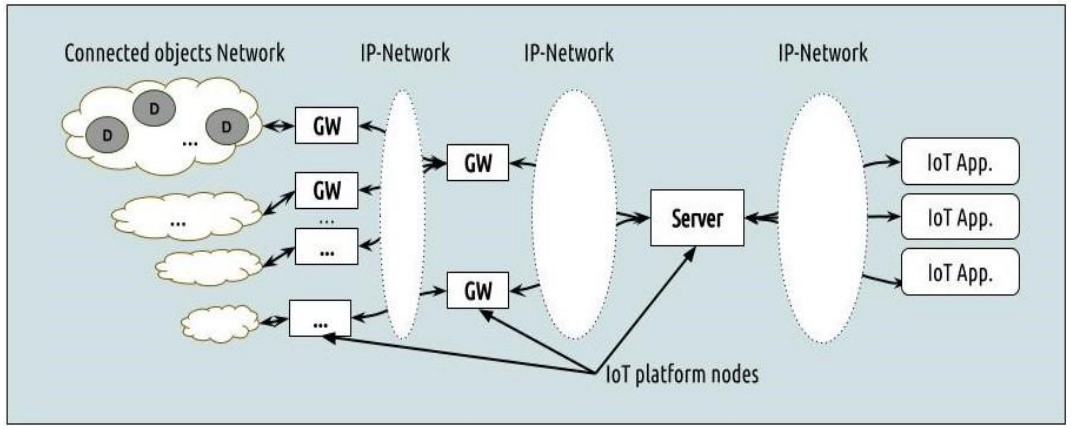
1. Aplicaciones de IoT y sus requisitos de QoS/QoE (tiempo de respuesta limitado, disponibilidad, etc.)

Ejemplo de requisitos de QoS/QoE de una aplicación (Requisitos de advertencia de infracción de señal de tráfico [3])

- Comunicación de infraestructura a vehículo
- Modo de transmisión: periódica
- Frecuencia mínima (tasa de actualización): ~ 10 Hz
- Latencia permitida ~ 100 ms

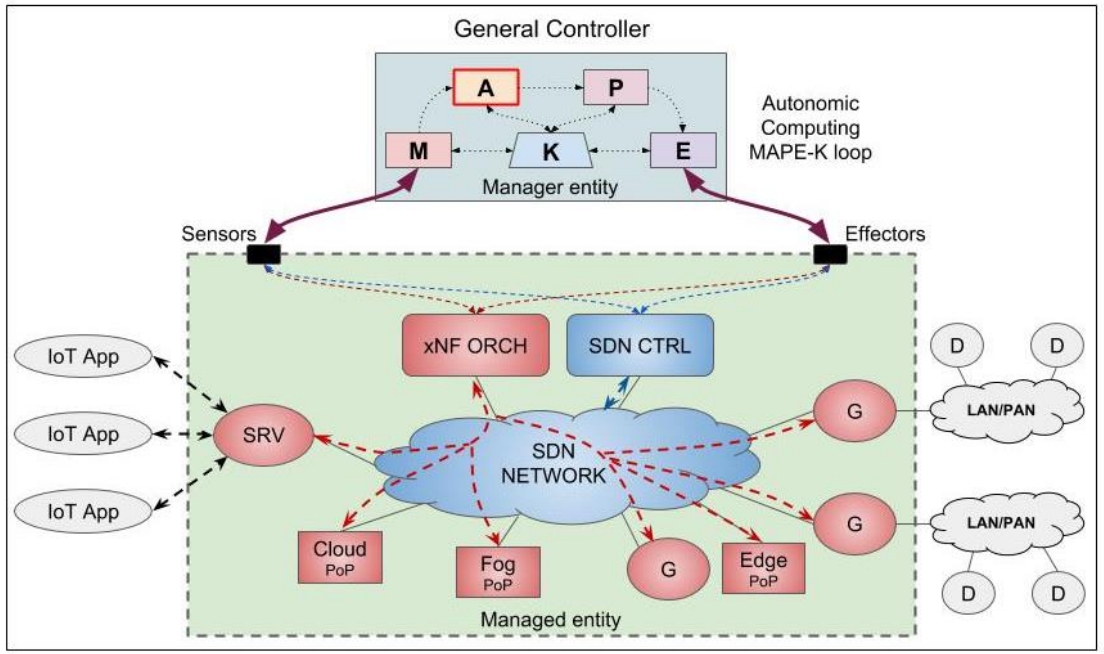
2. Dos cuellos de botella frente a QoS/QoE:

- a nivel de redes IP
- a nivel de los nodos de la plataforma IoT.



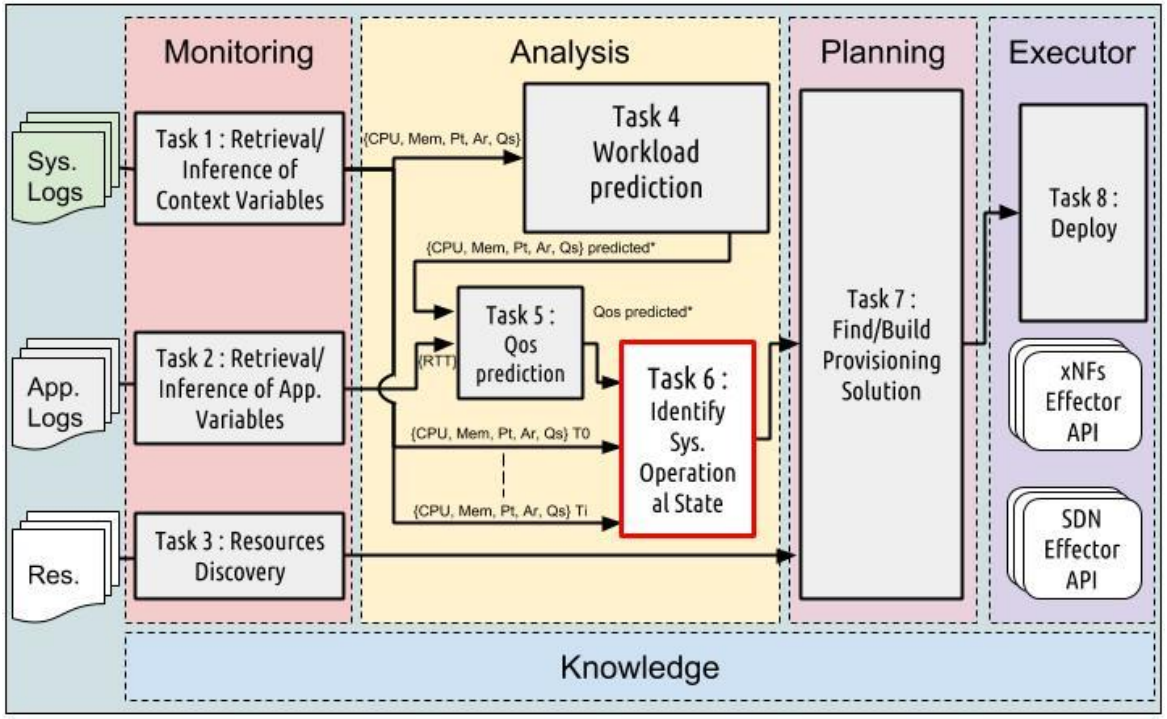
HLA Model for a Dynamic and Autonomic System

Un enfoque híbrido :



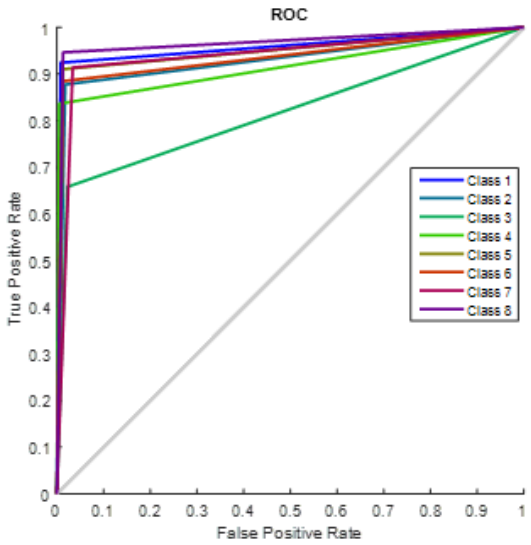
Sistemas de Comunicación 5G

An autonomic cycle for QoS provisioning



Performance metrics

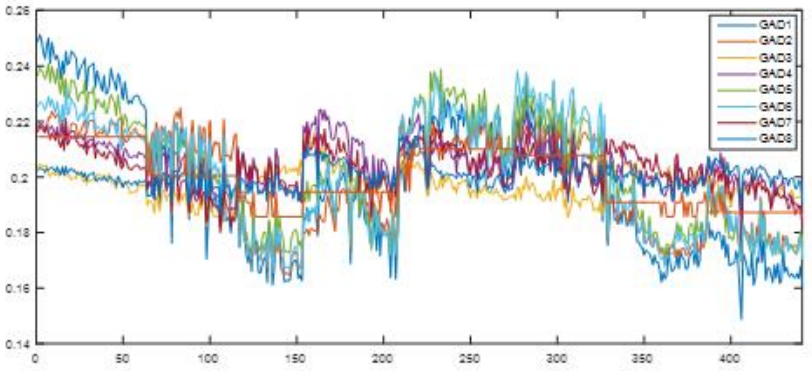
Accuracy	Precision	Recall	F-meas.	Sens.	Spec.	AUC
0,8740	0,8507	0,8678	0,8574	0,8678	0,9746	0,9212



ROC metric of the classification model

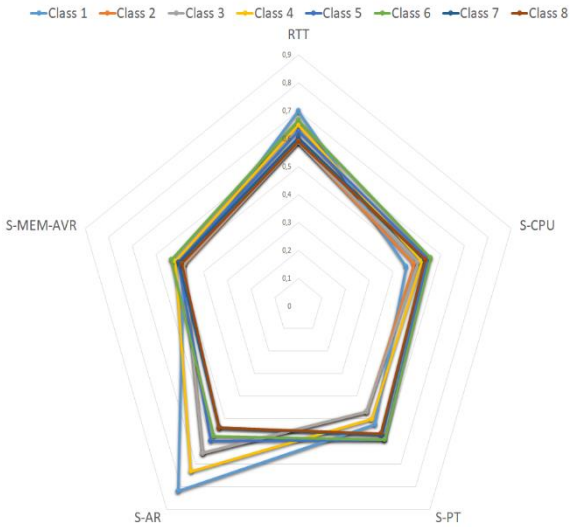
Sistemas de Comunicación 5G

Profile of each Cluster/Class



LAMDA result example

LAMDA = Learning Algorithm Multivariable and Data Analysis



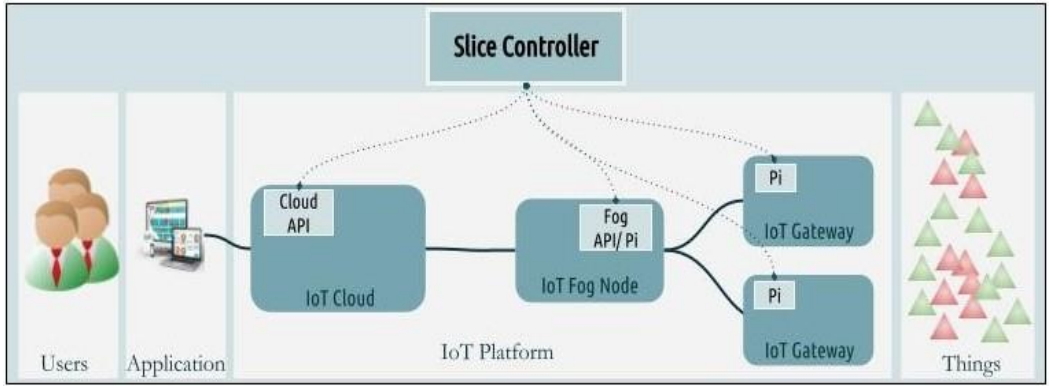
***General Profile** of the **IoT platform** with 16 descriptors*

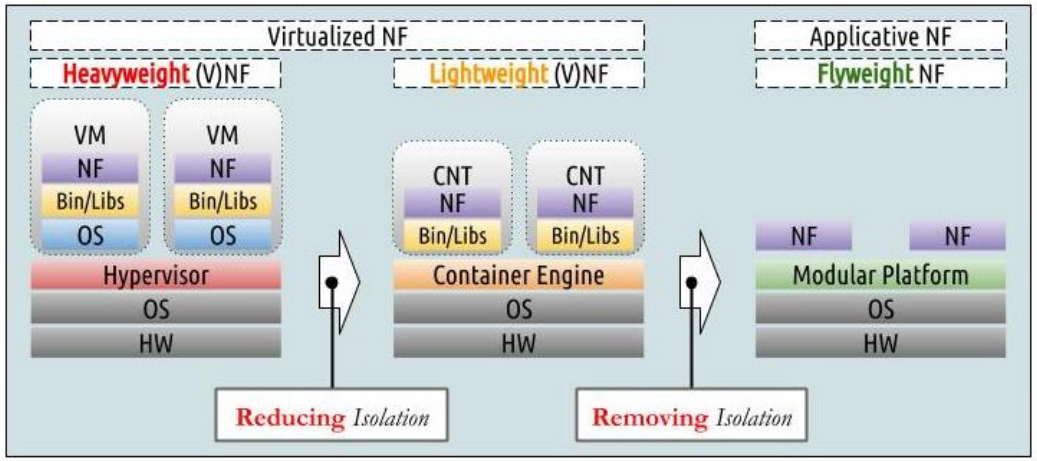
Profile of the **server** in the IoT platform

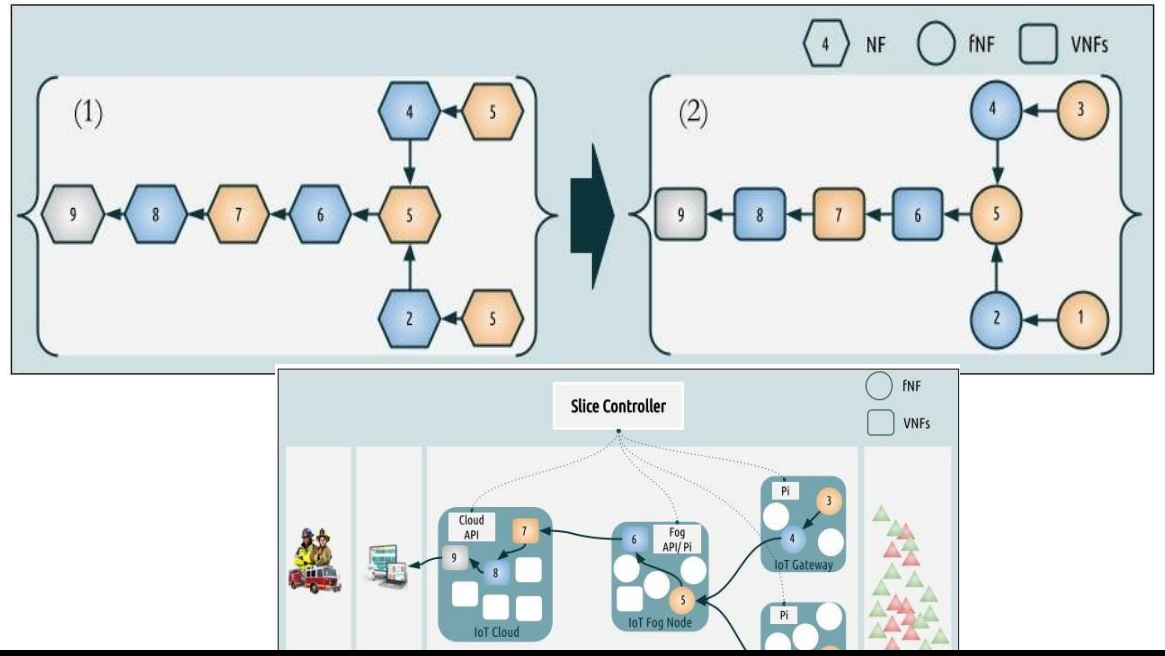
Sistemas de Comunicación 5G

- **Tactile Internet :** the managed entity to consider is the "network domain" which is composed by several entities such as Cloud, serving gateway(SG) and Tactile Support Engine (TSE).

Master Domain	Network Domain (Cloud, SG,... TSE)	Slave Domain







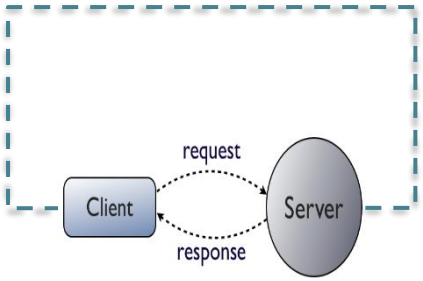
The requested slice has the following functional and non functional (i.e. QoS oriented) characteristics:

- allowable latency: 10ms
- availability: 90%
- services: Data Collection, Stream processing, Data Storage
- service life: 7h.

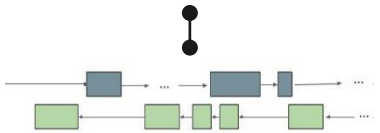
Sistemas de Comunicación 5G

Guarantee the Quality of Service (QoS) by identifying the name of the application given traffic measurements

Internet traffic classification

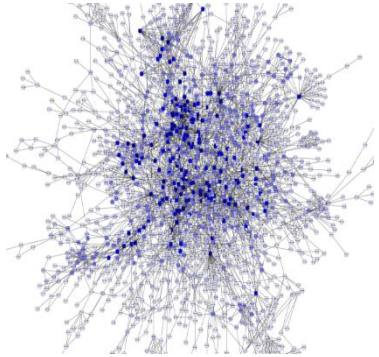


Data transfer



Flows of packets

Thousands of communications, in consequence, **guarantee** the QoS is challenging

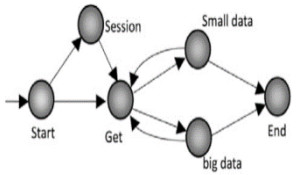


Traffic Classification

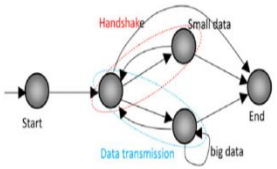
Change the communication settings to improve the QoS

Syntactic structure of some traffic

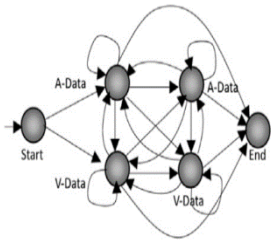
HTTP

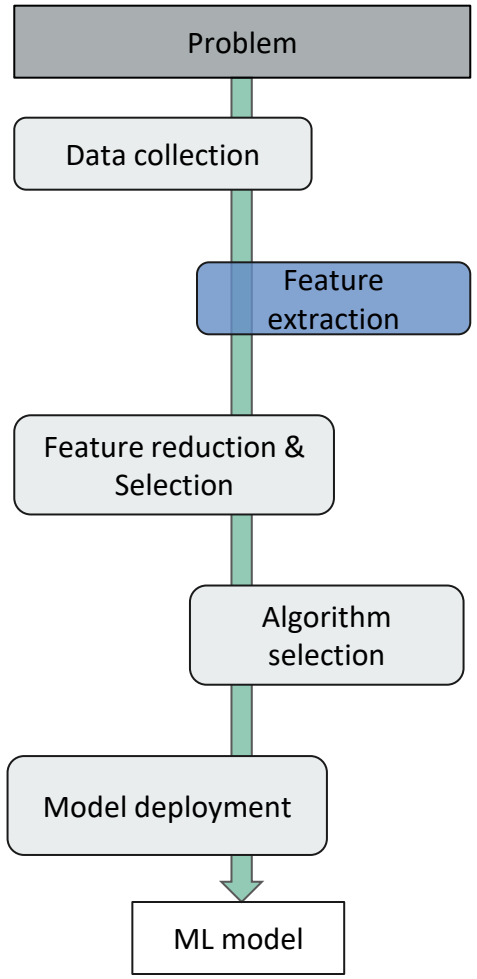


Bit torrent



Skype





Sistemas de Comunicación 5G

Statistical based feature extraction approach for the inner-class feature estimation using linear regression

Statistical based features

It is the most popular approach

It does not intrude into the packet content

It has a lightweight computation

It shows a high performance for discriminating the applications

$F_i = \{H_i, P_i, l_i\}$ Flow of packets

Feature	Description
Packet length	$B = len(p) \ \forall \ p \in P_i$
Inter-arrival time (IAT)	$IAT = t_i - t_{i-1}$

Statistical based features, such as:
Mean
Std
Maximum
Minimum

$X_i = [x_{1i}, x_{2i}, \ldots, x_{1k}]$

$F_i' = \{X_i, l_i\}$

Classical approaches: mean

- Moving average

$$\mu_n = \mu_{n-1} + \frac{1}{n}(x_n - \mu_{n-1})$$

- Weighted mean

$$\mu_n = \mu_{n-1} + \frac{w_n}{W_n}(x_n - \mu_{n-1})$$

- Exponential weighted mean

$$\mu_n = \mu_{n-1} + \alpha(x_n - \mu_{n-1})$$

- Logarithmic moving averages

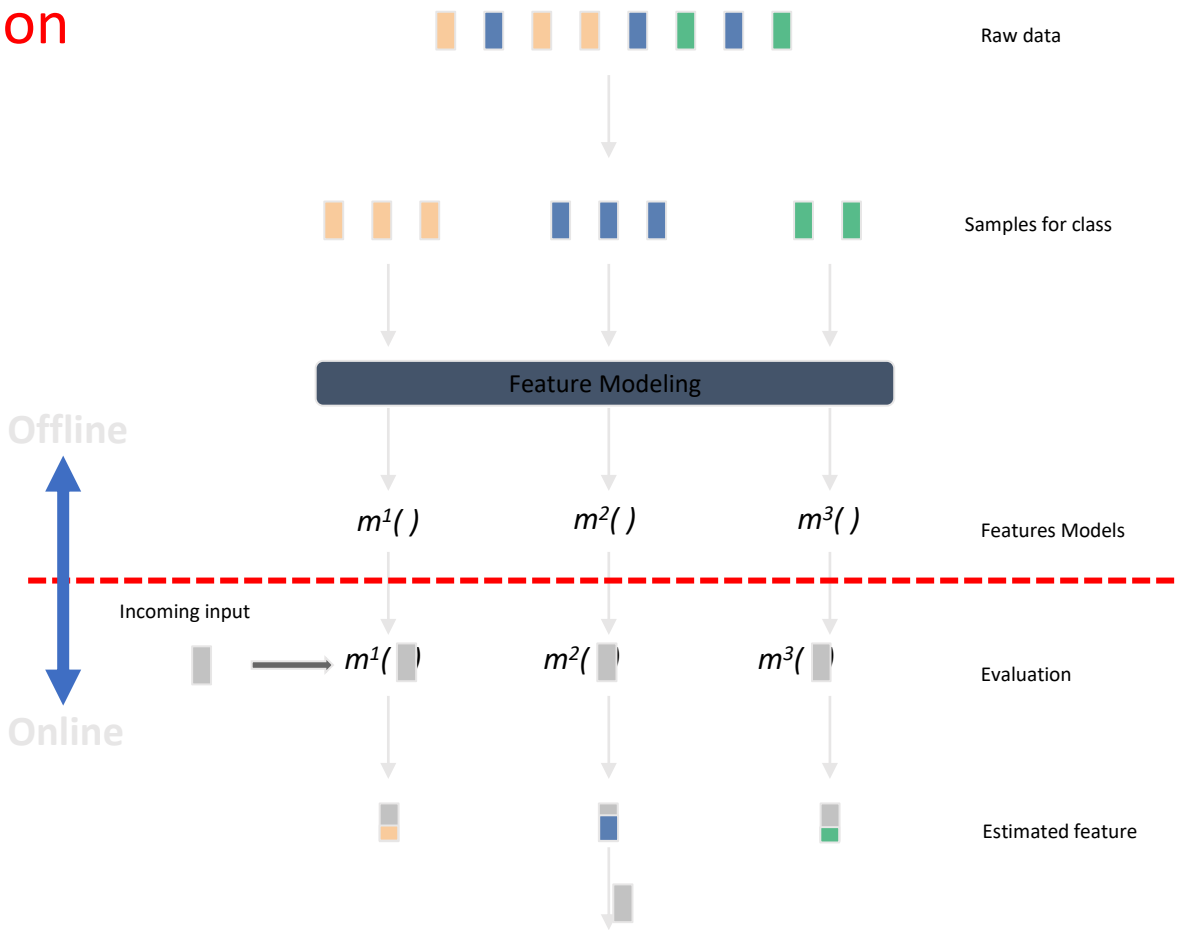
Sistemas de Comunicación 5G

Statistical based feature extraction approach for the inner-class feature estimation using linear regression

Assumptions

1. Raw inputs are differentiable from one another
2. The statistical behavior of a variable is different from class to class
3. Statistical features can be modeled for each class separately

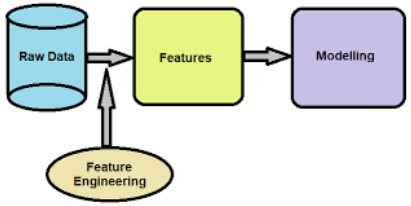
Approach

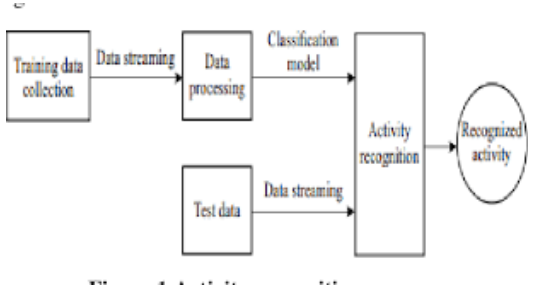


Conclusiones

- Meta-Aprendizaje

- Automatizar Ingeniería de Descriptores



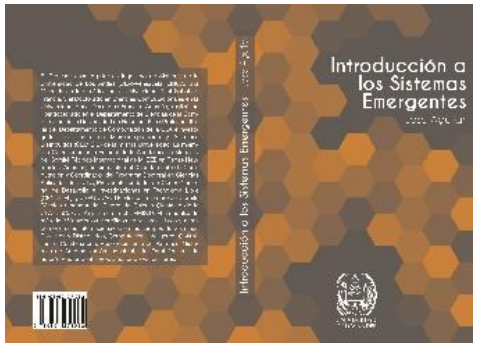


- Aprendizaje federado

- Automatizar Transferencia de Aprendizaje

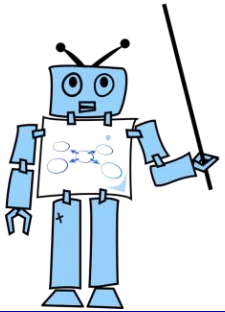
Conclusiones

- Control Emergente



http://bit.do/fSivD

- Meta-etiqueta en tareas de diagnóstico



- Aprendizaje Incremental

- ML explicativo

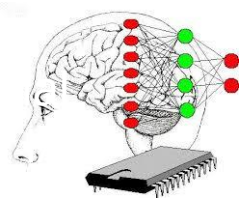
Conclusiones

En todos los dispositivos **habrá algo con IA**

- Smartphone
- Vehículos
- Neveras

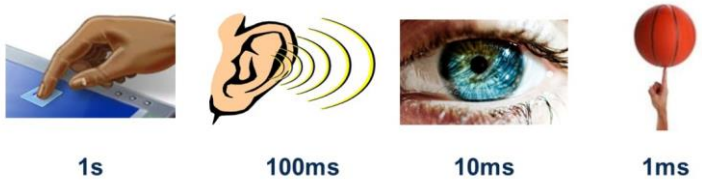
Nuevos descubrimientos **impactarán la IA**

- Conocemos solo alrededor del 10% del cerebro
- Cerebro humano está cambiando



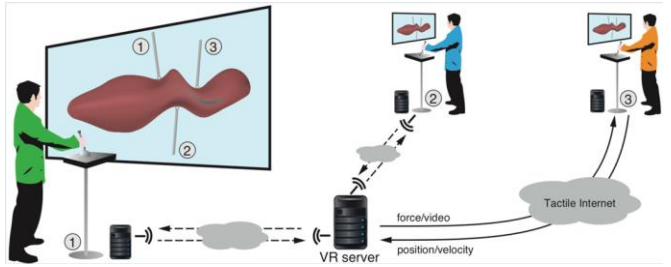
En todas las **actividades humanas** se **usará la IA**

- Economía
- Salud (Internet Táctil)
- Hogar
- Educación
- Transporte



Habrá **cambios sociales significativos**

- Vehículos Autónomos
- Costo y eficiencia energética
- Operaciones Remotas



“Si buscas resultados distintos,
entonces no hagas siempre lo mismo”

A. Einstein

www.ing.ula.ve/~aguilar

http://www.ing.ula.ve/~aguilar/distinciones/conferencias/

Thank you!

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Algunos últimos artículos

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- “A reinforcement learning based energy optimization approach for household fridges” Coautores: J. Giraldo, R. Mejia, *Sustainable Energy, Grids and Networks*, Vol. 36, 2023 (https://shorturl.at/cEHKV)
- “PRV-FCM: an extension of fuzzy cognitive maps for prescriptive modeling”, Coautores: W, Hoyos, M. Toro, *Expert Systems with Applications*, vol. 231, 2023 (https://shorturl.at/jmE07).
- "A Bio-inspired Emergent Control Approach for Distributed Processes", Coautor: M. García, *Applied Soft Computing*, vol. 141, 2023 (https://shorturl.at/vFY39).
- "A Bioinspired Emergent Control for Smart Grids," Coautores: M. Garcia, M. Rodríguez-Moreno, *IEEE Access*, vol. 11, pp. 7503-7520, 2023 (http://bit.do/fVXAU).
- "Autonomic Computing in a Beef-Production Process for Precision Livestock Farming", Coautores: R. García, M. Toro, N. Pérez, A. Pinto, P. Rodríguez, *Journal of Industrial Information Integration*, Vol. 31, 2023 (http://bit.do/fVKwy)
- “Deep Reinforcement Learning Approaches for the Hydro-thermal Economic Dispatch Problem considering the uncertainties of the context”, Coautores: A. Ramirez, M. R-Moreno, *Sustainable Energy, Grids and Networks*, 2023 (https://shorturl.at/ejmzL).
- "Evaluation of digital competence profiles using Dialetheic Logic" Coautores: A. Gonzalez, R. Dos Santos, *International Journal of Artificial Intelligence in Education*, vol. 33, no. 1, pp. 59-87, 2023 (http://bit.do/fTff6
- "Analysis of the Behavior Pattern of Energy Consumption through Online Clustering Techniques ", Coautores: J. Viera, M. R-Moreno, C. Quintero, *Energies*, vol. 16, no. 4, 2023 (https://www.mdpi.com/1996-1073/16/4/1649)
- “Management System for the Fattening Process of Bovines in Rotational Grazing using Diagnosis and Recommendation System” Coautores: R. Garcıa, Ch. Benitez, *CLEI Electronic Journal*, Vol 26, no. 2, 2023, (https://shorturl.at/hIL58).

Algunos últimos artículos

- C. Quintero-Gull, J. Aguilar,"LAMDA-HSCC: a semi-supervised Learning Algorithm based on the Multivariate Data Analysis", *Expert Systems with Applications*, vol. 202, 2022 (http://bit.do/fUbS7).
- A. Gonzalez, R. Dos Santos, J. Aguilar, "Evaluation of digital competence profiles using Dialetheic Logic" *International Journal of Artificial Intelligence in Education*, 2022 (http://bit.do/fTff6).
- J. Aguilar, O Buendia, A. Pinto, J. Gutierrez, "Social Learning Analytics for determining Learning Styles in a Smart Classroom", *Interactive Learning Environments*, Vol. 30, No. 2, pp. 245-261, 2022 (http://bit.do/e39V4).
- M. Garcia, J. Aguilar, "Emergent Control in the context of Industry 4.0" *International Journal of Computer Integrated Manufacturing*, vol. 35, no. 3, pp. 247-262, 2022 (http://bit.do/fSx7H).
- G. Santiago, J. Aguilar, "Ontological Model for the Acoustic Management in a Smart Environment", *Applied Computing and Informatics*, 2022 (http://bit.do/fTqJ3).
- L. Restrepo, J. Aguilar, M. Toro, E. Suescún. "A sustainable-development approach for self-adaptive cyber-physical system's life cycle: A systematic mapping study". *Journal of Systems & Software*, Vol. 180, 2021 (http://bit.do/fQ23P).
- C. Ouedraogo, S. Medjiah, C Chassot, K. Drira, J. Aguilar, "A Cost-Effective Approach for End-to-End QoS Management in NFV-enabled IoT Platforms" *IEEE Internet of Things Journal*, vol. 8, no. 5, pp. 3885-3903, vol. 8, No. 5, 2021, (http://bit.do/fJMKv).
- C. Salazar, E. Montoya. J. Aguilar, "Analysis of different affective state multimodal recognition approaches with missing data-oriented to virtual learning environment". *Heliyon*, Vol. 7, No. 6, 2021 (http://bit.do/fQ7F7).

Algunos últimos artículos

- F. Díaz, J. Aguilar, J. Altamiranda, N. Pérez, A. Pinto, "An Adaptive System for Emerging Serious Games using a Swarm Intelligence Algorithm" *IEEE Transactions on Game*,, Octubre, 2021 (http://bit.do/fSdrc).

- L. Morales, J. Aguilar, A. Rosales D. Pozo-Espin, "A Fuzzy Sliding-Mode Control based on Z-Numbers and LAMDA " *IEEE Access*, Vol. 9, pp. 117714-117733, 2021 (http://bit.do/fRDAd).

- L. Morales, J. Aguilar, O. Camacho, A. Rosales,"An Intelligent Sliding Mode Control based on LAMDA for a class of SISO uncertain systems" *Information Sciences*, Vol 567, pp 75-99, 2021 (http://bit.do/fPFai).

- W. Hoyo, J. Aguilar, M. Toro, "Dengue Models Based on Machine-Learning Techniques: A Systematic Literature Review" *Artificial Intelligence In Medicine*, Aceptado para publicación, Vol. 119, 2021 (http://bit.do/fRLdE).

- Y. Quintero, D. Ardilas, E. Camargo, F. Rivas, J. Aguilar, "Machine Learning Models for the Prediction of the SEIRD variables for the COVID-19 pandemic based on a Deep Dependence Analysis of Variables",*Computers in Biology and Medicine*, Vol. 134, 2021 (https://tinyurl.com/y96dzvwb).

- M. Sanchez, E. Exposito, J. Aguilar,"Implementing self-* autonomic properties in self-coordinated manufacturing processes for the Industry 4.0 context", Computers in Industry, Vol. 121, 2020 (http://bit.do/fFLBR)

- J. Cordero, J. Aguilar, K. Aguilar, D. Chávez, E. Puerto. Recognition of the Driving Style in Vehicle Drivers". *Sensors*, MDPI, Vol. 20, No. 9, 2020 (http://tiny.cc/0978nz)

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- J. Aguilar, J. Cordero, O. Buendia, "Specification of the Autonomic Cycles of Learning Analytic Tasks for a Smart Classroom", Journal of Educational Computing Research, vol 56 no. 6, pp. 866-891, 2018
- L. Morales, C. Ouedraogo, J. Aguilar, C. Chassot, S. Medjiah, Khalil Drira, "Experimental Comparison of the Diagnostic Capabilities of Classification and Clustering Algorithms for the QoS Management in an Autonomic IoT Platform", Service Oriented Computing and Applications, Elsevier, 2019
- F. Pacheco, E. Exposito, J. Aguilar, M. Gineste, C. Budoin, "Towards the deployment of Machine Learning solutions in traffic network classification: A systematic survey". IEEE Communications Surveys and Tutorials, 2019.
- J. Aguilar, A. Garces-Jimenez, N. Gallego-Salvador, J. Gutiérrez de Mesa, J. Gómez-Pulido, A. García-Tejedor, "A multi-HVAC system autonomic management architecture for smart buildings", IEEE Access, Vol, 7, pp. 123402 – 123415, 2019.
- O Buendia, J. Aguilar, A. Pinto, J. Gutierrez, "Social Learning Analytics for determining Learning Styles in a Smart Classroom", Interactive Learning Environments, Taylor & Francis, 2019
- M. Sanchez, J. Aguilar, E. Exposito, "Fog Computing for the integration of agents and web services in an autonomic reflexive middleware", Service Oriented Computing and Applications, Elsevier, Vol. 12, No. 3-4, pp. 333-347, 2018
- M. Mendonça, J. Aguilar, N. Perozo, "Ontological Emergence Scheme in Self-Organized and Emerging Systems". *Advanced Engineering Informatics*, vol. 44, 2020