

Un recorrido por casos de éxito de la aplicación del procesamiento de eventos complejos a ciudades inteligentes, salud y ciberseguridad

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- ▶ Procesamiento de eventos complejos
- ▶ Casos de éxito
- ▶ Publicaciones en revistas

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Sobre mí



- ▶ **Afiliación:** Profesor Titular de la Universidad de Cádiz (UCA).
- ▶ **Formación:** Ingeniero Informático y Doctor Internacional en Ingeniería y Arquitectura en el 2010 y 2014, respectivamente, por la UCA.
- ▶ **Labor profesional:** 11 años de experiencia docente e investigadora.
- ▶ **Líneas de investigación:**
 - ▷ *Software Engineering.*
 - ▷ *Complex Event Processing (CEP).*
 - ▷ *Real-time Big Data Analytics.*
 - ▷ *Event-Driven Service-Oriented Architecture (SOA 2.0).*
 - ▷ *Model-Driven Engineering (MDE).*
 - ▷ *Internet of Things (IoT).*
- ▶ **ORCID:** <https://orcid.org/0000-0002-8989-7509>

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- ▶ **Procesamiento de eventos complejos**
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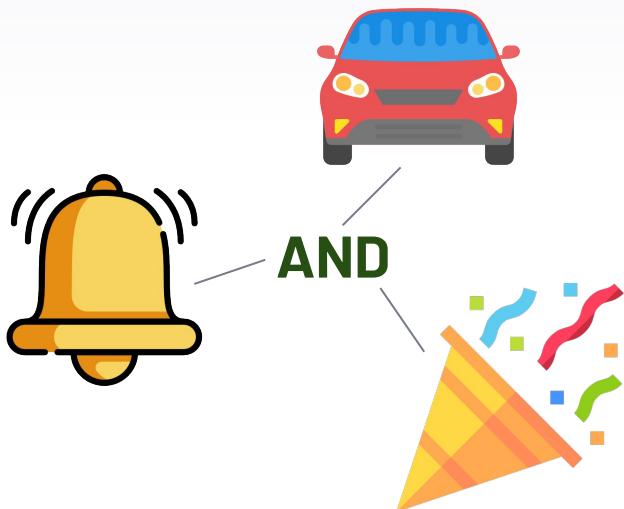
Definición de CEP

- ▶ Tecnología que permite procesar, analizar y correlacionar grandes cantidades de eventos.
- ▶ Para detectar y responder en **tiempo real** a situaciones de interés.
- ▶ Los **patrones de eventos** inferirán nuevos eventos más complejos ("situaciones") con mayor significado semántico.
- ▶ Requisitos software:
 - ▷ Motor CEP: Esper (<https://www.espertech.com/esper/>), Siddhi (<https://siddhi.io/>)...
 - ▷ EPL (*Event Processing Language*): EPL de Esper, SiddiQL...



Patrón de eventos

Eventos simples



Evento complejo

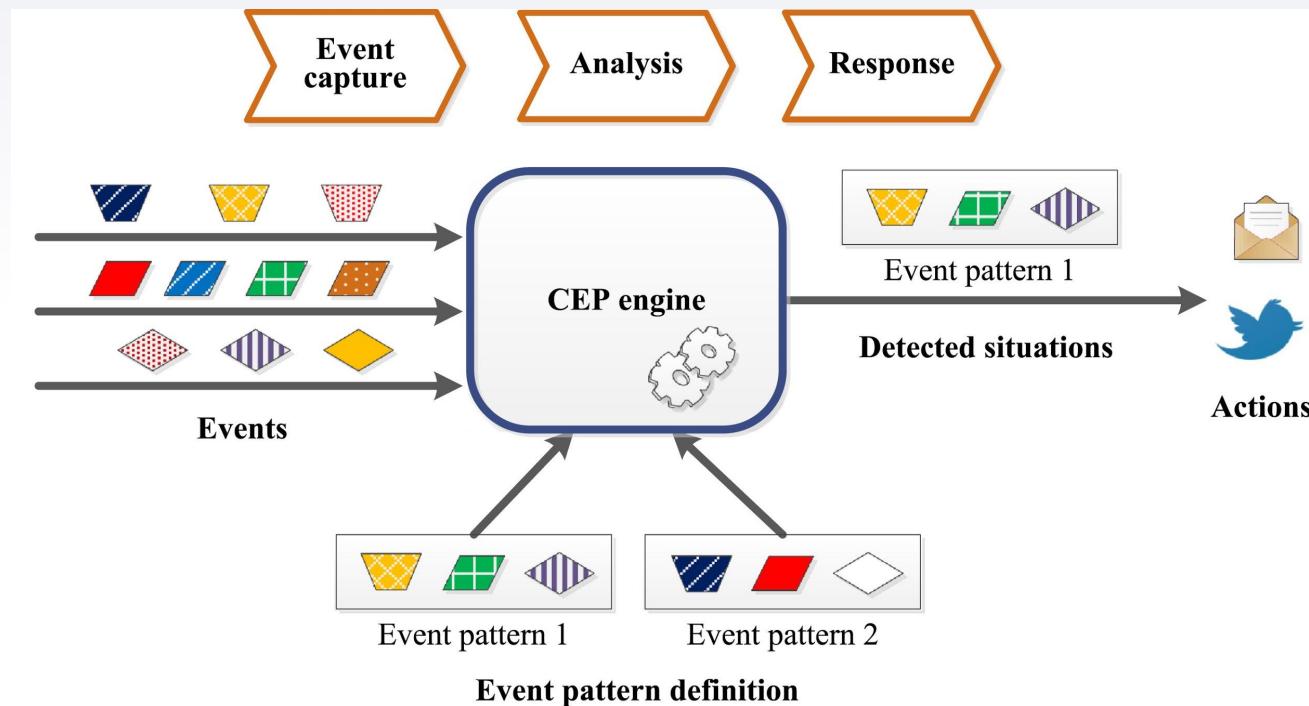


Fuentes de imágenes:

<https://www.flaticon.com/authors/vectors-market>

<https://www.freepik.com>

Etapas de CEP



Boubeta-Puig, J., Ortiz, G., & Medina-Bulo, I. (2015). MEdit4CEP: A model-driven solution for real-time decision making in SOA 2.0. *Knowledge-Based Systems*, 89, 97-112. <https://doi.org/10.1016/j.knosys.2015.06.021>

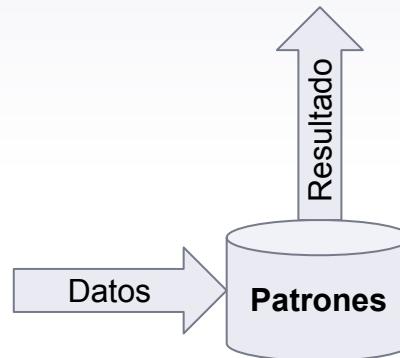
Procesamiento tradicional vs CEP

Procesamiento tradicional



La cotización de un valor o una noticia sobre una compañía en un instante determinado

CEP



Si se publica una noticia sobre una compañía y en menos de 30 s la cotización baja un 5%, entonces generar una orden de venta

CEP en el modelo 4D

Quiero saber cuanto antes qué está pasando para reaccionar de la mejor forma posible

¿Qué ha ocurrido?

Detect
(Detectar)



Derive
(Inferir)

¿Qué debemos hacer?

Decide
(Decidir)



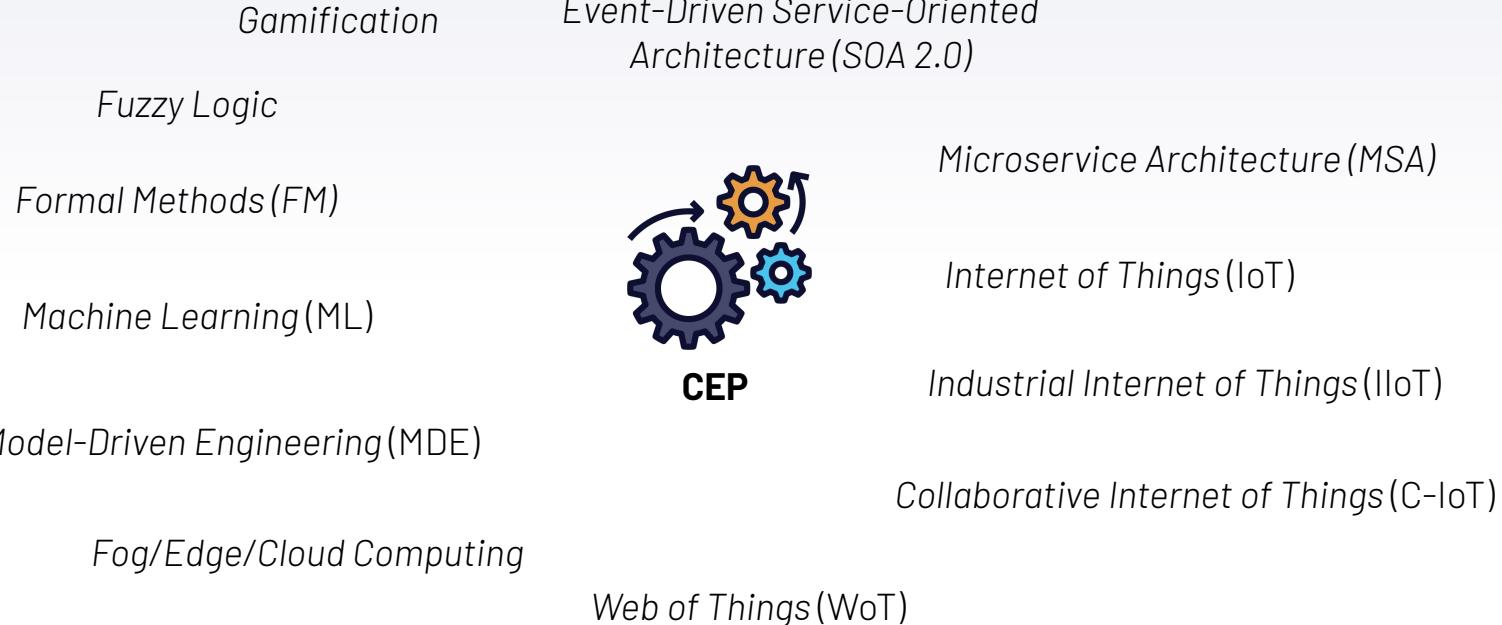
Do
(Actuar)

"No va a ser mejor el que más información tenga, sino el que mejor la sepa analizar y más rápidamente actúe" (Víctor Ayllón, CEO Novayre Solutions y actualmente Vicepresidente de Automatización de Appian Corporation)

Ventajas/beneficios de CEP

- ▶ Analítica de datos en **tiempo real**.
- ▶ Mejora de la calidad en las decisiones.
- ▶ Respuesta veloz.
- ▶ Prevención de sobrecarga de información.
- ▶ Reducción del esfuerzo humano.
- ▶ Facilita la integración con otros paradigmas/tecnologías.
- ▶ Otros beneficios:
 - ▷ <https://www.mordorintelligence.com/industry-reports/global-complex-event-processing-cep-market-industry>
 - ▷ <https://complexevents.com/2020/06/17/the-future-of-event-stream-analytics-and-cep/>

Integración de CEP con otros paradigmas



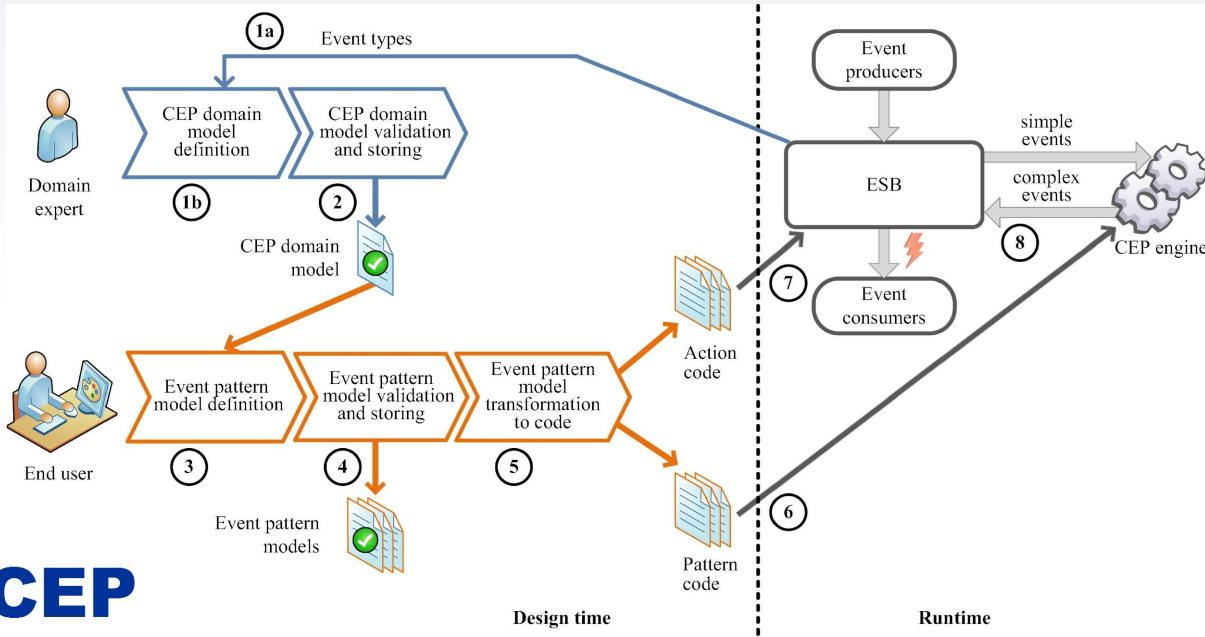
Trabajos sobre estas integraciones: <https://orcid.org/0000-0002-8989-7509>

Integración de CEP, SOA 2.0 y MDE



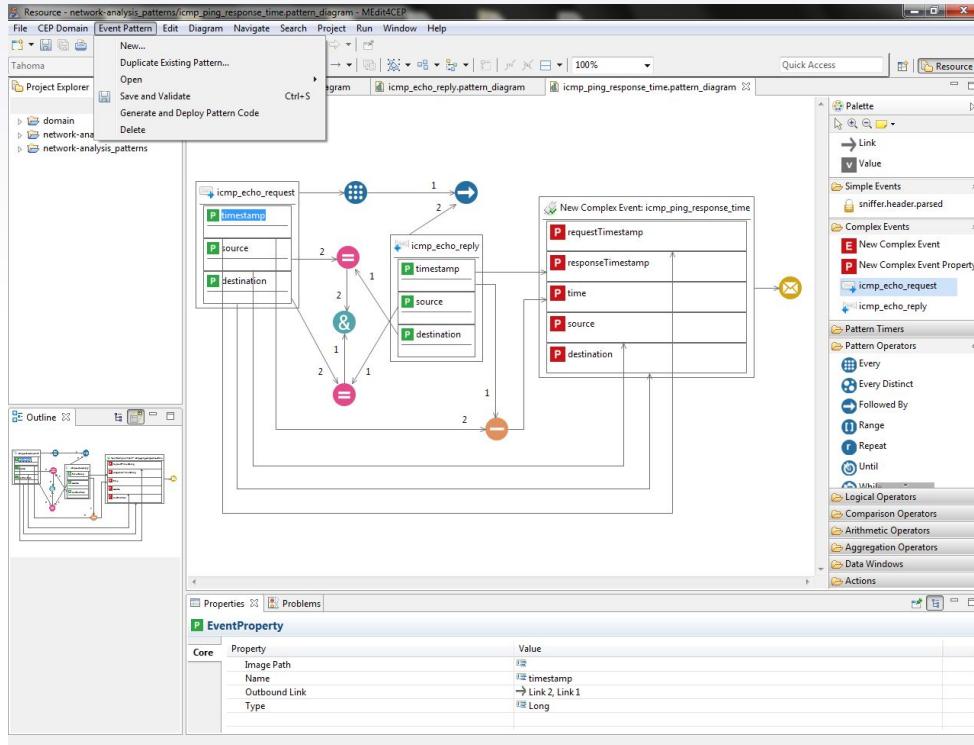
MEdit4CEP

<https://ucase.uca.es/medit4cep/>



Boubeta-Puig, J., Ortiz, G., & Medina-Bulo, I. (2015). MEdit4CEP: A model-driven solution for real-time decision making in SOA 2.0. *Knowledge-Based Systems*, 89, 97-112. <https://doi.org/10.1016/j.knosys.2015.06.021>

Herramienta MEdit4CEP



MEdit4CEP

<https://ucase.uca.es/medit4cep/>

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Escenarios de aplicación de CEP

- ▶ **Bolsa:** comprar y vender acciones automáticamente...
- ▶ **Comercio:** detectar compras fraudulentas...
- ▶ **Ciudad y puerto marítimo inteligentes:** detectar niveles de calidad de aire, saturación del tráfico rodado, ruido medioambiental, fugas en redes de abastecimiento de agua...
- ▶ **Ciberseguridad:** detectar ataques de seguridad en sistemas informáticos y dispositivos IoT...
- ▶ **Salud:** detectar epidemias, comportamientos anómalos en pacientes de Alzheimer, emergencias con mujeres embarazadas, niveles de polen...
- ▶ ...

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Detección de niveles de calidad de aire y saturación de tráfico rodado (I)

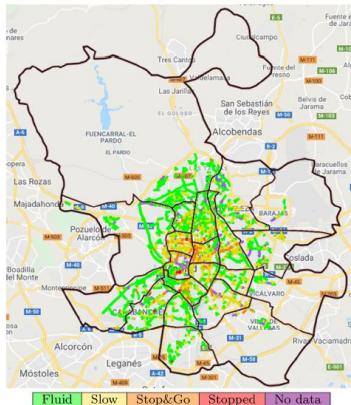


Table 3 AQI categories

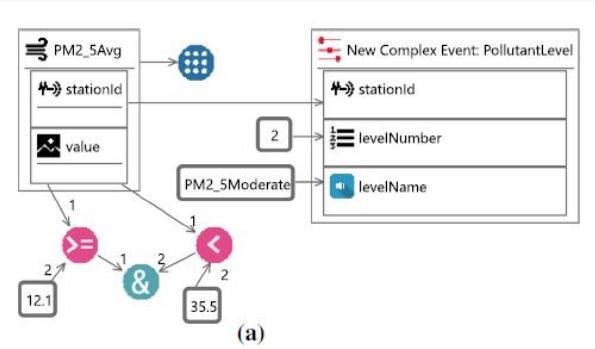
Air quality category	Pollutants							$PM_{2.5}$ ($\mu\text{g}/\text{m}^3$) 24 h	PM_{10} ($\mu\text{g}/\text{m}^3$) 24 h
	Name	L	Color	NO_2 (ppb) 1 h	SO_2 (ppb) 1 h	CO (ppm) 8 h	O_3 (ppm) 8 h		
Good	1	Green	0–53	0–35	0.0–4.4	0.000–0.054	0.0–12.0	0–54	
Moderate	2	Yellow	54–100	36–75	4.5–9.4	0.055–0.070	12.1–35.4	55–154	
Unhealthy for sensitive groups	3	Orange	101–360	76–185	9.5–12.4	0.071–0.085	35.5–55.4	155–254	
Unhealthy	4	Red	361–649	186–304	12.5–15.4	0.086–0.105	55.5–150.4	255–354	
Very unhealthy	5	Purple	650–1249	305–604	15.5–30.4	0.106–0.200	150.5–250.4	355–424	
Hazardous	6	Maroon	1250–2049	605–1004	30.5–50.4	> 0.200	250.5–500.4	425–604	

Table 1 Traffic level ratios in a trunk road/primary city

Level of traffic	Value	1-h average speed/speed limit
Free flow	1	> 0.87848
Heavy	2	0.75303–0.87848
Saturated	3	0.45306–0.75302
Stop and go	4	< 0.45306

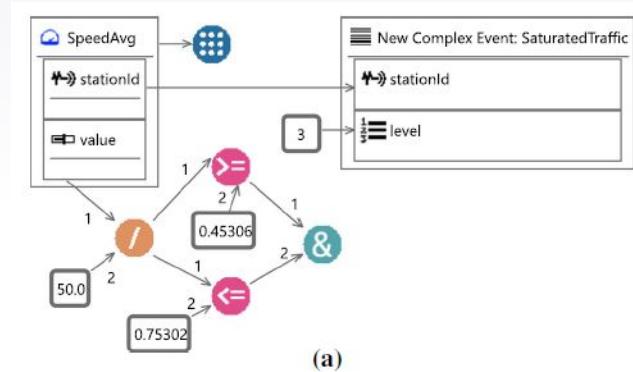
Díaz, G., Macià, H., Valero, V., Boubeta-Puig, J., & Cuartero, F. (2020). An Intelligent Transportation System to control air pollution and road traffic in cities integrating CEP and Colored Petri Nets. *Neural Computing and Applications*, 32(2), 405–426. <https://doi.org/10.1007/s00521-018-3850-1>

Detección de niveles de calidad de aire y saturación de tráfico rodado (II)



```
@Name("PM2_5Moderate")
insert into PollutantLevel
select a1.stationId as stationId,
       2 as levelNumber,
       'PM2_5Moderate' as levelName
from pattern [(every a1 =
    PM2_5Avg(a1.value >= 12.1 and
    a1.value < 35.5))]
```

(b)

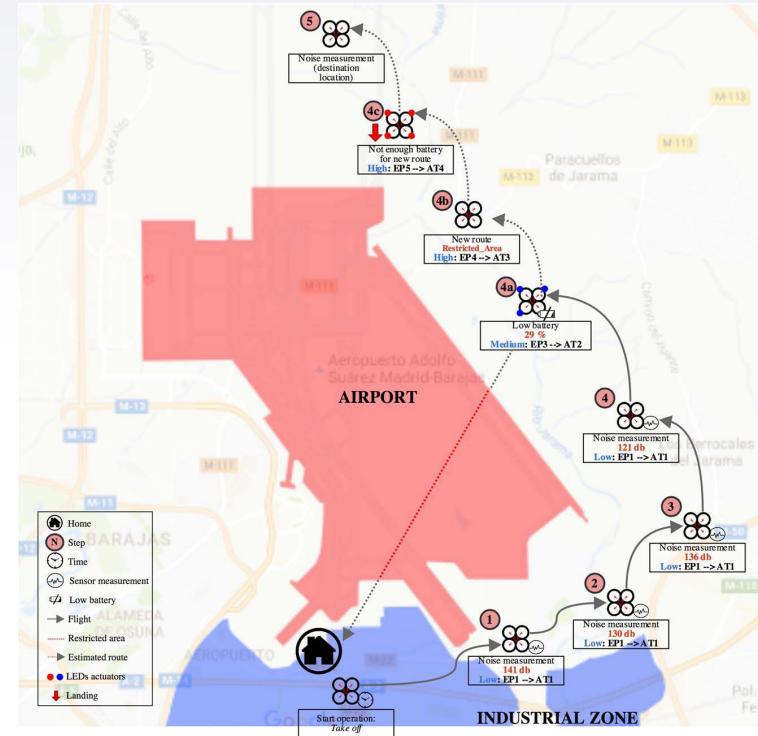
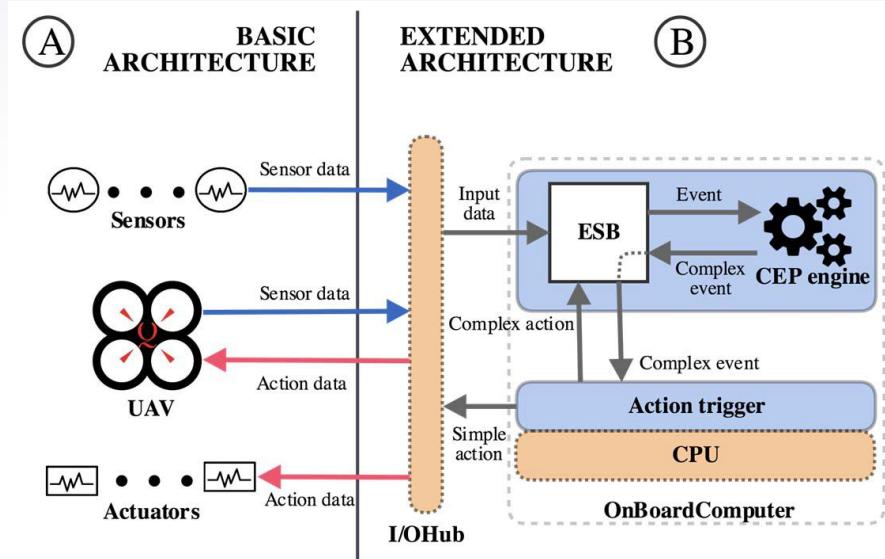


```
@Name("SaturatedTraffic")
insert into SaturatedTraffic
select a1.stationId as stationId,
       3 as level
from pattern [(every a1 = SpeedAvg(
    (a1.value / 50.0) >= 0.45306 and
    (a1.value / 50.0) <= 0.75302))]
```

(b)

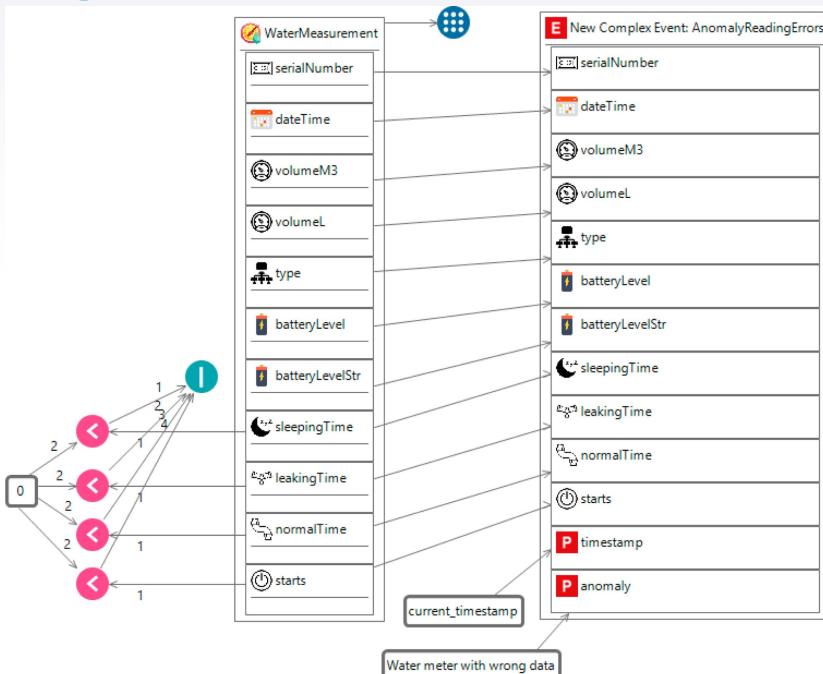
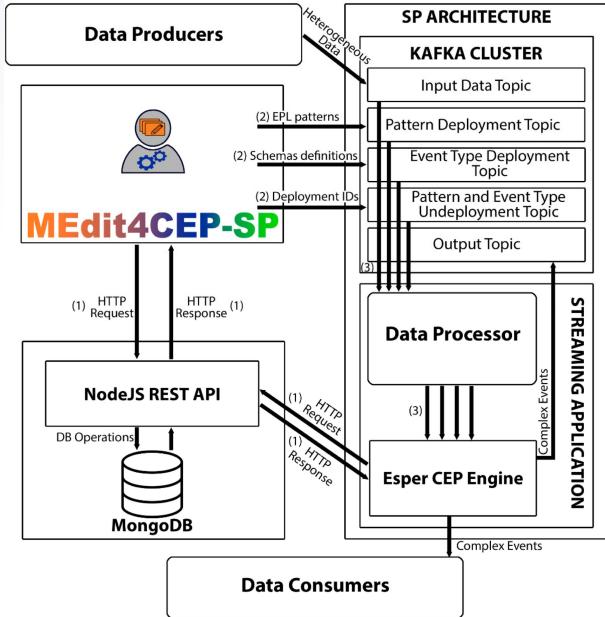
Díaz, G., Macià, H., Valero, V., Boubeta-Puig, J., & Cuartero, F. (2020). An Intelligent Transportation System to control air pollution and road traffic in cities integrating CEP and Colored Petri Nets. *Neural Computing and Applications*, 32(2), 405–426. <https://doi.org/10.1007/s00521-018-3850-1>

Detección de niveles de ruido medioambiental



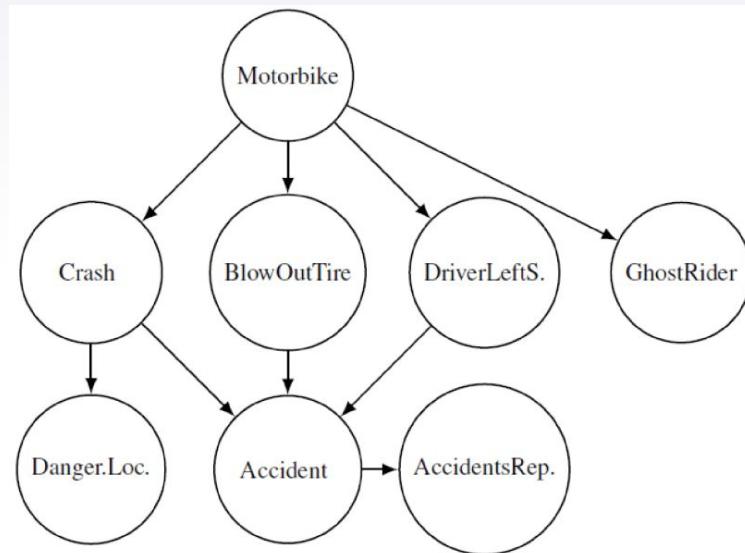
Boubeta-Puig, J., Moguel, E., Sánchez-Figueroa, F., Hernández, J., & Preciado, J. C. (2018). An Autonomous UAV Architecture for Remote Sensing and Intelligent Decision-making. *IEEE Internet Computing*, 22(3), 6-15. <https://doi.org/10.1109/MIC.2018.032501511>

Detección de anomalías en redes de abastecimiento de agua



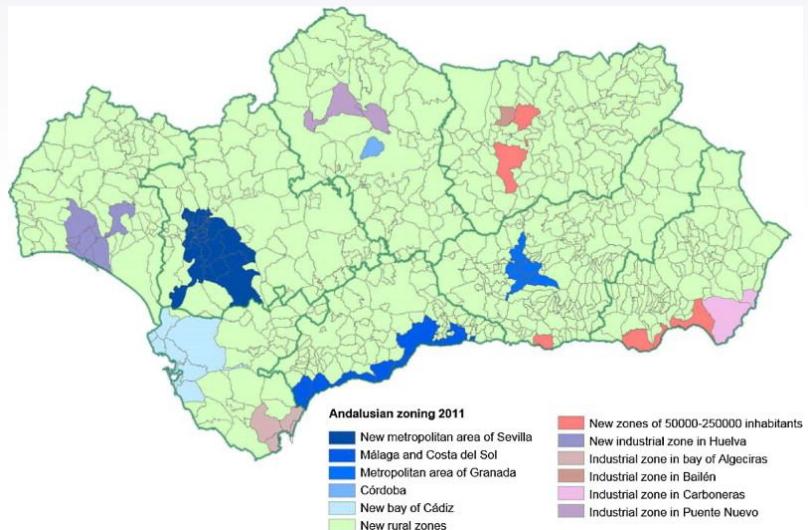
Corral-Plaza, D., Ortiz, G., Medina-Bulo, I., & Boubeta-Puig, J. (2021). MEdit4CEP-SP: A model-driven solution to improve decision-making through user-friendly management and real-time processing of heterogeneous data streams. *Knowledge-Based Systems*, 213, 106682.
<https://doi.org/10.1016/j.knosys.2020.106682>

Detección de accidentes en carretera



Burgueño, L., Boubeta-Puig, J., & Vallecillo, A. (2018). Formalizing Complex Event Processing Systems in Maude. *IEEE Access*, 6, 23222-23241.
<https://doi.org/10.1109/ACCESS.2018.2831185>

Detección de anomalías en redes de sensores



Boubeta-Puig, J., Bravetti, M., Llana, L., & Merayo, M. G. (2017). Analysis of temporal complex events in sensor networks. *Journal of Information and Telecommunication*, 1(3), 273-289. <https://doi.org/10.1080/24751839.2017.1347763>

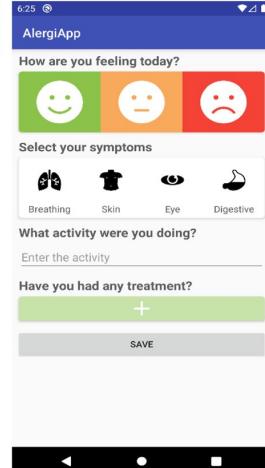
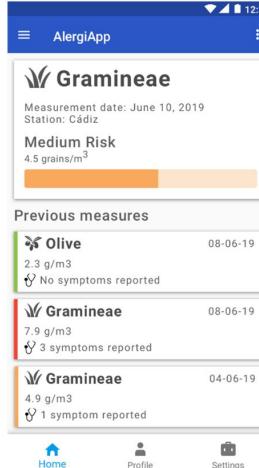
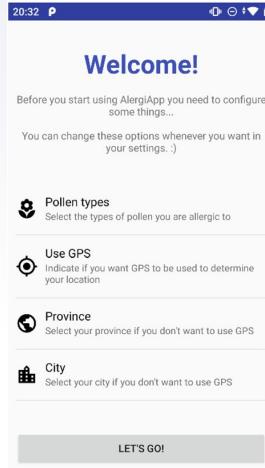
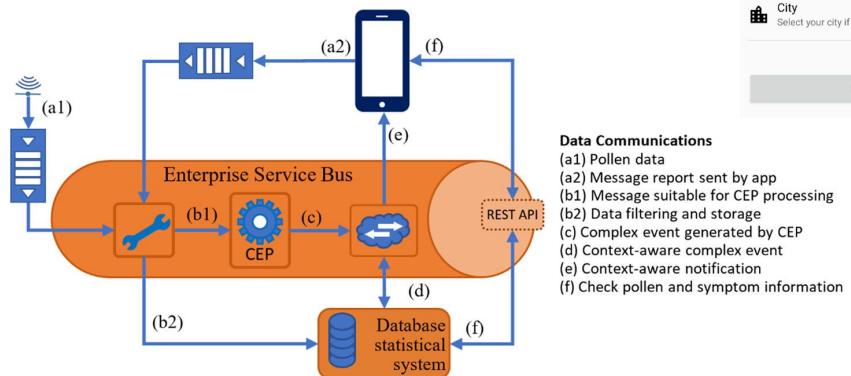
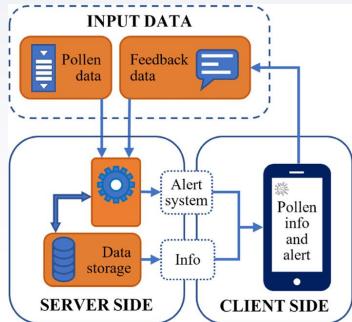
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Detección de epidemias/pandemias

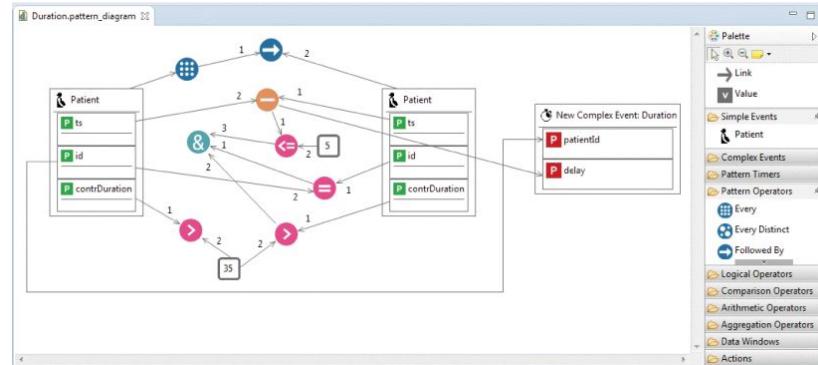
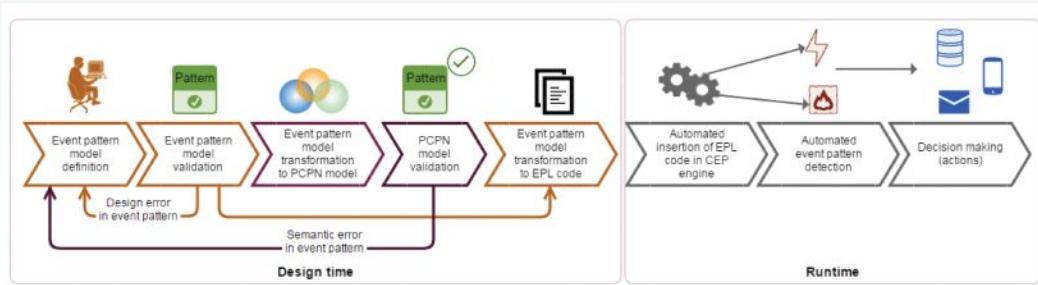
- ▶ Patrones de eventos de gripe aviar:
 - ▷ **Caso sospechoso:** el paciente tiene fiebre y mialgia, y mocos o tos... y tiene dolor de cabeza o fatiga...
 - ▷ **Caso confirmado:** el laboratorio confirma la infección de gripe aviar.
 - ▷ **Caso de epidemia:** existen 25 o más casos confirmados en un país durante 5 días.
 - ▷ **Caso de pandemia:** existen 2 o más casos de epidemia durante 3 días.

Detección de niveles de polen



Caballero, P., Ortiz, G., Garcia-de-Prado, A., & Boubeta-Puig, J. (2021). Paving the way to collaborative context-aware mobile applications: A case study on preventing worsening of allergy symptoms. *Multimedia Tools and Applications*. In press. <https://doi.org/10.1007/s11042-021-10759-6>

Detección de emergencias con mujeres embarazadas

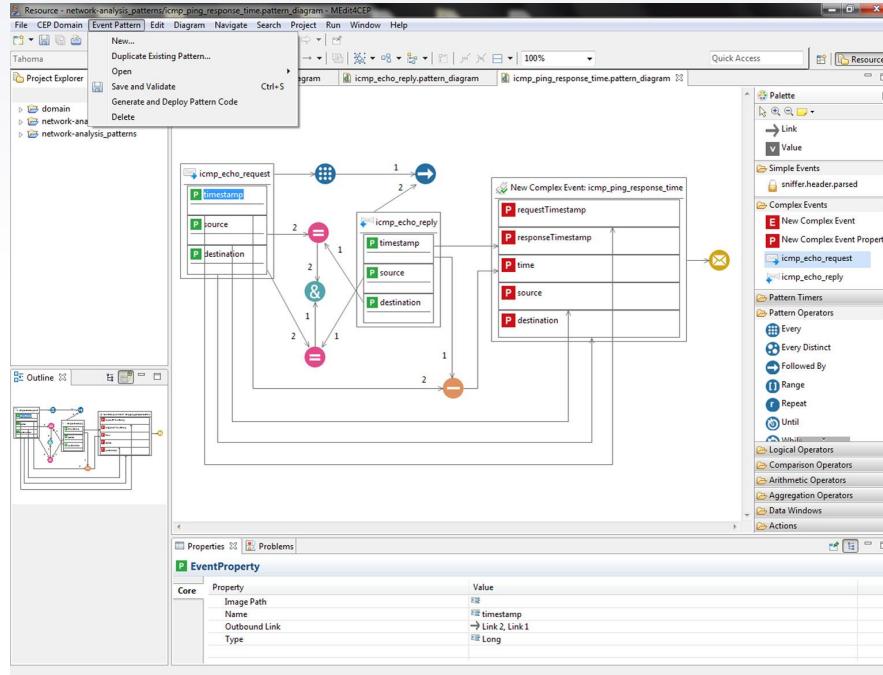


Macià, H., Valero, V., Díaz, G., Boubeta-Puig, J., & Ortiz, G. (2016). Complex Event Processing Modeling by Prioritized Colored Petri Nets. *IEEE Access*, 4, 7425-7439. <https://doi.org/10.1109/ACCESS.2016.2621718>

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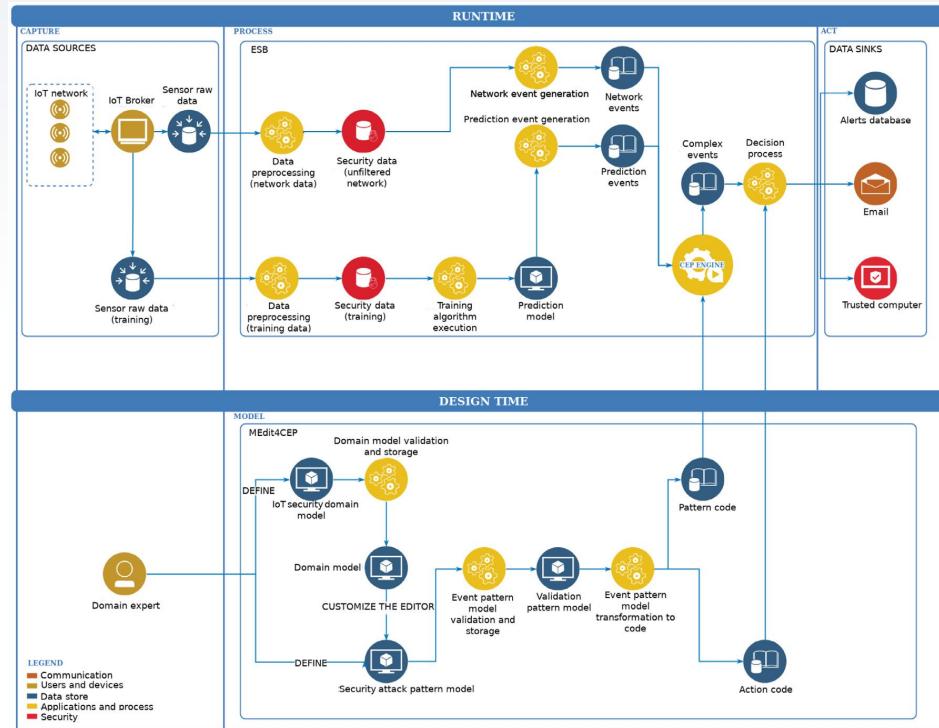
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Detección de anomalías/ataques



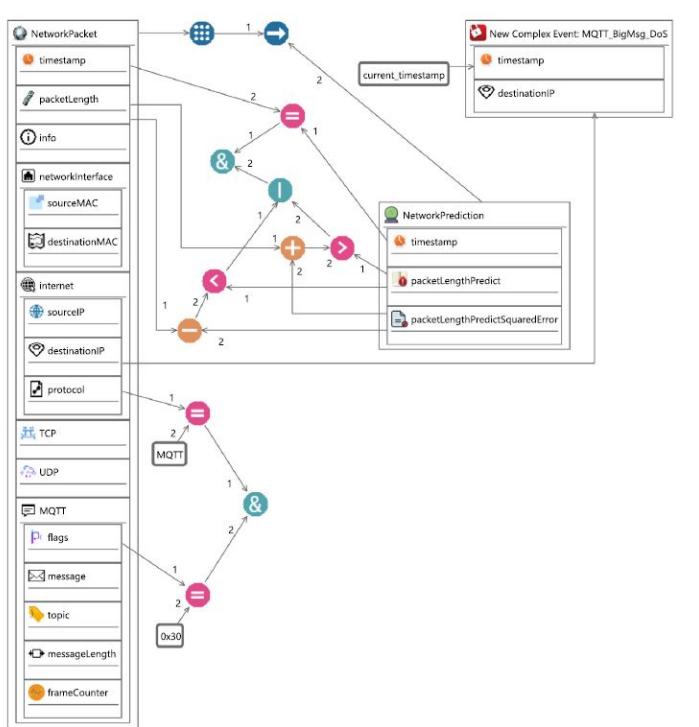
Boubeta-Puig, J., Ortiz, G., & Medina-Bulo, I. (2015). MEdit4CEP: A model-driven solution for real-time decision making in SOA 2.0. *Knowledge-Based Systems*, 89, 97-112. <https://doi.org/10.1016/j.knosys.2015.06.021>

Detección de anomalías/ataques IoT (I)



Roldán, J., Boubeta-Puig, J., Martínez, J. L., & Ortiz, G. (2020). Integrating Complex Event Processing and Machine Learning: An Intelligent Architecture for Detecting IoT Security Attacks. *Expert Systems with Applications*, 113251. <https://doi.org/10.1016/j.eswa.2020.113251>

Detección de anomalías/ataques IoT (II)



(a) Pattern model.

```
@Name("MQTT_BigMsg_DoS")
@Tag(name="domainName", value="IoTSecurity")
insert into MQTT_BigMsg_DoS
select current_timestamp() as timestamp, a1.internet.destinationIP as destinationIP
from pattern [((every a1 = NetworkPacket((a1.internet.protocol = 'MQTT' and
a1.MQTT.flags = '0x30))) -> a2 = NetworkPrediction((a2.timestamp = a1.timestamp
and (a2.packetLengthPredict < (a1.packetLength -
a2.packetLengthPredictSquaredError) or a2.packetLengthPredict >
(a1.packetLength + a2.packetLengthPredictSquaredError))))]

```

(b) Pattern implementation in Esper EPL.

Roldán, J., Boubeta-Puig, J., Martínez, J. L., & Ortiz, G. (2020). Integrating Complex Event Processing and Machine Learning: An Intelligent Architecture for Detecting IoT Security Attacks. *Expert Systems with Applications*, 113251. <https://doi.org/10.1016/j.eswa.2020.113251>

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Publicaciones en revistas (I)

CEP & SOA 2.0 & MDE:

- ▶ Boubeta-Puig, J. (2014). *Desarrollo Dirigido por Modelos de Interfaces Específicas de Dominio para el Procesamiento de Eventos Complejos en Arquitecturas Orientadas a Servicios* [Tesis doctoral, Universidad de Cádiz]. <http://hdl.handle.net/10498/17554>
- ▶ Boubeta-Puig, J., Ortiz, G., & Medina-Bulo, I. (2014). A Model-driven Approach for Facilitating User-friendly Design of Complex Event Patterns. *Expert Systems with Applications*, 41(2), 445-456. <https://doi.org/10.1016/j.eswa.2013.07.070>
- ▶ Boubeta-Puig, J., Ortiz, G., & Medina-Bulo, I. (2015). ModeL4CEP: Graphical domain-specific modeling languages for CEP domains and event patterns. *Expert Systems with Applications*, 42(21), 8095-8110. <https://doi.org/10.1016/j.eswa.2015.06.045>
- ▶ Boubeta-Puig, J., Ortiz, G., & Medina-Bulo, I. (2015). MEdit4CEP: A model-driven solution for real-time decision making in SOA 2.0. *Knowledge-Based Systems*, 89, 97-112. <https://doi.org/10.1016/j.knosys.2015.06.021>
- ▶ Calderón, A., Boubeta-Puig, J., & Ruiz, M. (2018). MEdit4CEP-Gam: A model-driven approach for user-friendly gamification design, monitoring and code generation in CEP-based systems. *Information and Software Technology*, 95, 238-264. <https://doi.org/10.1016/j.infsof.2017.11.009>
- ▶ Boubeta-Puig, J., Díaz, G., Macià, H., Valero, V., & Ortiz, G. (2019). MEdit4CEP-CPN: An approach for complex event processing modeling by prioritized colored petri nets. *Information Systems*, 81, 267-289. <https://doi.org/10.1016/j.is.2017.11.005>
- ▶ Corral-Plaza, D., Ortiz, G., Medina-Bulo, I., & Boubeta-Puig, J. (2021). MEdit4CEP-SP: A model-driven solution to improve decision-making through user-friendly management and real-time processing of heterogeneous data streams. *Knowledge-Based Systems*, 213, 106682. <https://doi.org/10.1016/j.knosys.2020.106682>

Publicaciones en revistas (II)

CEP & IoT & Fog/Edge/Cloud Computing:

- ▶ García de Prado, A., Ortiz, G., & Boubeta-Puig, J. (2017). CARED-SOA: A Context-Aware Event-Driven Service-Oriented Architecture. *IEEE Access*, 5, 4646-4663. <https://doi.org/10.1109/ACCESS.2017.2679338>
- ▶ Garcia-de-Prado, A., Ortiz, G., & Boubeta-Puig, J. (2017). COLLECT: COLlaborativE ConText-aware service oriented architecture for intelligent decision-making in the Internet of Things. *Expert Systems with Applications*, 85, 231-248. <https://doi.org/10.1016/j.eswa.2017.05.034>
- ▶ Garcia-de-Prado, A., Ortiz, G., Boubeta-Puig, J., & Corral-Plaza, D. (2018). Air4People: A Smart Air Quality Monitoring and Context-Aware Notification System. *Journal of Universal Computer Science*, 24(7), 846-863. <https://doi.org/10.3217/jucs-024-07-0846>
- ▶ Boubeta-Puig, J., Moguel, E., Sánchez-Figueroa, F., Hernández, J., & Preciado, J. C. (2018). An Autonomous UAV Architecture for Remote Sensing and Intelligent Decision-making. *IEEE Internet Computing*, 22(3), 6-15. <https://doi.org/10.1109/MIC.2018.032501511>
- ▶ Corral-Plaza, D., Boubeta-Puig, J., Ortiz, G., & Garcia-de-Prado, A. (2020). An Internet of Things Platform for Air Station Remote Sensing and Smart Monitoring. *Computer Systems Science & Engineering*, 35(1), 5-12.
- ▶ Corral-Plaza, D., Medina-Bulo, I., Ortiz, G., & Boubeta-Puig, J. (2020). A stream processing architecture for heterogeneous data sources in the Internet of Things. *Computer Standards & Interfaces*, 70, 103426. <https://doi.org/10.1016/j.csi.2020.103426>
- ▶ Caballero, P., Ortiz, G., Garcia-de-Prado, A., & Boubeta-Puig, J. (2021). Paving the way to collaborative context-aware mobile applications: A case study on preventing worsening of allergy symptoms. *Multimedia Tools and Applications*. In press. <https://doi.org/10.1007/s11042-021-10759-6>

Publicaciones en revistas (III)

CEP & Services & Microservices

- ▶ Ortiz, G., Caravaca, J. A., Garcia-de-Prado, A., Chavez de la O, F., & Boubeta-Puig, J. (2019). Real-Time Context-Aware Microservice Architecture for Predictive Analytics and Smart Decision-Making. *IEEE Access*, 7, 183177-183194.
<https://doi.org/10.1109/ACCESS.2019.2960516>
- ▶ Gamaza, Á., Ortiz, G., Boubeta-Puig, J., & Garcia-de-Prado, A. (2020). REST4CEP: RESTful APIs for complex event processing. *Science of Computer Programming*, 198, 102515. <https://doi.org/10.1016/j.scico.2020.102515>

Publicaciones en revistas (IV)

CEP & Formal Methods:

- ▶ Macià, H., Valero, V., Díaz, G., Boubeta-Puig, J., & Ortiz, G. (2016). Complex Event Processing Modeling by Prioritized Colored Petri Nets. *IEEE Access*, 4, 7425-7439. <https://doi.org/10.1109/ACCESS.2016.2621718>
- ▶ Burgueño, L., Boubeta-Puig, J., & Vallecillo, A. (2018). Formalizing Complex Event Processing Systems in Maude. *IEEE Access*, 6, 23222-23241. <https://doi.org/10.1109/ACCESS.2018.2831185>
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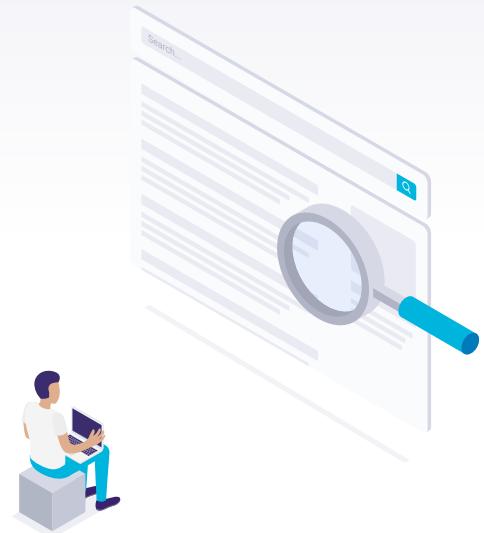
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¡Muchas gracias por su atención!

¿Preguntas?

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