Smart Outdoor Light Desktop Central Management System

Dolores María Llidó Escrivá*, Joaquín Torres-Sospedra† and Rafael Berlanga-Llavori*
*Department of Software and Computer Systems, Universitat Jaume I, Castellón de la Plana, España
†Institute of New Imaging Technologies, Universitat Jaume I, Castellón de la Plana, España
`[ dllido , jtorres , berlanga ] @uji.es`

***Abstract*—Light pollution and nature preservation, are new trends in which the European cities are involved as they evolve into Smart Cities. Internet of Things are changing the way that sensors and management control systems are designed and implemented. In this article, our main objective is to present an Outdoor Light Desktop Central Management architecture using current IoT (Internet of Things) and GIS technologies to improve the energy efficiency, user experience and safety feeling at the same time we are going to decrease light pollution of LED lamps. The challenge is to provide a lighting control system to suit each zone, from residential areas and public spaces to industrial parks, and each context. Furthermore, the design of the technological multi-platform able to operate with any kind of electrical device will be useful in the area of outdoor lighting.**

***Index Terms*—Outdoor Light, Streaming Data, Internet of Thing, GIS, Smart Cities, Control systems**

I. INTRODUCTION

Light pollution and nature preservation, are two of the trends in which the European cities are involved in to comply with Kyoto Protocol (1995) and ratified in 2015 the Paris Agreement on COP 22 Climate Change Conference [1]. In the second commitment period the EU has committed to cut its blue-house gas emissions by at least 20% by 2020. But the goal of lighting policy should be to provide the light needed for any given task while minimizing both the energy (street lights consumes $\approx 30\% - 40\%$ of the entire city power [2]) use and negative environmental side effects of the light [3]. Additionally, smart light control is seen as a significant example of an ideal and friendly environment [4]

Existing systems are far less flexible and only enable lights to be either on or off. LED lights have three key benefits, namely: they can be controlled with high precision, dimmed rapidly and adjusted continuously to create the visibility level and safety feeling required. Moreover, LED lights provide high quality light, less environmental damage, and lower long-term costs. During the last years Europe's public sector has beginning to adopt LED luminaires following the European Policies. However, administrations can hardly afford an intelligent light central management system (CMS) [5], mainly due to its high cost and financial restrictions.

With existing intelligent light central management system, Data collection can be a difficult exercise due to national legislations and to some reluctance to work with the private sector. As a consequence, taking profit from Big Data and Machine Learning to improve the whole system becomes much more difficult.

This paper proposes the use of a geographic information system (GIS) to create an Smart Outdoor Light Desktop CMS for residential areas like university campus, parking areas or, even, a small city. The use of GIS will allow us not only the creation of a map web user interface to help the lights management. Spatial analysis with GIS will allow to minimize the number of the required sensors, to optimize the required intensity of the light using location and terrain topography. One of the advantages of applying GIS is that we can calculate the influence areas of lamps according to its bulb properties, post height and terrain properties among others.

Figure 1 shows an example of the SmartLigth Monitoring System, which is hosted at the UJI's SmartCampus website. In the figure, the location of the road (orange) and pedestrian (yellow) lights are shown in a map-based interface. This interface also facilitates the management and monitoring of lights by just clicking on the light.

The goals of the proposed system can be summarized as follows:

- Managing and controlling luminaires using a map-based interface and web technologies.
- Switching on the lamps only when there is not enough daylight.
- Adapting light luminosity level to the presence of pedestrians and vehicles to improve the user experience and safety feeling.
- Using GIS to improve the required luminosity level for each lamp according to its location and proximity.
- Using advanced techniques of Big Data and Machine Learning for the establishment of interactive lighting patterns and for the statistical analysis of the luminaires live cycle.

A requirement of this system is its interoperability and easy access through a set of diverse devices (computer, tablets, phones) to the monitoring system.

The main contribution of our proposed lighting system is the exhaustive use of GIS. In particular, we are going to use the geographic information not only to improve the user experience, through insightful visualizations, but also to control the light intensity in combination with other environmental data provided from sensors. Finally, another feature of our system is that our sensors and luminaires are Internet of Things (IoT) devices that send to the cloud the information in real time using streaming stubs [6]. All this work has been developed under the *Smart Ways project* [7].

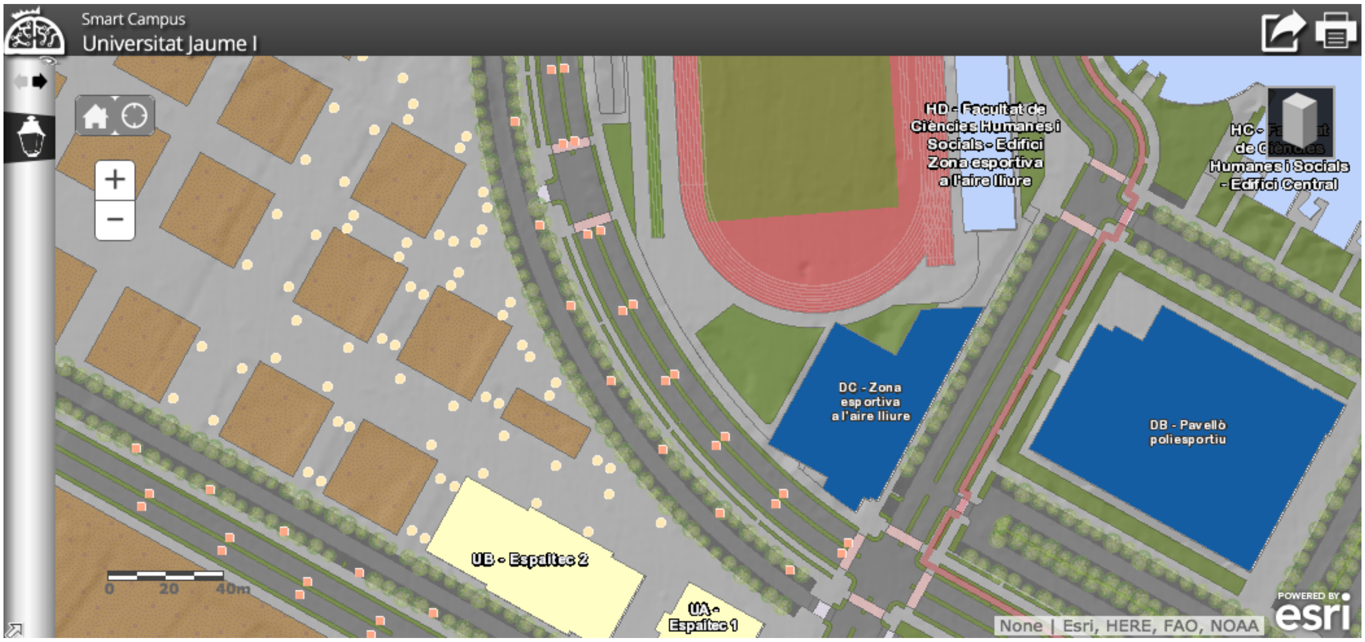


Fig. 1: SmartLight Monitoring System. Orange squares refer to road lights, whereas yellow markers stand for pedestrian lights.

The use case introduced in this paper is located in the Campus of the University Jaume I. The campus is designed as a single-walled space in order to encourage closer human relationships, and is equipped with up-to-date academic, research, cultural and social facilities. It is a blue, sustainable campus that promotes energy saving and the use of renewable energies. It offers among others recycling points for material recovery, and monitoring sensors for energy consumption. The campus also promotes high accessibility, with public transportation running through the campus, and barrier-free architecture for disabled people. Summarizing, this campus effectively works as a small city.

Due to limitations related with the luminary costs [8], [9], and the problems with data gathering [5], this work simulates the performance of the luminaires and their sensors for an area of the campus. Simulations are controlled with real IoT gateways and are fully integrated with the GIS-based SmartUJI platform [10], [11], where lamp failures can be also taken into account.

The remaining of this paper has been organized as follows: Section 2 presents an overview of lighting outdoors systems and introduces some required concepts. Section 3 presents the proposed smart-light architecture. Section 4 presents a case study in our university campus. Current trends and future work are presented in Section 5.

II. STATE OF THE ART

Nowadays the lighting control consists of hardware implemented using a segment controller (usually following DALI protocol IEC 62386 [12]) or a dedicated outdoor light controller (OLC) on each LED street-light (controlled by a wireless technology like XBee, GSM, or Wi-Fi, among others). The ISO/IEC 14908-1:2012 specifies a communication protocol for local area control networks [13].

The standard supporting hybrid wired/wireless outdoor lighting control is the ISO 14908, an open, proven, multi-vendor standard. Its standard features include switching on/off, luminosity dimming commands, lamp feedback monitoring, failure identification, electrical and energy measures and run hours metering. LED luminaires allow continuous dimming values ranging from 0 (the light is off) to 100 (the light is providing the maximum light intensity).

Intelligent luminaires save energy not only by using LED technology, they also provide a intelligent unit control with some optimal programmed tasks that change the dimming of the LED luminaires using predefined rules and the characteristics related to the place where the lamp is located. This control unit, which might differ depending on the light brand and model, is set when the lamp is installed to a particular location. Usually, these lamps require a Wi-Fi connection to manage each control unit remotely.

Most of the European cities want to be more efficient to dismiss light pollution and energy cost. The first step is replacing the street luminaires with smart street lights. These are more energy-efficient and in a few years they recover the initial investment. Despite the standards, which promote the interoperability between different manufacturers, current network CMS and OCL data formats are proprietary of each light manufacturer, and therefore difficult to integrate in external systems.

At the national level there are examples of related experiences, like the Smart City Project in Santander [14], developed by Telefónica I+D and the Cantabria University that uses Fiware [15]. This project includes a test case that involves the use of wireless LED street-light with an intelligent wireless OLC on each light. In [16], [17] each lamp post uses an electronic card for management and a ZigBee network protocol to transmit data to the central control unit.

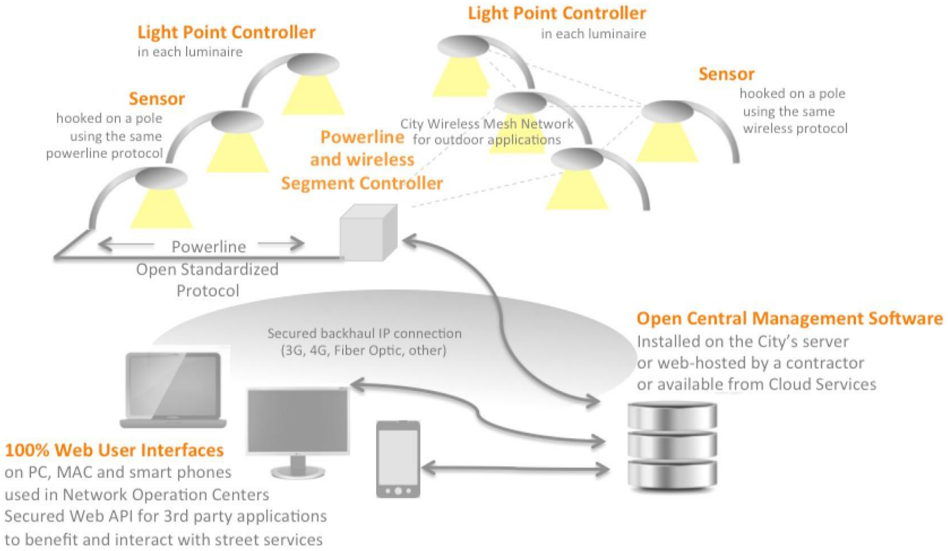


Fig. 2: LonMark Architecture [18].

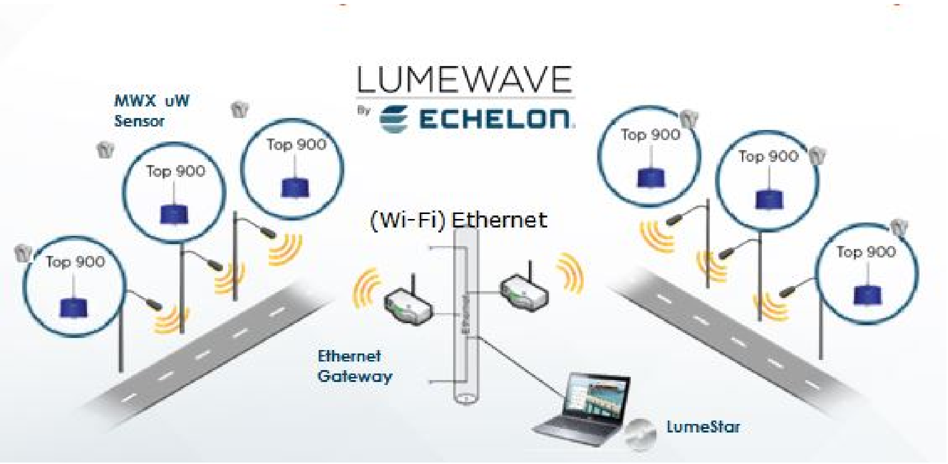


Fig. 3: ECHELON Architecture [19].

There are two solutions to improve the energy savings: adaptive lighting (e.g., Philips Lumimotion) and interactive light (e.g., Lumewave-Echelon). Adaptive lighting is the alteration of the output or duration of lighting in response to demand, real-world lighting conditions, or other parameters. In this context, the main goal is to configure a network central management system to improve outdoor lighting energy efficiency. Interactive lighting is mainly applied in pedestrian zones, and it aims to adjust illumination parameters accordingly to some detected events (e.g., the presence of people).

	LED	LED & network	Adaptive LED & network
Total retrofit per fixture [USD$]	360	595	645
Annual energy consumption [kWh]	232	162	71
Energy Savings [%]	72	80	91
Annual maintenance costs [USD$]	94.91	101.57	110.67

TABLE I: Table Cost Efficient Street luminaires from [8]

In Table I, we can see how the use of LED luminaires allow us to improve energy saving up to 72%, but using adaptive dimming and Network Control systems we can improve a 20% more the energy efficiency (up to 91%) with a good level of visibility and without decreasing the sense of safety. This information is obtained from [8], which presents some use cases of outdoor lighting control solutions.

Although most of the actual solutions reduce the energy consumption, they are still too expensive see the retrofit costs in Table I). In the best of the cases most of the cities are nowadays installing LED luminaires with a OLC that modifies the dimming of the LED luminaires using time-based rules. This solution improves the existing systems, which are amortized in a few years.

Philips solution to connect luminaires to the cloud is the Starsense Wireless OLC [20], which can be installed on the LED Starsense luminaires. This company also offers an standalone lighting system specifically designed to minimize light consumption without compromising people's safety (*LumiMotion*). For example, it enables the regulation of street lighting depending on the cross-walk [21]. Thus, this solution can be regarded as an interactive LED lighting system

LonMark [18] proposes the directives called *Market, Challenges, Solutions and Next Steps for "Open Street-light Control System for Smarter Cities"*. They present a system architecture for dynamic street-light control, which relies on the following key components: light point controllers, gateways (OLC), segment controllers, meters, sensors, digital and analogue inputs and other devices. This architecture is presented in Figure 2.

Following these directives, Echelon's Lumewave wireless outdoor lighting control solution provides a complete system that includes the following components: lighting controllers and modules, gateways, and a desktop central management software (*LumInsight*). Figure 3 scketches its architecture. Cambridge use case developed by *Echelon* is an example of adaptive street lighting [22].

LonMark deploys its use case in Paris (street lights), using components from several manufacturers [23]. To monitor the system, this system uses a Vision Central Management Software [24], which is a commercial solution for cities that can be adapted to any manufacturer. It also provides control over light point controllers, cabinet controllers, smart meters, sensors and other smart city equipments from 40 suppliers, all in a single unified Central Management Software.

In [25] authors present an interactive solution. Once a pedestrian is located, lamps are switched on along the connecting area between the pedestrian and the infrastructure zones. This solution improves the efficiency of the system without decrease user experience and safety feeling.

However, there is also interest in combining interactive lightning with non-pedestrian events. e.g. Novak et al. [26] introduced a way of integrating intelligent streetlight with traffic management into a Smart City platform in order to increase energy efficiency of a city.

The fast evolving technological advance of IoT, along with the sustained competition between manufacturers of the required devices for both wireless control and data gathering from sensors, is going to make this technology more accessible, and a good solution to be installed to allow a wireless OLC gateway to control the luminaires.

For example, *Libelium* [27] designed an IoT Sensor Platform, where sensors continuously send data using a wireless connection with a Waspmote device. They also propose an IoT gateway named *Meshlium*, which is in charge of collecting and storing locally the sensor data. The *Meshlium* gateway [27] can send all these data to any cloud platform. In [17] authors present an outdoor light monitoring and control system that showed energy savings around 70.8%. This work was a prototype tested within a university campus. It is worth mentioning that they also proposed to reduce the number of sensors by supplying data loss with WIMAX and GPRS technologies.

III. SYSTEM OVERVIEW AND ARCHITECTURE

Wireless intelligent LED dimming lamps[18] are provided with a software component and a small memory. The software component allows users to configure the lamps matching the light intensity to the space usage, and it integrates some energy management functions like an astronomical clock for enabling adaptive lighting through a calendar and light sensors. The CMS, according to the standards, should support Light Points, Segment Controllers, Gateways, Sensors, Weather Stations, Energy Meters among other object types. The CMS should be based on an open Web Application Server, with which each lamp can be network controlled to change its intensity, and each lamp reports to the CMS its status/intensity change/energy consumption. In case of connection failures with the CMS, a local memory will be in charge of storing the sensor data so that it can be sent to the CMS as soon as the communication is restored, avoiding data loss.

Our system makes extensive use of a GIS server. Street information as well as the placement of lamps are stored in GIS layers. Monitoring systems are devised as responsive web application, which are accessible by secure web clients to control the outdoor light system.

The rest of the system is implemented using REST services. Like in other systems [23], all gathered information is visualized in maps. But unlike them, we explore all the GIS functionalities to perform spatial analysis to optimize the system.

We present in Figure 4 our Smart Outdoor Light Desktop Central Management System architecture. The architecture is composed of:

- A set of LED outdoor luminaires installed on a restricted area. *Lamp Node*.
- A set of IoT Lamp Gateways, one for each luminary aimed at implementing a wireless OLC.
- A set of sensors installed on the lamp post or in any other location.
- A set of IoT Sensors Gateway to control the sensors.
- A data repository (DB). It should be a data cloud-based storage, which is charge of storing static information like the luminaires properties like characteristics, location and identifier (*lamp properties table*), the sensor properties (*sensor properties table*), dynamic data like the actual status of each lamp (*lamp status table*), the data generated by the sensor (*sensor records table*), and the historical register of the status of the lamps for Big Data analysis (*historical lamp event table*).
- A GIS server. This component is not only included to show maps, but also to analyse and process data stored locally and in the cloud to perform spatial analysis. In our case, the GIS database contains the feature layers of the target area, the roads, the buildings and the luminaires among other locations. This component is able to compute the optimal route between two any points, and to identify the lamps near a desired point and the lamps near a walking route.
- The Smart Collector. It is the component in charge of receiving all the data from sensors and lights, store it on the DB, detect event patterns and activate the event-response. The Smart Collector is continuously receiving information from sensors and luminaires in streaming. As the event patterns are activated by the sensors or luminary, which are located in specific places, we can know where luminosity needs to be modified. The information is

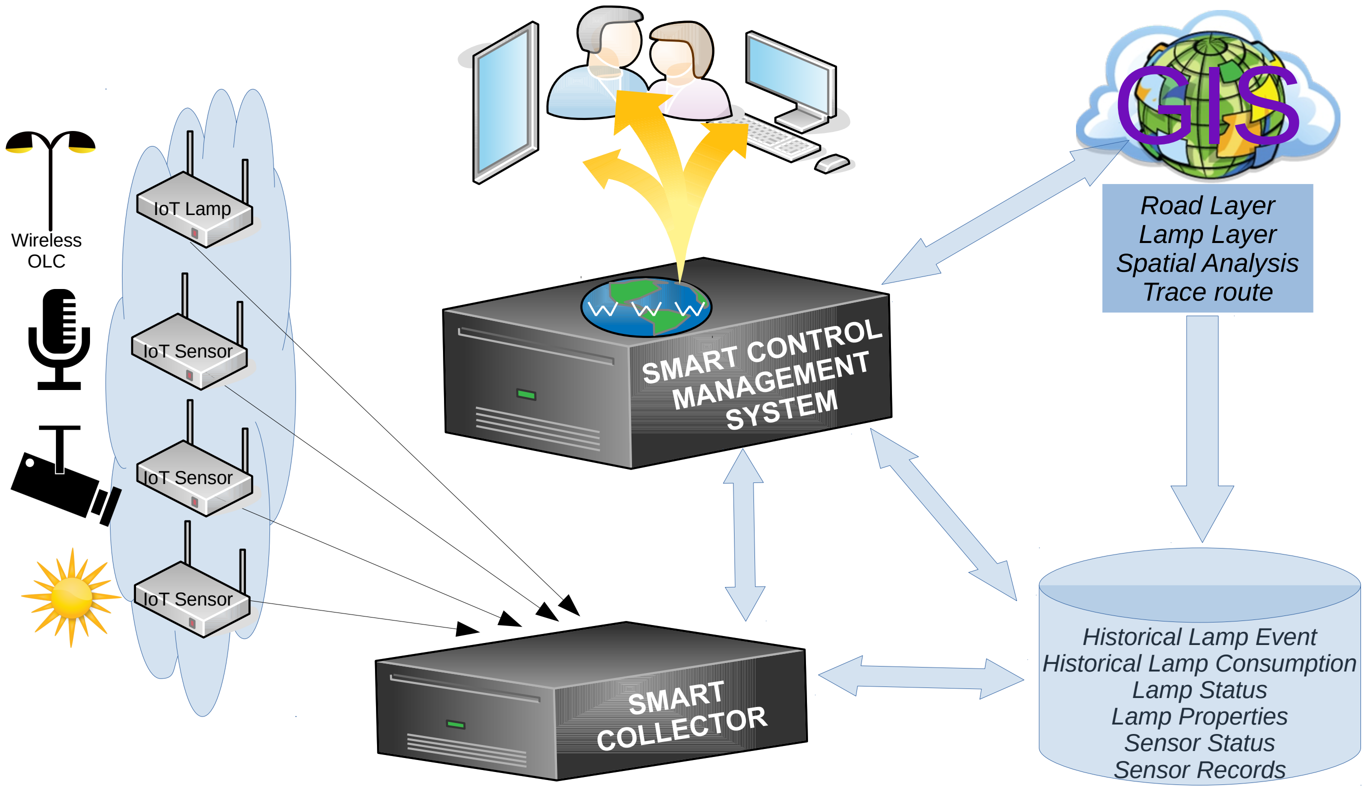


Fig. 4: Smart Outdoor Light Desktop Central Management Software Architecture

stored in the DB and the GIS component will help us to know which lamps are in the influence area of each event pattern. Once and event pattern is activated the Smart Collector sends to the Smart Central Management System a list of instructions and/or alarms. Its most important task is to analyse all the received information to detect event patterns.

- The Smart Central Management System. It is the component in charge of sending the instructions to the luminaires through the IoT Lamp Gateway and reporting its status from the DB. The Smart Central Management System will enable users to configure Light Points, program the on/off/dimming times and intensity levels, help to diagnose failures of light nodes, and execute the response of the events generated by the Smart Collector and/or to generate alarms to notify issues to the operators.
- The Desktop Monitoring System (Web Application). Using a Web application, the operator will control and monitor the working area, and analyse in real-time the energy consumption and light performance.

IV. SOFTWARE SOLUTION

This section introduces the proposed software solution for developing the smart light central management system. In our prototype we defined the required software for the IoT and the data interchange protocol for lamps and sensors in order to control the devices and obtain their data in real-time.

The GIS database requires the feature layers of our campus, the roads, the buildings, and the luminaires among other locations. The GIS system is able to compute the optimal route between two any points. Thus we can enable the lamps near a desired point or the lamps near a walking route.

The GIS component is required when applying changes in the light intensity of the luminaires in the following case scenarios:

- Automatically soft lighting in low-traffic areas.
- Change from low intensity to higher in the neighbours lamps of a damaged lamp.
- Change from low intensity to higher in sections with circulating pedestrians.
- Change from low intensity to higher when a moving vehicle is detected near a pedestrian zone.
- Illuminate a route when a driver specifies its destination.
- Identify the lights that intersects a vehicle's route.
- Identify the lights around a pedestrian.

As previously said, our University is developing a Smart Campus platform (http://smart.uji.es/) whose aim is to improve monitoring and management of campus resources. It has all the topographic layers and a complete and accurate cartographic of our campus. It is developed in the SmartUJI platform [10], [11] a web interface that allows users to obtain map-based information about the different facilities of the campus. This platform gives users a simple an intuitive way to manipulate and visualize data. Moreover, due to its architecture and design choices, the SmartUJI platform is modular, scalable and multi-platform. All data and services can be accessed and invoked through standard interfaces. The result is a dynamic web interface relying on an ArcGIS Server [28].

We decided to adopt the Smart UJI Campus in our project to develop the Desktop Monitoring System, and the SmartUJI platform web services to query the GIS. In the SmartUJI platform the interfaces of the GIS services have been deployed as Rest Web Services by using Apache Axis 2, Java and JSON as the interchange data format.

The repository has been implemented in MongoDB. Although there exist interesting alternatives for the components of the proposed intelligent system (e.g. the MongoDB database engine could have been replaced by a NoSQL database like HBase or Cassandra), our aim was to reduce the diversity of technologies in the SmartUJI ecosystem. Having many technologies for the same purpose might increase the maintenance costs (more complex maintenance and upgrade procedures). Additionally, it has been shown that MongoDB is well-suited for IoT and Big Data applications [29].

The use of streamed feeds [6] provide the abstraction of a dynamic content object containing a stream of sensor data. This data object can be sent to a server so that it immediately process all data from sensors and luminaires to detect events and inform the CMS. The analysis of data from sensors is a recent research area studied in Big Data Streaming.

To allow a real-time application for gathering stream data from sensors and lights, we adopt the architecture proposed in [29]. We chose Apache Kafka as streaming processing platform. Apache Kafka is an open-source stream processing platform that provides a low-latency platform for handling real-time data feeds. Kafka interoperates with external systems (for data import/export) via Kafka Connect and provides Kafka Streams, a Java stream processing library. Notice that all data are treated in real-time, and therefore they should be time-stamped.

At this respect, Apache Kafka Producer seems to be a good choice for sending time-stamped JSON data produced by the IoT gateways. Apache Kafka Consumer can be used in the Smart Collector to collect all the data from the sensors and luminaires to perform data analysis over the Kafka Streams API.

In our use case the luminaires are LED lamps with a network control unit developed as an IoT gateway as well as the sensors (cameras, light sensor or noise sensors) developed as Kafka producers. But in a real scenario, the IoT devices of the luminaires could be implemented using other technologies, but we only have to create or configure over the Smart Collector a Kafka connector to each IoT device. Today we can find connectors to a large variety of big data software and protocols like Google pub/sub, MQTT, elasticsearch, mongoDB or Azure IoTHub.

In order to simulate the lamps in a realistic scenario, we implemented a *lamp failure simulator* as a web service that randomly activates failures of one of more luminaires during a specified time span, after then the light returns to its default value. This service could be configurable to different values to make different simulations A simulated failure can consists of a random defect in just one single luminary or a voltage rise that affects a segment of unprotected luminaires.

In traditional lights system, the luminaires are distributed into segments controllers. In Dali protocol each lamp is identified by 8 bits (Id), 4 bits are used to identify the segment controller, and the other 4 bits are used to identify the luminaires. Dimming lamps could change its light intensity level value from 0-10V. LED lamps allow continuous intensity values from 0% to 100%.

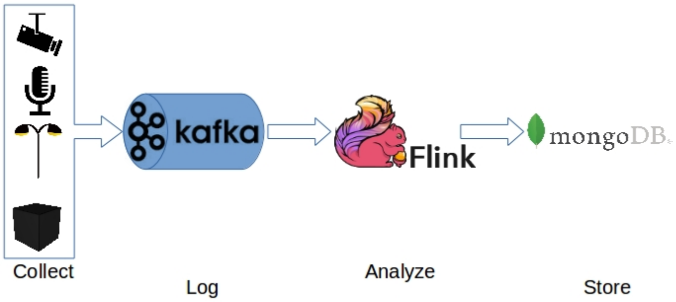


Fig. 5: Smart Collector.

In Dali protocol each device communicates with each other and it sends the following instructions: “on” (switch on the lamp), “off” (switch off the lamp), “direct level 50%” (0-100 intensity of the lamp), “step up” (increase a level the intensity), and “step down” (decrease a level the intensity).

We define a status parameter to define the intensity light level of the lamp. A status value of 0 means that the luminary is off. Values from 0 to 100 represents continuous light intensity levels. Additionally, we have also assigned 3 more status: LampFail (-3), ElectricityFail (-2), LampOn (-1).

Lamps are classified into two types: lamps installed on the streets (’road lamps’) and the lamps installed on other areas (’pedestrian lamps’). Generally this lamps should have different characteristics and the response to presence of pedestrians or vehicles will require different rules.

When a new **Lamp Node** is configured, the operator sets its geographical coordinates and properties on the *Lamp Properties table* on the DB repository. The table fields are id (lamp identifier), $dflt$ (default intensity level), $position$, sc (segment controller), and $type$ (0 street/1 pedestrian).

The **IoT Lamp Gateway** can receive instructions to change the Lamp Node status and its default configuration from the Smart Central Management System and must send in streaming all the lamps changes and failures to the Smart Collector. To preserve the system from failures, the IoT Lamp Gateway has a memory to store all the Lamp Node changes and the default lamp configuration. In case of loss of connectivity to the intelligent OLC, the luminary will continue working using its pre-configured programming (default intensity level) and internally save all the changes on a local table on the IoT gateway. Therefore, information stored on the historic table and real-time data will be received when the stream data is connected to the intelligent OLC, which in charge of maintaining the data on the DB.

The functionality is implemented using Rest Web services, and the Lamp Node status is send in streaming to the Smart Collector using a Kafka provider, that sends JSON messages with (id, $status$, $timestamp$).

The following Rest Web Services have been developed for the IoT Lamp Gateway:

- setLight: which receives orders from Smart Central Management System to change its lamp status or dimming value.
- sendChanges: which sends events and the historical stored data from its lamp to the cloud.
- configureLight: which allows the operator to configure the lamp with some internal parameters, like its identifier and default dimming value.
- GetLight: which returns the current status of its light.

The most basic task of the **Smart Collector** is to collect the data from the sensors and luminaires and store them on the repository (i.e., MongoDB). The data from the IoT Lamp Gateway and IoT Sensor Gateway are updated on two tables: *Lamp Status table* and *Sensor Records table*. Also the Smart collector will keep a backup of each lamp status on the *Historical Lamp Event table*.

The key software components of the Smart Collector (see figure 5) are: Kafka[30], a distributed streaming platform and FLINK[31], a streaming data-flow engine that provides data distribution, communication, and fault tolerance for distributed computations over data streams [32]. Moreover, the Smart Collector has also to analyse the data to detect events and patterns to improve the system. In this work, to test the architecture we have defined several simple patterns and a list of instructions to be send to the Smart Central Management System. The simple patterns and instructions are as follows:

- When the light sensor sends a value that is greater/lower than a given threshold all the lamps must be switched on/off.
- When the video sends data in streaming, the Smart Collector must analyse the video to obtain the location, number of pedestrians, its movement direction and the number of people, and eventually send an instruction to the Smart Central Management System to optimize the required light in this area.
- When the Smart Collector does not obtain data from a lamp during a period, it must change its status to a failure level, and send an alarm to the Smart Central Management System.
- When the collector receives a failure from a lamp, after checking the DB, if it is a new event, it must send to the Smart Central Management System an instruction to increase the luminosity level of the neighbour lamps.

To detect the presence of pedestrians and cars, the previous work about real-time person tracking presented in [33], [34] will be applied.

In our use case (i.e, a University campus), people usually follow the same routines each day of the week, as the activities are planned beforehand in a fixed calendar. Thus, people usually follows the same paths within the campus at the same specific hours, and therefore our system could foresee the luminosity requirements at each time and place.

The **Smart Central Management System**,the core of the system, should provide street-light specific features such as:

- Programming and commissioning schedulers.
- Real-time control and monitoring of light points.
- Smart light dimming.
- Dimming a set of lights in a route.
- Dimming a set of lights in influence area.
- Dimming a specific set of lights.
- Big Data analysis, including maintenance reporting, lamp failure analysis, energy consumption reporting, energy saving calculation, complex alarm triggering and notification, lamp lifetime analysis and data history analysis.

```
 getLightProperties:{return:[
{id:00010001,dflt:50
position:[4865050.7,-8081.2],sc:1,type:0},
{id:00010002,dflt:50
position:[4865073.1,-8111.1],sc:1,type:0},
...
{id:00320012,dflt:50
position:[4865402.0,-8193.1],sc:32,type:0}
]}
```

(a)

```
 getLightStatus:{return:[
{id:00010001,
status:{value:-1,timestamp:1478076027}},
{id:00010002,
status:{value:-2,timestamp:1477459364}},
...
{id:00320012,
status:{value:80,timestamp:1478088945}}
]}
```

(b)

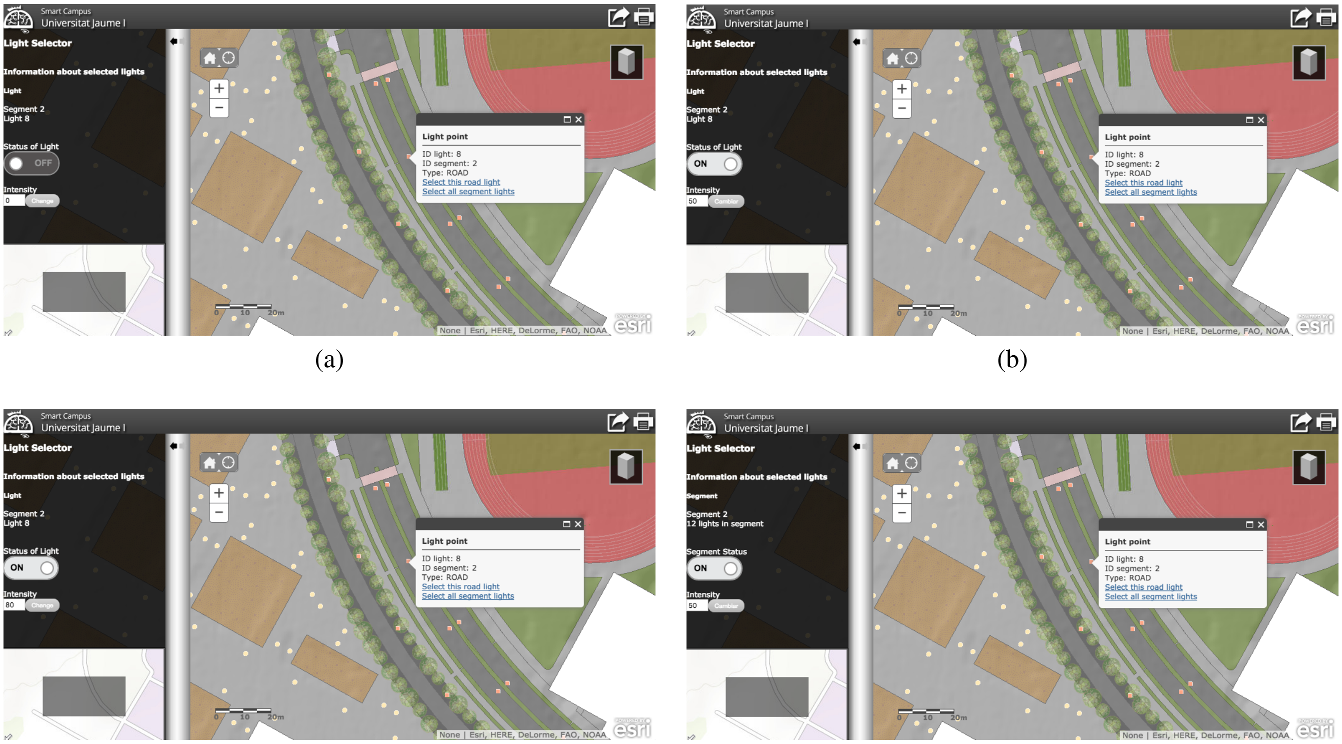
```
 getLightProperties:{
parameters:[{id:00010002}],
return:[
{id:00010002,dflt:50
position:[4865073.1,-8111.1],sc:1,type:0}
]}
```

(c)

```
 getLightStatus:{
parameters:[{sc:0001}],
return:[
{id:00010001,
status:{value:-2,timestamp:1477459364}},
{id:00010002,
status:{value:-2,timestamp:1477459364}},
...
{id:00010011,
status:{value:60,timestamp:1478088930}}
{id:00010012,
status:{value:70,timestamp:1478088940}}
]}
```

(d)

Fig. 6: Sample of two Web Services of the IoT Lamp Gateway



(a)

Information about selected lights

Light

Segment 2
Light 8

Status of Light: OFF

Intensity: 0 Change

Light point

ID light: 8
ID segment: 2
Type: ROAD
Select this road light
Select all segment lights

(b)

Information about selected lights

Light

Segment 2
Light 8

Status of Light: ON

Intensity: 50 Cambiar

Light point

ID light: 8
ID segment: 2
Type: ROAD
Select this road light
Select all segment lights

(c)

Information about selected lights

Light

Segment 2
Light 8

Status of Light: ON

Intensity: 80 Change

Light point

ID light: 8
ID segment: 2
Type: ROAD
Select this road light
Select all segment lights

(d)

Information about selected lights

Segment

Segment 2
12 lights in segment

Segment Status: ON

Intensity: 50 Cambiar

Light point

ID light: 8
ID segment: 2
Type: ROAD
Select this road light
Select all segment lights

Fig. 7: Desktop Monitoring System: (a) selecting light, (b) switch on a single light, (c) modify light intensity, (d) select multiple lights.

The Smart Central Management System obtains the data from MongoDB, and call to the IoT lamp gateway web services to modify or configure the lamps. For the core functionality of the system to access to the IoT Lamps Gateways or change the Lamp Nodes status from the Desktop Monitoring System, the following Rest Web Services have been developed:

- getLightProperties: which lists all lamps and shows their features from the *Lamp Properties table*: identifier, default intensity level,location (longitude and latitude), segment controller, and type. See example in Figure 6 (a).
- configureLight: which configures or updates the properties of a lamp. The IoT Lamp Gateway obtains its identifier, and the default intensity level to switch on the lamp. Also it stores/updates the values on the *Lamp Properties table*.
- getLightStatus: which returns the current status of the lamp from the *Lamp Status table*. See example on Figure 6 (b).
- setLightStatus: which sends to the IoT lamp gateway the instruction to modify the status of a light. If there is some failure of the lamp the status could not be changed.
- showHistoryLightControl: which shows the historical data attached to a Lamp Node on the DB.
- assignCalendarLightControl: Programmed modifications of lamp calendar to the IoT lamp gateway.

In this services, we can specify several parameters to select a lamp by its ”id” (value different of 0 selects a lamp node with this identifier), see Figure 6 (c), or to select a group of lamps by its segment controller ”sc” (value 0 selects all, other value selects all the lamps of this segment controller), see Figure 6 (d).

The **Desktop Monitoring System** a web interface to the Smart Central Management System will allow:

- Show in a map of the area with a layer that contains the lamps. Using different colour and symbols it is possible to see the on/off status, type of lamps, and other attributes.
- Select a lamp and visualize its properties.
- Select a lamp and change its status: on/off/dimming.
- Select a lamp and obtain statistical data: consume, time on, failures, among other useful data.
- Select a lamp and show all the lamps in the same segment.
- Select a segment and visualize all its lamps, change all the lamp status.

Figure 7 shows some examples, as screen shots, about how the status of the luminaires can be controlled by using the Smart Central Management System. In Figure 7 (a), we have selected a street luminary, the light 8 from segment 2, which was initially off. Using the left menu (see the *Status of Light* switch), we can switch on/off its status. In Figure 7 (b), we have switched on the light using the left menu. The light is then switched on with the default intensity value, which was 50 for this lamp. In Figure 7 (c), the light intensity was increased to 80. To this purpose, the *Intensity* textbox was accordingly modified and the `Change` button was pressed. The interactions shown in Figures 7 (a)-(c) demonstrates that a light status can be easily modified with the map-based interface. In Figure 7 (d), we show that it is also possible to change the status of all the lights in a segment. To apply changes in multiple lights, we have to click the link *Select all segment lights* first. In the left panel, it can be checked that all lights have been selected (12 lights in this case). Notice that each change, individual or multiple, must wait to obtain a response from the IoT gateway with the real status of the lamp, to ensure that the action was successfully performed.

V. CURRENT TRENDS AND FUTURE THOUGHTS

In this paper, we have presented a new architecture, which takes advantage from IoT devices and cloud computing, which allows us to improve energy savings. Big Data analysis and geospatial analysis have been proposed to create a list of instructions to be send to the required lamps. The objective of those instructions is to maintain the most suitable light on roads and pedestrian areas depending on weather conditions and safety issues.

In the field of light systems, IoT, Big Data and Cloud Computing are still under development, being implemented only for a few some smart cities projects. We think that once electronic facturers start to open its solutions and the interconnectivity between these components are standardized, the companies will be allowed to integrate data from sensors, lamps and energy consumption to its own data so that they can obtain the full advantages of Iot and Cloud Computing. The cost of this technology should not be the problem because they can obtain numerous benefits, to mention a few: improve energy efficiency and energy pollution, allow us to predict the energy requirements, or be more efficient and smart against failures from the point of view of drivers and pedestrians.

Unlike other smart light solutions, we decided to implement a Smart Central Management System, which combines real-time and historical information from sensors, as well as light status and the spatial location of the lamps.

We have mainly introduced the architecture and defined the requirements of the proposed IoT Lamp Gateway. Finally, a prototype is also presented as a proof of concept. As future work, we plan an exhaustive evaluation of the methods in order to measure the energy savings achieved by our proposal. This architecture is modular, scalable and multi-platform, so it could be implemented in local server or in the cloud computing servers as well as all programs and technologies selected to implement this prototype.

The use of the most advanced techniques of Big Data for the establishment of vehicle routing policies, interactive lighting patterns and behavioural analysis, will revert to an optimization of interaction between users and the client application.

ACKNOWLEDGEMENT

We would like to thank all the current and former members of the Geospatial Technologies Research Group who contributed on creating and maintaining the UJI's Smart Campus platform and applications.

Parts of this work were funded by the Spanish Government through the project *Smart Ways - Desarrollo de una Plataforma Tecnológica orientada a la eficiencia de los recursos en el campo de las nuevas tecnologías Internet of Things* (RTC-2014-1466-4, Spanish Ministry of Economy and Competitiveness, Retos colaboración).

REFERENCES

[1] UNFCCC, "Background on the unfccc: The international response to climate change." [Online]. Available: http://unfccc.int/essential_background/items/6031.php

[2] Z. Kaleem, T. M. Yoon, and C. Lee, "Energy efficient outdoor light monitoring and control architecture using embedded system," *IEEE Embedded Systems Letters*, vol. 8, no. 1, pp. 18–21, March 2016.

[3] C. Kyba, A. Hänel, and F. Hölker, "Redefining efficiency for outdoor lighting," *Energy & Environmental Science*, vol. 7, no. 6, pp. 1806–1809, 2014.

[4] R. Klimek, "Proposal of a multi-agent system for a smart outdoor lighting environment," in *Artificial Intelligence and Soft Computing*, L. Rutkowski, M. Korytkowski, R. Scherer, R. Tadeusiewicz, L. A. Zadeh, and J. M. Zurada, Eds. Cham: Springer International Publishing, 2017, pp. 255–266.

[5] E. Secretariat, "Bottom up to kyoto," 2017. [Online]. Available: http://www.eib.org/epec/ee/documents/factsheet-street-lighting.pdf

[6] R. Dickerson, J. Lu, J. Lu, and K. Whitehouse, "Stream feeds-an abstraction for the world wide sensor web," in *The Internet of Things*. Springer, 2008, pp. 360–375.

[7] "Geotec projects," visited on 01-May-2017. [Online]. Available: http://www.geotec.uji.es/projects/

[8] P. Arani and K. Johnson, "Adaptive led street and area lighting," 2014. [Online]. Available: http://cltc.ucdavis.edu/sites/default/files/files/publication/FINAL_DRAFT_BC_Adaptive_Area_Lighting_140613.pdf

[9] B. Goesmann and N. Graeber, "Networked adaptive exterior lighting," 2014. [Online]. Available: http://www.echelon.com/assets/blt64442cf555a47d25/Outdoor-Lighting-Wireless-Vacavalley-case-study.pdf

[10] M. Benedito, D. Gargallo, J. Avariento, A. Sanchis, M. Gould, and J. Huerta Guijarro, "UJI Smart Campus: Un ejemplo de integración de recursos en la Universitat Jaume I de Castelló," in *IV Jornadas Ibéricas de Infraestructuras de Datos Espaciales (JIIDE 2013). Toledo, noviembre 2013.* Centro Nacional de Información Geográfica, 2013.

[11] J. Torres-Sospedra, J. Avariento, D. Rambla, R. Montoliu, S. Casteleyn, M. Benedito-Bordonau, M. Gould, and J. Huerta, "Enhancing integrated indoor/outdoor mobility in a smart campus," *International Journal of Geographical Information Science*, vol. 29, no. 11, pp. 1955–1968, 2015. [Online]. Available: http://dx.doi.org/10.1080/13658816.2015.1049541

[12] DALI, "Digital addressable lighting interface," visited on 01-May-2017. [Online]. Available: http://www.dali-ag.org/

[13] ISO, "Information technology – control network protocol," Standard ISO/IEC 14908-1, 2012, visited on 01-May-2017. [Online]. Available: http://www.iso.org/iso/catalogue_detail.htm?csnumber=60203

[14] L. Sánchez, I. Elicegui, J. Cuesta, L. Muñoz, and J. Lanza, "Integration of utilities infrastructures in a future internet enabled smart city framework," *Sensors*, vol. 13, no. 11, p. 14438, 2013. [Online]. Available: http://www.mdpi.com/1424-8220/13/11/14438

[15] "Fiware," visited on 01-May-2017. [Online]. Available: https://www.fiware.org/

[16] F. Leccese, M. Cagnetti, and D. Trinca, "A smart city application: A fully controlled street lighting isle based on raspberry-pi card, a zigbee sensor network and wimax," *Sensors*, vol. 14, no. 12, p. 24408, 2014. [Online]. Available: http://www.mdpi.com/1424-8220/14/12/24408

[17] Z. Kaleem, T. M. Yoon, and C. Lee, "Energy efficient outdoor light monitoring and control architecture using embedded system," *IEEE Embedded Systems Letters*, vol. 8, no. 1, pp. 18–21, March 2016.

[18] LONMARK. (2014) Open streetlight control system for smarter cities. [Online]. Available: http://www.lonmark.org/connection/solutions/lighting/outdoor/Documents/20140227-SmartStreetlight-LONMARK-Whitepaper.pdf

[19] "Echelon's lumewave wireless outdoor lighting control." [Online]. Available: http://www.echelon.com/applications/rf-outdoor-lighting

[20] "Philips lighting," visited on 01-May-2017. [Online]. Available: http://www.lighting.philips.com/

[21] G. de Haan, P. Verhoeven, and H. Broers, "Wireless distributed sensing for intelligent outdoor illumination," *Master Thesis*, 2013.

[22] ECHELON. (2014) Cambridge, ma: Setting the example for adaptive street lighting. [Online]. Available: http://www.echelon.com/assets/blt39b6475f3f7acf71/CambridgeCaseStudy.pdf

[23] LONMARK. Spie, paris france spie contributes to smarter, more energy efficient environments for six parisian cities using l on w orks streetlight management & control system. [Online]. Available: http://www.lonmark.org/connection/case_studies/documents/SPIE%20Case%20Study_3-24-1.pdf
[24] Streetlight-Vision, visited on 01-May-2017. [Online]. Available: http://www.streetlight-vision.com/
[25] R. Müllner and A. Riener, "An energy efficient pedestrian aware smart street lighting system," *International Journal of Pervasive Computing and Communications*, vol. 7, no. 2, pp. 147–161, 2011.
[26] T. Novak, K. Pollhammer, H. Zeilinger, and S. Schaat, "Intelligent streetlight management in a smart city," in *Proceedings of the 2014 IEEE Emerging Technology and Factory Automation (ETFA)*, Sept 2014, pp. 1–8.
[27] Libelium, visited on 01-May-2017. [Online]. Available: http://www.libelium.com
[28] ESRI, "Arcgis server," visited on 01-May-2017. [Online]. Available: http://server.arcgis.com
[29] S. Ewen. (2015) Advanced streaming analytics with apache flink and apache kafka. [Online]. Available: http://kafka-summit.org/sessions/advanced-streaming-analytics-with-apache-flink-and-apache-kafka/
[30] Apache, "Kafka," visited on 01-May-2017. [Online]. Available: https://kafka.apache.org/
[31] ——, "Flink," visited on 01-May-2017. [Online]. Available: https://flink.apache.org/
[32] S. Baltagi, "Apache flink what how why who where," 2016. [Online]. Available: http://www.slideshare.net/sbaltagi/apacheflinkwhathowwhywhowherebyslimbaltagi-57825047
[33] L. Jia and R. J. Radke, "Using time-of-flight measurements for privacy-preserving tracking in a smart room," *IEEE Transactions on Industrial Informatics*, vol. 10, no. 1, pp. 689–696, 2014.
[34] S. Chun and C.-S. Lee, "Applications of human motion tracking: Smart lighting control," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops*, 2013, pp. 387–392.

Dolores Maria Llidó Escrivá She holds a PhD in Computer Science from Jaume I University (2002). Her main research activities are in computer science, information extraction, data-mining semantic web and Internet technologies. She participate in several European projects like: ESMI, GRASP, ARTIS, SERTI. Now she participates in Spanish projects related with information extraction, linked data and data-mining, geographic information systems, and internet of thing.

Joaquin Torres-Sospedra is a Researcher at the Institute of New Imaging Technologies. He holds a Bachelor's Degree in Computer Science (2003) and a PhD with distinction (2011), both from Universitat Jaume I. His main research interests are in the areas of Indoor Positioning and Navigation, Wi-Fi fingerprinting, Machine Learning, Pattern Recognition, Multiple Classifier Systems, Sensor Fusion, Knowledge-based Systems and Interoperability.

Rafael Berlanga is a full-time professor of computer science at Universitat Jaume I, Spain, and leader of the Temporal Knowledge Bases group. His current research concerns novel information extraction and text mining methods for enabling business intelligence over very large resources such as the web of data and social media. He has published more than 30 contributions to high-impact international journals and numerous contributions to international conferences. He has lead several R&D projects aimed at smart processing of semi-structured data.