A Web System for Managing and Monitoring Smart Environments

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Abstract. Smart environments have the ability to record information about the behavior of the people by means of their interactions with the objects within an environment. This kind of environments are providing solutions to address some of the problems associated with the growing size and ageing of the population by means of the recognition of activities, monitoring activities of daily living and adapting the environment. In this contribution, a Web system for managing and monitoring smart environments is introduced as an useful tool to activity recognition. The Web system has the advantages to process the information, accessible services and analytic capabilities. Furthermore, a case study monitored by the proposed Web System is illustrated in order to show its performance, usefulness and effectiveness.

Keywords: Smart environments · Behavioral detection · Monitoring smart environments · Managing smart environments · Sensor-based activity recognition

1 Introduction

The number of elderly will reach 2 billion by the year 2050 and a key issue for this people is to stay as long as possible in their own homes in order to have a healthy ageing and wellbeing [1]. One of the most common diseases in this group is related to cognitive processes such as dementia. These illnesses are currently incurable, hence efforts are focused towards delaying their progression.

The dementia has a number of symptoms including memory loss, mood changes, communication problems and eventually results in problems with the completion of everyday tasks once the condition reaches the later stages, including activities of daily living (ADLs) and instrumental ADLs (IADLs) [2,3]. These alterations require long term monitoring and support in order to maximize quality of life and minimize progression.

F. Ortuño and I. Rojas (Eds.): IWBBIO 2016, LNBI 9656, pp. 677–688, 2016.
DOI: 10.1007/978-3-319-31744-1_59

In the early stages of dementia, it is useful to provide support in the form of prompting through the completion of ADLs and IADLs, offering a series of reminders for tasks such as medication management, eating or grooming [4–6].

Smart environments have the ability to record information about the behavior of the person by means of his/her interaction with the objects within an environment [7]. So, smart environments are residences with sensor technology in which sensors are connected to a range of objects or locations and networked in order to be used to identify people in the environment and their actions [8].

This kind of environments are providing solutions to address some of the problems associated with the growing size and ageing of the population by means of the recognition of activities, monitoring activities of daily living in order to adapt the environment.

Regarding a software tool for monitoring smart environments, we can find the tool presented in [9] in order to visualizate the data generated in real-time or summarized, using a density ring visualization format. However, this tool is a desktop application that must be installed on a personal computer to manage and monitor a smart environment. So, it does not allow the management of smart environments in a Web system.

In this contribution, we introduce a Web system for managing and monitoring smart environments in order to provide a useful tool to activity recognition. The Web system illustrates information about the behavior of the person by means of his/her interaction with the objects within a smart environment. The proposed Web system has been developed to be intuitive and flexible, providing the advantages to process the information with accessible services and analytic capabilities. To do so, the proposed Web system allows managing the components involved in each smart environment registered in the system: plane of the smart environment, objects, sensors, events, etc. The data generated within the environment can be visualized by the proposed Web system in real-time, off-line, and, finally, consulted using different filters.

In order to show the usefulness of the proposed tool, a case study has been designed for monitoring the smart lab of University of Jaen with six contact sensors (open/close) and three multisensors by using the introduced Web system.

The rest of the contribution is set out as follows: Sect. 2 introduces some preliminaries regarding sensor-based activity recognition. Section 3 presents our proposed Web system for managing and monitoring smart environments. Section 4 shows a case study monitored in the University of Jaen by the proposed Web System. Finally, in Sect. 5, conclusions are drawn.

2 Related Works

Sensor-based activity recognition is an important research topic that involves multiple fields of research including pervasive and mobile computing [10,11], context-aware computing [12–14] and ambient assisted living [15,16].

This area of research has witnessed a significant level interest mainly as a result of the rapid advances in the sensor technology development coupled with demands from an application perspective [8]. Advances in technology developments have mainly focused on providing a wide range of low cost sensors, with low-power requirements and decreased form factor.

These sensors can be connected to a range of objects or locations and networked and used to identify people in the environment, their actions, their emotions and to provide personalized assistance with their everyday tasks.

The process of activity recognition aims to recognise the actions and goals of inhabitants within the environment based on a series of observations of actions and environmental conditions. It can therefore be deemed as a complex process that involves the following steps: (i) to choose and deploy the appropriate sensors to objects within the environment in order to effectively monitor and capture a user's behavior along with the state change of the environment; (ii) to collect, store and process information and, finally, (iii) to infer/classify activities from sensor data through the use of computational activity models.

Traditionally, approaches used for sensor-based activity recognition have been divided into two main categories: Data-Driven Approaches (DDA) and Knowledge-Driven Approaches (KDA). The former, DDA, are based on machine learning techniques in which a preexistent dataset of user behaviors is required. A training process is carried out, usually, to build an activity model which is followed by a testing processes to evaluate the generalization of the model in classifying unseen activities [17–19]. With KDA, an activity model is built through the incorporation of rich prior knowledge gleaned from the application domain, using knowledge engineering and knowledge management techniques [20,21].

It is necessary to train and test in depth activity models in order to check their adaptation with information about the behavior of the people by means of their interactions with the objects within an environment. In the following section, we introduce a Web system for managing and monitoring smart environments.

3 A Web System for Managing and Monitoring Smart Environments

In this section, we present a Web system for managing and monitoring Smart Environments as an useful tool to activity recognition. To do so, we pay attention to the architecture of the system, the database model and, finally, its functionality.

At the following URL: http://sinbad2.ujaen.es:8094/Smartlab, the proposed Web system is located.

3.1 Web System Architecture

Data generated by smart environments requires fusion information, accessibility services and analytic capabilities. The proposed Web system is focused on providing these requirements to friendly collect and handle the information offered by the set of sensors from a smart environment, suitable for using by non-technical users.

The proposed Web system processes the data generated from heterogeneous sensors to a homogeneous structure which is unique for any set of sensors within smart environments. In order to include a persistence of sensor data, we have defined an appropriate relational model, which has been focused on handling large volumes of data [22], whose persistence follows the next structure:

- *Objects*, which are related to physical sensor which are deployed on the environments.
- *Environments* to group the objects and sensors deployed in the environment. In this way, this approach enables the monitoring of multiple smart environments for scientific and analytic purposes.
- *Location*. Due to the fact that the object location usually changes continuously, we relate a dynamic set of locations to each object with its smart environment.
- *Property-Value*. We collect the sensor values adding a type which increases the interpretability of raw data.

In the context of smart environments, usually, an object is the abstraction of a sensor. So, when an object is created, a set of rules should be provided in order to define the interpretation of the values provided by its sensor. Therefore, the set of objects defined in each smart environment registered in our system should have three values: Object-property-value. Furthermore, in order to locate the object in the smart environment, its location must also be provided. We highlight we have defined an abstract schema where any mobile, wearable or ambient sensor can be described.

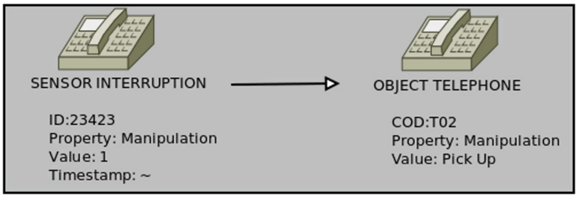

Fig. 1. Switch sensor associated to phone with the interpretation of values

The proposed Web system is transparent to all devices that interact with it. To create this interoperability between sensors, our system makes use of a central API provided by REST, where only the communication protocol, Hypertext Transfer Protocol (HTTP), is shared. With this solution, we can consume or produce content of our API on any platform, regardless of operating system or system architecture, thus having multiple heterogeneous clients. Using the REST services, any mobile or ambient computer is enable to send the data collected by their sensors.

The components of our architecture are described in Fig. 2:

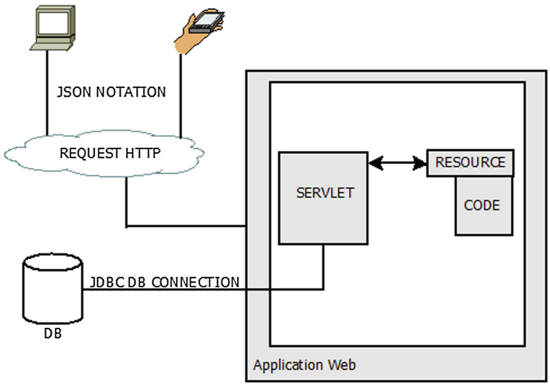

Fig. 2. System architecture based on REST service

– **Web Server**, being its aim to develop core services in order to provide a abstraction layer where different clients can communicate with the system. The remote services have been developed using Web Services, increasing the transparency and accessibility of mobile, web or desktop clients.
  In our Web system, we have implemented Web Service based on Representational State Transfer (REST) that has a client server architecture in which each service is identified by a URL. These services communicate with the server via servlet, providing a multi-platform architecture that uses the HTTP protocol. Each servlet is responsible for translating HTTP requests (GET, PUT, POST and DELETE), traveling accompanied by information in a language with a specific structure in JavaScript Object Notation (JSON) that is a simple and lightweight text-based format, which arises as XML alternative. So, the structure object-property-value is carried out using the notation JSON that are implemented by REST technology. Therefore, both the client and the server may make the exchange of information and both know the protocol and format of the information. Following, two main remote services are described:

Environment Sensors: Return sensors of an environment registered in the system
/service/sensors/{*environmentID*} "idSensor": "00144F0100006C62","idType": "Sunspot","active": true, "idSensor": "34037272","idType": "Tynetec","active": true

Current Status: Return current status of environment and position map.
/service/object/environment/{*environmentID*}*/currenstatus* [JSON] "idObject": 21,"idSensor": "34037288","codObject": "M01", "description": "Puerta", "timestamp": "2015-11-27 11:32:43.0", "valueDescription": "Abierta", "posX": 641.0, "posY": 226.0,

– **Client**. A web client to consult the data from a Web browser. To provide a friendly user interface, we have integrated Bootstrap in the web view due to is one of the most important frameworks for the design of web applications based on HTML5 and CSS3. Its main advantage is the functionality to adapt to the resolution of the device that are used. To do this, Bootstrap divides the screen into 12 parts and resolutions in 4 types. Thus, the web is adjusted in a very simple manner to each device. Furthermore, we have used Angularjs that is a framework of the Javascript language, developed by Google. The main idea of Angularjs is developing a Web application on a single page. So, we have extended the traditional HTML by using specific tags, which will provide it with new features. Angularjs uses the MVC (Model, View, Controller) and is compatible with all current browsers (Chrome, Firefox, Opera, Safari), in addition to support mobile browsers (webkits).

3.2 Database Model

Modeling of Spatio-Temporal dimension is key in the analysis of data [23] but it is necessary designing scalable data storages that provide efficient data mining [24].

To do so, we have defined a relational model based on an entity relationship schema that are illustrated in Fig. 3. The general schema is divided into two packages. These packages work together to provide meaning to our Web system. Following, we describe the main components:

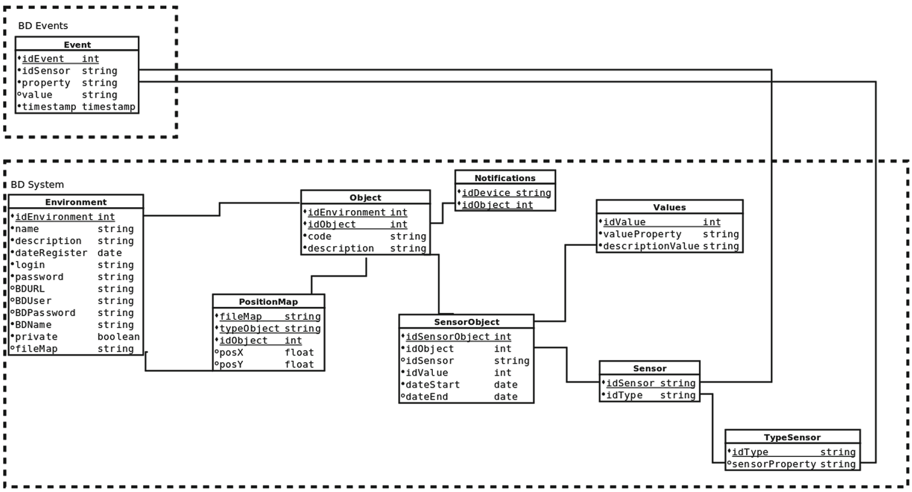

Fig. 3. Entity relationship schema

– *Events*: It is the most important component of package. This package contains one single table to store raw information of each sensor for each smart environment.
– *Web System*: This package translates the information from the sensor to a natural language. It contains the following components:

- *Environment*: This component describes different properties. One of them is the possibility to provide privacy to the environment. So, users could login to service for managing and monitoring the environment. Other property is the option of give a external database to the system to translate raw information of the sensors.
- *PositionMap*: This component collects the position of each sensor in the system dynamically.
- *Object*: It defines the object and its description, associating the object with its environment.
- *SensorObject*: This component can associate a sensor with an object, considering the time of association. So, this component has the following values: dateStart and dateEnd in order to indicate whether the sensor is currently located at object.
- *Value*: This component contains the value of a sensor with an interpretable description of the measure.

3.3 Web System Functionality

At this point, we present the functionality of the system that is shown from the point of view of the role that performs it.

There are 2 types of roles in the system: *administration* and *public*. The *administration* role is focused on manage smart environments and the *public* role is oriented to monitor smart environments. Following, we briefly summarize the actions that can be carried out for each role.

Administration role: The actions that can be performanced with this role are:

- **Manage smart environments**. To add, edit and delete smart environments and its properties: description, plane, URL of database, etc.
- **Manage sensors**. To add, edit and delete sensors in the Web system. Currently, our approach includes two types of sensors: contact sensors (open/close) and multisensors that can measure acceleration, light and temperature.
- **Manage objects**. In order to add, edit and delete objects in a smart environment and associate with a sensor.
- **Manage object location**. In order to locate objects in the plane of the smart environment.

Public role: The actions that can be performanced with this role are:

- **Visualization of current status**. The plane of a smart environment is illustrated with the set of sensors and the last values provided for each property of each sensor.
- **Visualization of past states (Historic)**. For a given time (day and hour), the plane of a smart environment is illustrated with the set of sensors and the set of values provided for each property in this moment for each sensor. Furthermore, the system can play the events that have occurred in one day through a timeline (off-line) in the plane of a smart environment.

– **Consultation past events (Historic)**. Reports about events within smart environment are provided. These reports can consider a date, a period and a number of recent changes. Furthermore, graphics of event frequency in each sensor per hour are illustrated.

4 Case Study

In order to highlight the effectiveness of the proposed Web system, a case study has been designed for monitoring the smart-lab of University of Jaen.

The smart lab is located in a room of 25 square meters in the CEATIC[1] (Center for Advanced Studies in Information Technology and Communication) of University of Jaen. In the smart lab are distributed the following four areas: a lobby, a living room, a kitchen and a bedroom with an integrated bathroom. Figure 4 illustrates the areas of the smart lab of the University of Jaen from different points of view.

Fig. 4. Smart lab of the University of Jaen

[1] http://ceatic.ujaen.es/es/smart-lab-0.

Several sensors were located in different places of the smart lab, in order to gather the data from the interactions between the people within environment.

Regarding the sensors, two type of sensors were deployed: contact sensors (open/close)[2] and multisensors[3] that can measure acceleration, light and temperature that are illustrated in Fig. 5.

The sensors' network was composed by six contact sensors (open/close) and three multisensors. Contact sensors were located in the following objects: Front door, TV remote, bathroom faucet, refrigerator, microwave, bed room closet door. Multisensor was located in the kitchen, living room and in the workplace. The plane of the smart lab is illustrated in Fig. 6 in which the location of each sensor is indicated.

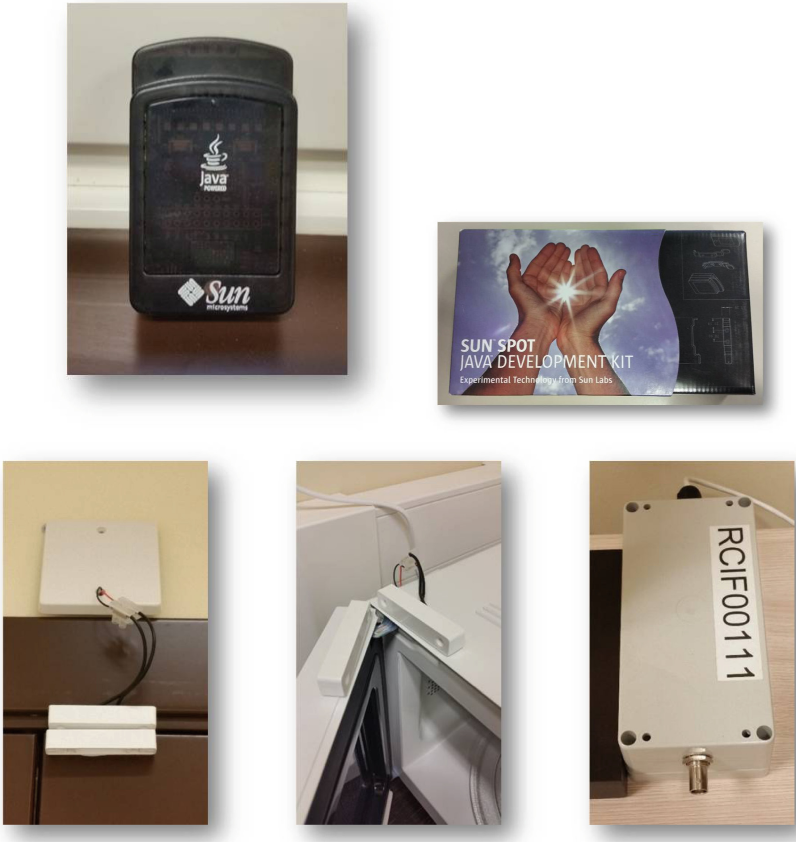

Fig. 5. Contact sensors and multisensors

[2] www.tynetec.co.uk.
[3] http://sunspotdev.org/.

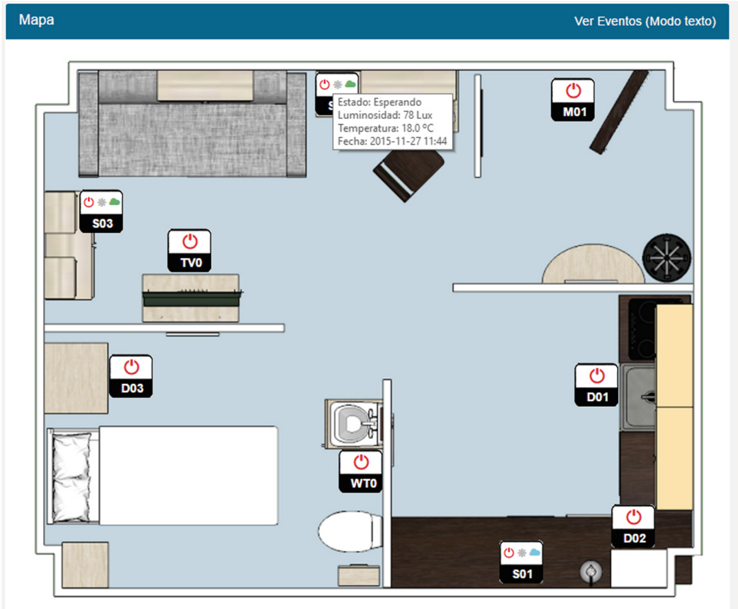

Fig. 6. Plane of the smart lab and deployed sensors

The proposed Web system was capable of visualizing the real-time state of the environment, showing events occurring in the environment. Figure 7 illustrates the last ten events generated in the smart lab.

Objeto	Fecha Evento	Estado	Descripción
TV0	2015-10-15 17:40	Encendido	Televisión
TV0	2015-10-15 20:49	Encendido	Televisión
TV0	2015-10-16 09:00	Encendido	Televisión
TV0	2015-10-16 09:00	Encendido	Televisión
D01	2015-10-16 09:01	Abierta	Frigorífico
WT0	2015-10-16 09:20	Encendido	Grifo
D01	2015-10-16 09:54	Abierta	Frigorífico
TV0	2015-10-19 09:40	Encendido	Televisión
WT0	2015-10-19 09:40	Encendido	Grifo
D01	2015-10-19 09:40	Abierta	Frigorífico
WT0	2015-10-27 09:30	Encendido	Grifo

Fig. 7. Last ten events in the smart lab

5 Conclusions and Future Works

In this paper, a Web system for managing and monitoring smart environments has been introduced that aims to facilitate user interpretation of the data provided by the sensors generated by the interactions with the objects within an environment. The data generated within the environment can be visualized by the proposed Web system in real-time, off-line, and, finally, consulted using different filters. To do so, we have described the architecture of the system, the database model and, finally, its functionality. Furthermore, the introduced Web system has been tested for managing and monitoring a smart lab in the University of Jaen. However, the platform described in this paper has been developed for managing and monitoring of smart environments a scalable way. In future work, we focus on extending and deploying the Web System in the Smart Lab of University of Ulster.

One limitation of the introduced Web system is that includes only two types of sensors: contact sensors (open/close) and multisensors that can measure acceleration, light and temperature. Currently, we are working to incorporate other types of sensors such as motion or proximity.

On the data persistence, this first work includes a relational database. In future works, we will work on translating the relational schema to a BigTable Model, where tables are translated to family columns and attributes to single columns. It will provide redundancy and online analytical processing of huge amount of sensor records using several clusters.

On the data analysis, our future works are focused on including a sensor-based real-time activity recognition under a knowledge-driven approach based on fuzzy rules.

Acknowledgements. This contribution has been supported by research projects: UJA2014/06/14 and CEATIC-2013-001.

References

1. Smith, G., Della Sala, S., Logie, R.H., Maylor, E.A.: Prospective and retrospective memory in normal aging and ementia: a questionnaire study. Memory **8**, 311–321 (2000)
2. Alzheimer's society. What is dementia? (2013). http://www.alzheimers.org.uk/site/scripts/documents_info.php?documentID=106
3. Von Strauss, E.: Aging and the occurrence of dementia: findings from a population-based cohort with a large sample of nonagenarians. Arch. Neurol. **56**(5), 587–592 (1999)
4. Holder, L.B., Cook, D.J.: Automated activity-aware prompting for activity initiation. Gerontechnology **11**(4), 534–544 (2013)
5. Feuz, K.D., Cook, D.J., Rosasco, C., Robertson, K., Schmitter-Edgecombe, M.: Automated detection of activity transitions for prompting. IEEE Trans. Hum. Mach. Syst. **45**(5), 575–585 (2014)

6. Das, B., Cook, D.J., Schmitter-Edgecombe, M., Seelye, A.M.: Puck: an automated prompting system for smart environments: toward achieving automated prompting-challenges involved. Pers. Ubiquit. Comput. **16**(7), 859–873 (2012)
7. Cook, D.J., Augusto, J.C., Jakkula, V.R.: Ambient intelligence: technologies, applications, and opportunities. Pervasive Mobile Comput. **5**(4), 277–298 (2009)
8. Chen, L., Hoey, J., Nugent, C., Cook, D.J., Yu, Z.: Sensor-based activity recognition. IEEE Trans. Syst. Man Cybern. Part C Appl. Rev. **42**(6), 790–808 (2012)
9. Synnott, J., Chen, L., Nugent, C.D., Moore, G.: Flexible and customizable visualization of data generated within intelligent environments. In: 2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), pp. 5819–5822, August 2012
10. Satyanarayanan, M.: Pervasive computing: vision and challenges. IEEE Pers. Commun. **8**(4), 10–17 (2001)
11. Varshney, U.: Pervasive healthcare and wireless health monitoring. Mobile Netw. Appl. **12**(2–3), 113–127 (2007)
12. Emmanouilidis, C., Koutsiamanis, R.-A., Tasidou, A.: Mobile guides: taxonomy of architectures, context awareness, technologies and applications. J. Netw. Comput. Appl. **36**(1), 103–125 (2013)
13. Makris, P., Skoutas, D.N., Skianis, C.: A survey on context-aware mobile and wireless networking: on networking and computing environments' integration. IEEE Commun. Surv. Tuts. **15**(1), 362–386 (2013)
14. Perera, C., Zaslavsky, A., Christen, P., Georgakopoulos, D.: Context aware computing for the internet of things: a survey. IEEE Commun. Surv. Tuts. **16**(1), 414–454 (2014)
15. Alam, M.M., Hamida, E.B.: Surveying wearable human assistive technology for life and safety critical applications: standards, challenges and opportunities. Sensors **14**(5), 9153–9209 (2014). (Switzerland)
16. Van Hoof, J., Wouters, E.J.M., Marston, H.R., Vanrumste, B., Overdiep, R.A.: Ambient assisted living and care in The Netherlands: the voice of the user. Int. J. Ambient Comput. Intell. **3**(4), 25–40 (2011)
17. Gu, T., Wang, L., Wu, Z., Tao, X., Lu, J.: A pattern mining approach to sensor-based human activity recognition. IEEE Trans. Knowl. Data Eng. **23**(9), 1359–1372 (2011)
18. Li, C., Lin, M., Yang, L.T., Ding, C.: Integrating the enriched feature with machine learning algorithms for human movement and fall detection. J. Supercomput. **67**(3), 854–865 (2014)
19. Martin, L.A., Pelaez, V.M., Gonzalez, R., Campos, A., Lobato, V.: Environmental user-preference learning for smart homes: an autonomous approach. J. Ambient. Intell. Smart. Environ. **2**(3), 327–342 (2010)
20. Chen, L., Nugent, C.: Ontology-based activity recognition in intelligent pervasive environments. Int. J. Web Inf. Syst. **5**(4), 410–430 (2009)
21. Chen, L., Nugent, C.D., Wang, H.: A knowledge-driven approach to activity recognition in smart homes. IEEE Trans. Knowl. Data Eng. **24**(6), 961–974 (2012)
22. Shah, M., Big data, the internet of things (2015). arXiv preprint arXiv:1503.07092
23. Maryvonne, M., Bédard, Y., Brisebois, A., Pouliot, J., Marchand, P., Brodeur, J.: Modeling multi-dimensional spatio-temporal data warehouses in a context of evolving specifications. Int. Arch. Photogrammetry Remote Sens. Spat. Inf. Sci. **34**(4), 142–147 (2002)
24. Zaslavsky, A.B., Perera, C., Georgakopoulos, D.: Sensing as a service and big data (2013). CoRR, abs/1301.0159