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Pervasive sensors network for wellness based-on Raspberry Pi

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Abstract

Pervasive sensors networks coexist with users offering them services transparently, without the need for users to interact directly. This work defines an architecture that allows the creation of products and services to provide home automation functionalities for a large segment of population. A platform, on a low cost device and high-capacity computing, as basis of a transparent and indistinguishable sensors network has been designed. This includes simple configuration methods and it is capable of accommodating multiple services, from automation of blinds, lighting controls or security, to mechanisms for monitoring a patient health. A medication reminder service and warning, completely transparent to the user, has been the first developed application. This service plays, at the configured time, a reminder through the speakers. The user will close the event, simply performing the action (take the pill), thanks to the information transmitted by a device installed in the medicines drawer. Otherwise, if he forgets, the system will remind it to the user from time to time.

Keywords: Home automation, sensors, Raspberry Pi, Z-wave.

1. Introduction

The proposed work creates an integrated and unintrusive computing and communication environment for people. For this purpose, devices in everyday life have been introduced, to run seamlessly, in an indistinguishable way. Thereby, people focus on doing their tasks and not on the tools they use, because it runs unnoticed and it does not interfere with the planned activities.

The starting point is a facility of low cost and high computing power that allows us deploying applications and services to improve the wellness of people, especially the elderly. Equipment should be usable at homes with simple configuration that minimizes human intervention. The development of a (mobile) application that analyses the environment (e.g. connectivity) is proposed, as well as support to the configuration of this equipment.

At the same time, a platform to interact with automation household items, if any, has been integrated into the device, such as lights, windows, doors, drawer of medicines. The platform is ready to add modules, to provide new services such as automated blinds, irrigation mechanisms, security, lighting or energy control, among others, or to add interfaces to facilitate human-machine communication by voice control or presence detection.

In addition, a first service has been implemented. It serves to remind the intake of meds by setting alarms. When an alarm is triggered, the speakers plays the text entered in the configuration, which could be the name of the drug or a brief description. The user hears the message and when it interacts with the drawer of medicines, the system recognizes the action and completes the task. In case of forgetting to take the pill, messages will be play from time to time as a reminder.

In the next section, the current environment is analysed, where the social and technological context in which it works is defined. In section 3, the problem and the solution adopted to resolve it is detailed. Section 4 describes the structure that has been designed to fulfil the objectives, aiming to offer a solution as simple and user-friendly as possible. Lastly, the costs are analysed and, finally, the conclusions are presented.

2. Current environment

The current social and technological situation must be explained, because it is important to follow the rapid evolution in both fields.

First, a discussion about technological society and how is being redistributed the generational pyramid is detailed. It will continue with the state of art, where technologies currently available and their capabilities will be described.

2.1. Social status

Currently the technology is the starring in all aspects and levels of society. Internet, the network of networks, is arriving at most of homes, which have private networks to provide Internet access to multiple devices or provide their own services, such as media centres.

In addition, advances in processing have allowed everyone to afford more powerful computers, and, the size and the cost of simpler products has been reduced.

On the other hand, society is adapting quickly to new technological environments, promoting their development and incorporating new functionalities to their daily life.

Nowadays, the technology reaches all ages, from children's games to improvements in the quality of life of elder people.

Historically, society is structured in a pyramid; young people at the base and at the top is located the elderly, but this distribution is turning, as provided by the Statistics National Institute from Spain [1], and it can be extrapolated to the developed countries. Advances in welfare and declining birth rate leads to a general aging of society.

Figure 1 shows the population (males and females) of Spain and their age, comparing data from 2013 with a forecast in 2023.

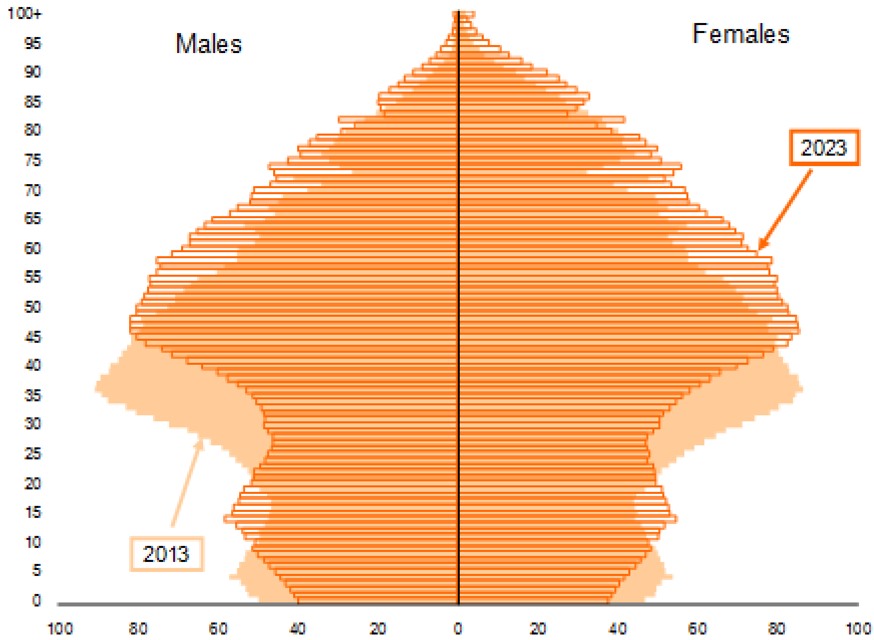

Figure 1. Population pyramid. Years 2013 and 2023. Spain.

This situation has not become unnoticed by the commercial sector, which has redistributed its efforts to develop products of interest in this new major consumer and especially in the field of health, one of their most concerned and worrying issues. The fact of not having enough young people to address these needs gives technology the opportunity to replace these functions.

Another major role in today's consumer society is energy efficiency. Any resource optimization is welcome. In this line home automation, which provides an improved level of household resources is found as a good choice, plus a set of new services and amenities. A simple example is the automation of lights and blinds; firstly, it saves the user the task and, secondly, it enables energy savings, since the sensors will make a perfect fit between the indoor light and sun light, which allows decreasing energy consumption and economic cost of the electric bill.

2.2. State of the art

There are several alternatives specifically focused on medication reminder to achieve medication adherence [2], and most of them are mobile applications such as pill reminders [3], which are based on the user's need to operate the technology properly and the interest to do it. Nevertheless, the solution introduced in this paper makes the technology transparent to the user, simplifying the complexity of human-computer interaction.

It is important to know the current technologies able to be chosen to create a central automation at home.

As mentioned above, products with small size and low cost are currently available, which have enough power to carry out specific tasks. Some examples include Raspberry Pi [4], Arduino, PICAXE or BASIC Stamp. The first two have become very popular; they are based on a microcontroller board and a development environment for free software and hardware. This allows it to be accessible to any interested person and it can generate synergies with the efforts of other developers.

Particularly, Raspberry Pi was selected for its low cost (less than $40) and greater features. In Table 1, its technical specifications are found.

Table 1. Raspberry Pi specifications.

	Model A	**Model B**
Price	25$	35$
SoC	Broadcom BCM2835 (CPU + GPU + DSP + SDRAM + USB port)	
CPU	ARM1176JZF-S a 700 MHz (ARM11 family)	
GPU	Broadcom Video Core IV, OpenGL ES 2.0, -2 y VC-1, 1080p30 H.264/MPEG-4 AVC	
Memory (SDRAM)	256 MB (share with the GPU)	512 MB (share with the GPU)
Ports USB 2.0	1	2 (throw integrated USB Hub)
Video inputs	Connector [MIPI] CSI	
Video outputs	RCA (PAL and NTSC), HDMI (rev1.3 and 1.4), Interface DSI to LCD panel.	
Audio outputs	3.5 mm connector, HDMI	
Integrated memory	SD / MMC / SDIO slot	
Network connectivity	Anyone	10/100 Ethernet (RJ-45)
Energy	500 mA, (2.5 W)	700 mA, (3.5 W)
Power supply	5V throw Micro USB or GPIO header	
Size	85.60mm × 53.98mm	
Supported operating systems	Debian, Fedora, Arch Linux, Slackware Linux, RISC OS	

There exist applications such as OpenRemote [5] or DomotiGa [6] to provide the necessary services in a network for home automation. DomotiGa was chosen because of its greater power and compatibility with multiple sensor technologies.

DomotiGa is an open source software project that is growing progressively. It has a modular structure, so that it adapts very well to the needs of users. Examples of such modules are convergence of devices, event manager, communication with social networks, climate control, security monitoring, sensors location and their information within a map of the house, multiple connectors of current sensor technologies, and so on. On the other hand, its main disadvantage is the complexity; this software is aimed at experts.

Finally, there is a very large market for sensors, devices capable of translating any physical magnitude in digital and transmit the results, as well as actuators that allow, from a logical order, performing some physical action. Multiple solutions have been created for the transmission of information between sensors, they can be based on technologies such as X10, Bluetooth, ZigBee, Ethernet, Wireless, Z-wave, among many others. Two groups differ, those using wireless transmissions and not. The first case provides high mobility at the expense of a channel with higher interference and lower speeds. The second, less mobility without interference channel.

The wireless sensors have been chosen following the desired characteristics, and among them, Z-wave technology has been selected, as it currently is offering a large market at the best price. The sensors create ubiquitous or pervasive networks [7] [8] in order to be part of the user's environment.

3. Problem and solution

The future society is an aging population that requires special attention and care.

The problem to be addressed is to create a platform that will include applications related to sensors in home, to improve user comfort. This platform includes a medication reminder functionality to avoid elderly forgetting their medicine intake. As a consequence, their quality of life will improve, because the first task of remembering when and which medicine to take is removed and, secondly, the treatments efficiency will improve, and, thirdly, it can prevent health problems which involve readmission to hospital because of forgetting to take some pills.

The offered solution consists on a series of configurable alarms to send emails or play through the speakers any desired text. From there, the user receives the message and takes the medicine from their medicine drawer, which is controlled by a sensor if it is open. This sensor will report to the system the activity so it knows that user has carried out the action; if such confirmation is not received, the system recalls reminder messages.

3.1. Objectives

The objectives to be achieved by this solution are to:

1. Create a modular platform. Admitting future extensions and different architectures; such as architecture-based processing in the cloud.
2. Provide a mechanism for configuring the product at home, by using a mobile application or web browser, and allowing non-technical users, a simple way to configure equipment connectivity.
3. Implement a service for device administration.
4. Implement a service for creating events.
5. Develop a simple and intuitive visual environment for novice users.
6. Create a pill reminder application to facilitate human-machine interaction through sound messages over the speakers and gathering information from sensors. The application triggers an alarm and activates a service to remind the user, multiple times, in order to take the medication in case he has forgotten.

4. Architecture

In this section the configured structure to carry out the objectives will be explained. Two versions are defined. The first is based on placing all the intelligence on Raspberry Pi controller to act as the scenario cornerstone. In the following sections elements of the scenario and the connections at all levels will be described. The second version is detailed in the final section, a structure based on the cloud and the web site is separated from the Raspberry Pi to place it in a more powerful external server.

4.1. Global structure

In the Figure 2, the structure is shown. In the centre, there is located the core, the intelligence, operating on the Raspberry Pi. This is connected to a speaker and a sensors network, which can contain different technologies since DomotiGa, the application used, allows it.

On the scenario, an access point to the Internet is need, and, as a consequence, an ISP (Internet Service Provider), to provide such connectivity. At the same time, the access point gives access to the Raspberry Pi to other devices through the private network.

The Internet connection is compulsory to enjoy the functionality of emailing or text2speech (text-to-voice). As a provider of the latter function, Google service has been chosen for its quality and availability.

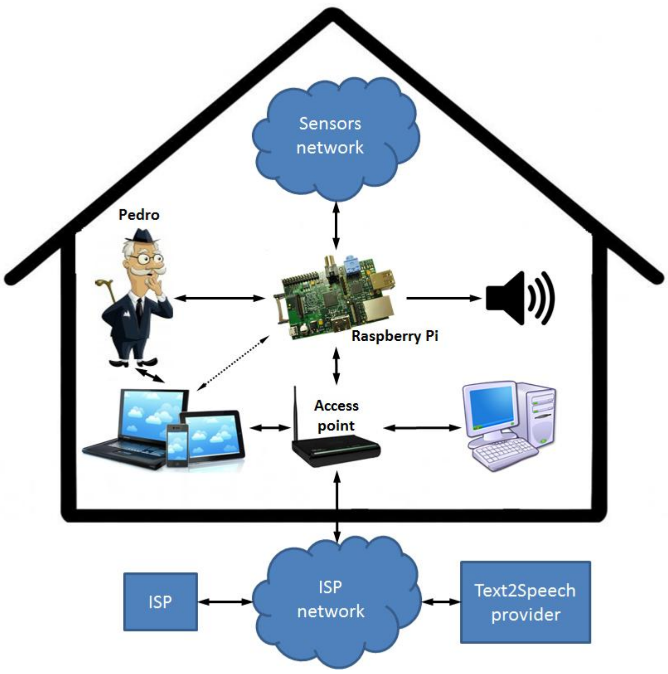

Figure 2. Global Scenario.

4.2. Initial setup

The mechanism designed to simplify the user configuration and use of the platform is based on the use of an application to scan the environment (tracking and identifying access points) and to perform the connection configuration of the platform, minimizing human intervention. To make it possible, these steps must be followed.

First, once the product arrives home, somebody must configure the device wireless connection to connect to the access point. This requires putting Raspberry Pi in configuration mode to allow a direct connection between this and a mobile device or PC via wireless (see Figure 3).

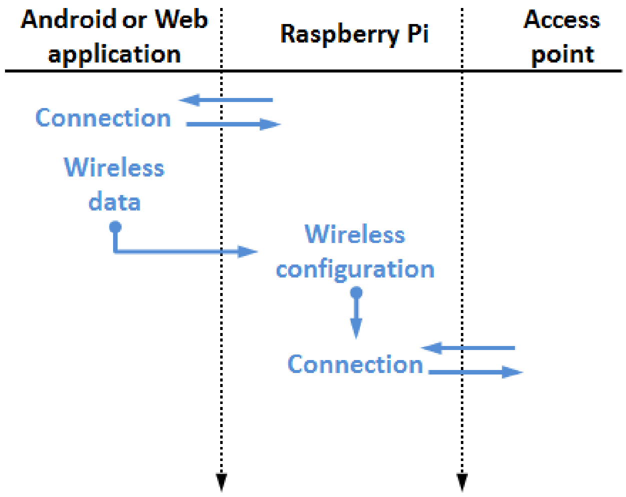

Figure 3. Timing diagram. Initial communication.

After configuring the device, direct connection disappears and, thereafter, the Raspberry Pi can be accessed through the private home network hotspot (see Figure 4).

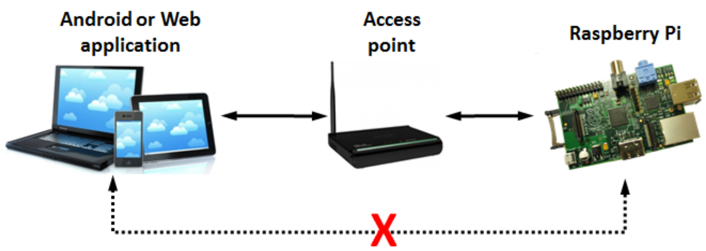

Figure 4. Change of scenario from configuration mode to standard mode.

4.3. Example of use

In Figure 5, the need and usefulness of the elements described above is demonstrated. The detailed example is for the default embedded functionality which informs Pedro (the user) that must take a med. This service manages some alarms that have been pre-planned and interacts with the user by means of phrases that have been customized. At the same time the system concludes that Pedro has taken the pill because a sensor in the drawer of medicines notifies this action.

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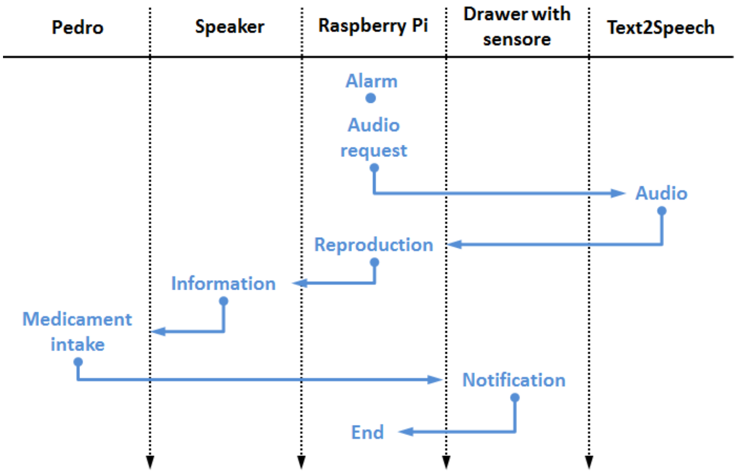

Figure 5. Timing diagram. Medication alarm process.

4.4. Raspberry Pi hardware

The needed hardware to get the connections above-mentioned, as can shown in Figure 6, are the Raspberry Pi, 802.11a/b/g Wireless adapter, Z-wave adapter and a separate circuit that has been required to design and build. This additional circuit, based on two buttons, simplifies the configuration and use of the platform (*configuration* button and *linking devices* button).

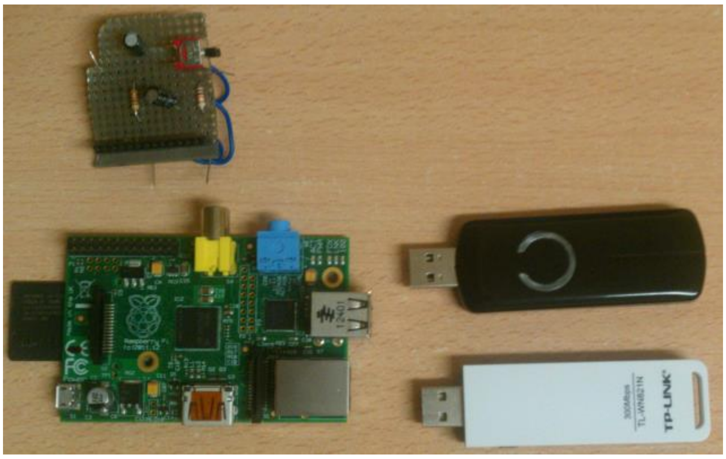

Figure 5. Required hardware.

The two adapters are connected via USB and a USB HUB if the size or physical layout is too small.

The Raspberry Pi provides a connection through multiple GPIO (General Purpose Input/Output); input-output pins that allow a developer the addition of hardware directly to the board. This mechanism will be detailed later.

In Figure 7, the functionality, needs and connectivity of each element added to the Raspberry Pi is detailed. The arrows indicate the direction in which information is transmitted.

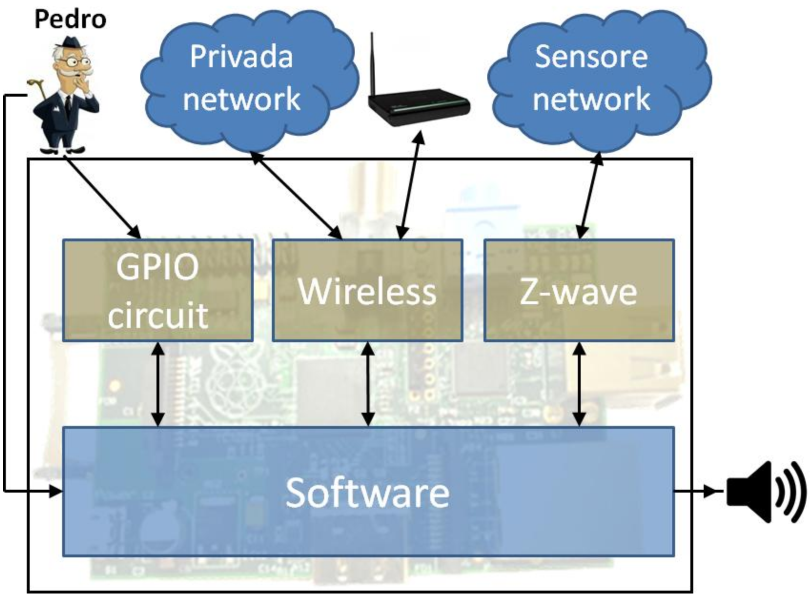

Figure 6. Outline of the hardware connected to the Raspberry Pi.

4.5. Circuit connected to the GPIO of the Raspberry Pi

The final product needs to allow the user giving two basic commands and it is best achieved by two buttons directly connected to the motherboard. To incorporate these pushbuttons, two circuits are created (Figure 8).

The resistor and the capacitor provide, respectively, safety and reliability. The resistance prevents from the generation of short-circuit and system overload. The capacitor removes the high frequencies generated, by pressing and releasing the button, and smoothing the output signal.

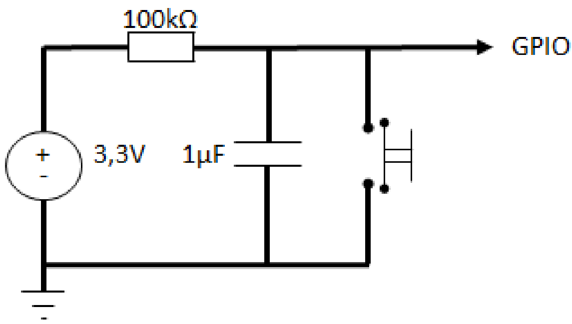

Figure 7. Circuit design for a pushbutton.

The appearance of the prototype can be seen in Figure 6, the device located over the Raspberry Pi.

The first button is responsible for setting the Raspberry Pi in configuration mode. This involves the creation of a private wireless network to allow connection of the device (mobile or PC) that will provide the required data to connect to the access point.

The second button is a shortcut offered to the user to link quickly and easily a new device (Z-wave sensor).

4.6. Raspberry Pi software

At a logic level, two programs are required: DomotiGa and a developed web application. DomotiGa is a software developed by the open-source software community that implements multiple protocols and standards in the field of home automation. Additionally, it implements a very unfriendly management interface and a XML-RPC (Extensible Markup Language - Remote Procedure Call) API which allows other applications being implemented.

In Figure 9, the relationship to the hardware is shown and how the internal communication between the web application and DomotiGa is done via the XML-RPC protocol. Additionally, DomotiGa provides extra information to the application via transmissions REST (Representational State Transfer).

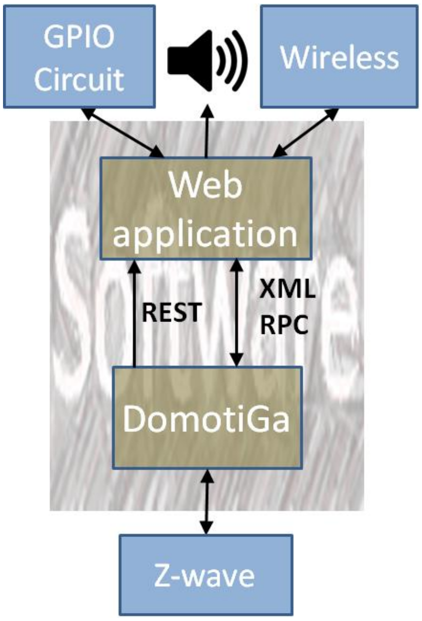

Figure 9. Software implemented in Raspberry Pi and its connections with the hardware.

4.7. DomotiGa

The required modules from DomotiGa are:

- Event Manager, which allows creating new events, modifying and listing them, and activating functions at the specified time.
- Sensor Manager, which allows adding new sensors, modify and list them, and send commands to actuators.
- Z-Wave Plug, which enables communication between Z-Wave sensors and DomotiGa.
- XML-RPC API, which allows external applications be able to communicate with DomotiGa and use the functions implemented, all using the XML format.

They are shown in Figure 10.

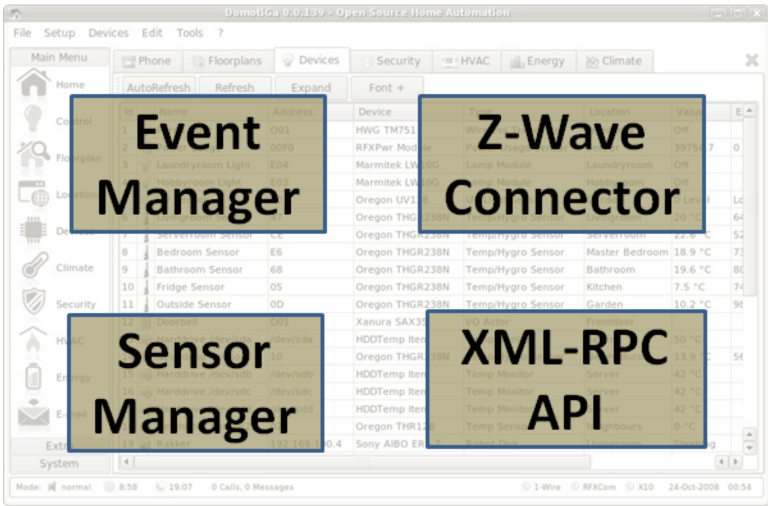

Figure 8. Required modules from DomotiGa.

The XML-RPC module does not include all the specific functionalities that are necessary to carry out the desired communications. DomotiGa is open source, so that developers can get the source code and they can make the appropriate adjustments. In our case, all the essential modifications of the code have been notified to DomotiGa, and they are pending of approval and merging into the original code for next releases.

The new features (developed modifications) of DomotiGa that have been added into CXMLRPC class are:

- LocationsGetList, which provides the list of spatial locations including by default in DomotiGa.
- ModifyDevice, which modifies the information of a sensor in device list.
- ZWaveAddDevice, which adds a new Z -wave sensor; this function prepares the Z-wave plug for a new connection; once a device is connected automatically, a new entry in the list of devices is created.
- ZWaveDeleteDevice, which deletes a sensor from the list of devices.
- TriggerGetList, which returns the list of triggers.
- TriggerGet, which returns the complete information of a particular trigger.
- TriggerDelete, which deletes a trigger.
- TriggerAdd, which adds a trigger.
- ActionGetList, which returns the list of all actions.
- ActionDelete, which deletes an action.
- ActionAdd, which adds a new action.
- EventGetList, which returns the list of all events.
- EventGetAction, which returns the list of actions related to a specific event.
- EventDelete, which deletes a specific event.
- EventAdd, which adds an event.
- EventActionDelete, which removes the link between an event and an action, so that action ceases to belong to the event.

- EventActionAdd, which adds a new link between an event and an action.

4.8. Web application

The application is designed to offer to the user a much simpler web control interface, compared to the one that comes with DomotiGa, and offer new features too.

The use of web services have been chosen to provide a multi-platform environment, and in addition the website is ready for proper viewing on devices such as smartphones, tablets or PCs.

From the advanced version of the website, devices and events are available (Figure 11), as well as the option of creating new (Figure 12), modify or delete. The wireless data and the email address to receive scheduled notifications can be also configured.

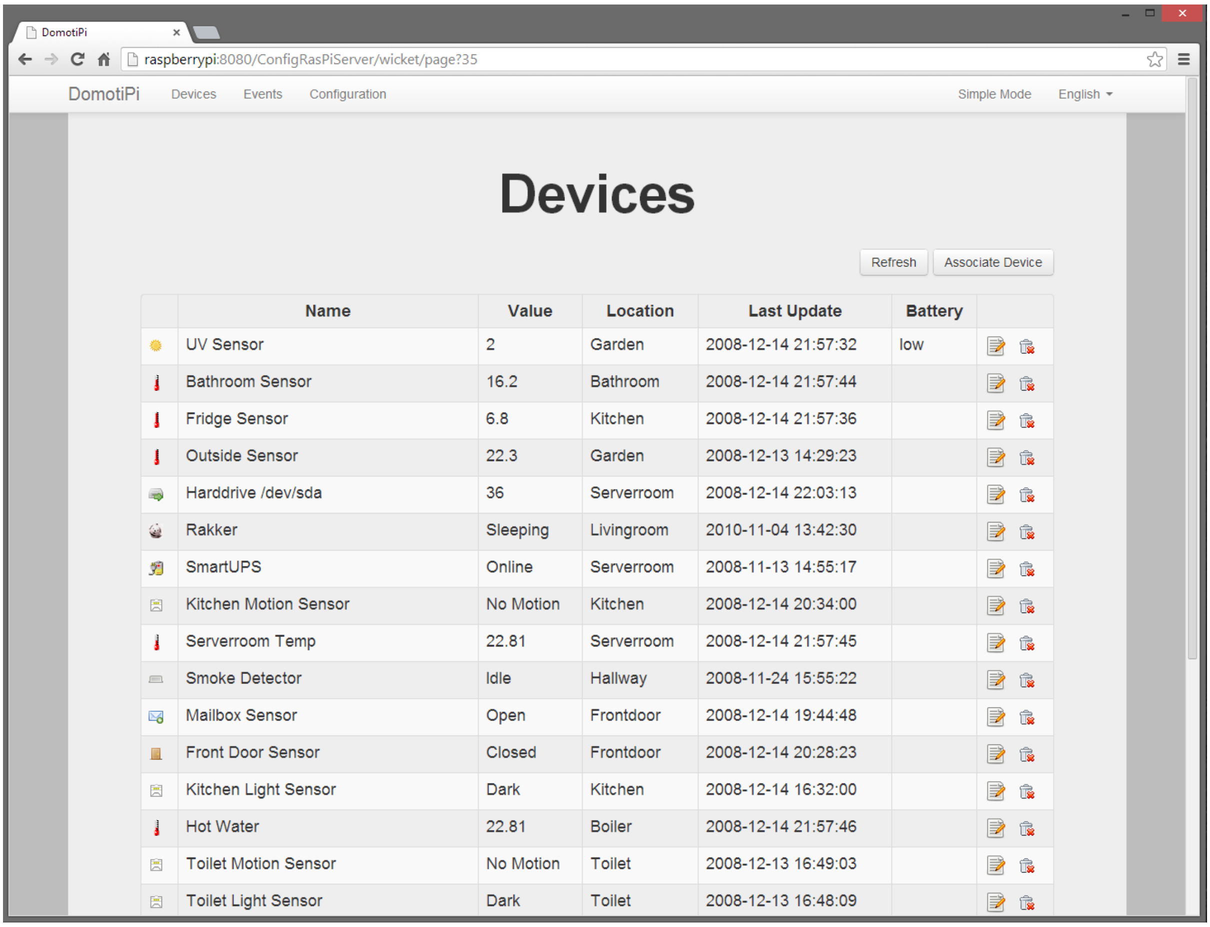

Figure 9. Website. List of associated sensors.

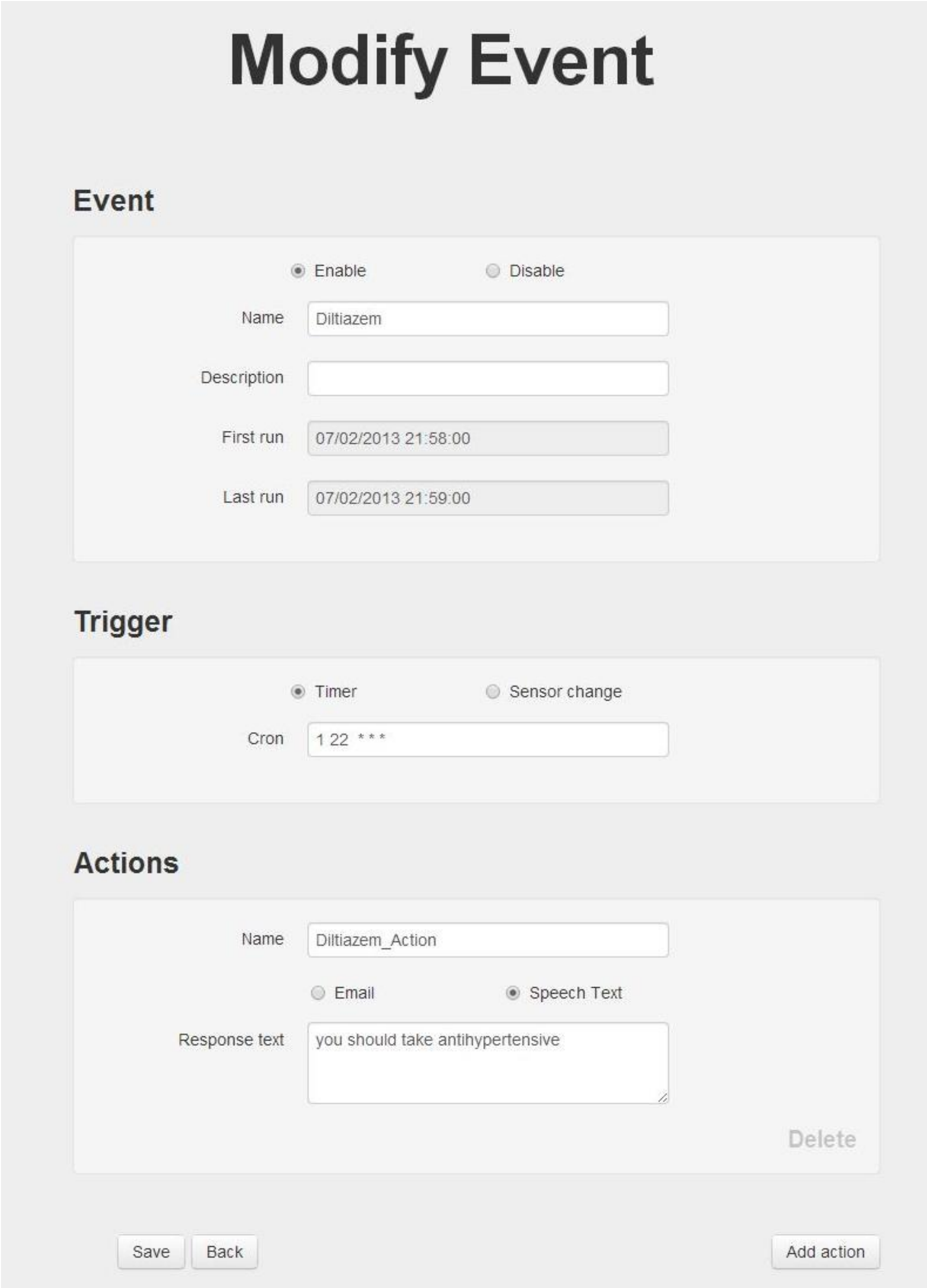

Figure 10. Website. Create or edit an event from the advanced mode.

In the simple version, several modules have been developed, by default the module to remember to take medication is included. This module allows adding which medications should be taken at which times of the day in a very simple and intuitive way (Figure 13). For any other specification, from the advanced mode, which lets configure more parameters by access to the event.

Figure 13. Website. Create or modify a Medicine event type.

4.9. Structure-based cloud

The Raspberry Pi has very limited hardware and it does not support the addition of huge amount of services. Thanks to the modular design, a second structure has been created where the web application is separated from Raspberry Pi and located in a computer with more resources.

In Figure 14, a new piece in the scenario, the web application server, is shown. This is an extra requirement to the user, a computer running 24 hours 7 days a week connected to the home network.

This change allows the Raspberry Pi diminishing its number of tasks. From now on, it only is used as a sensors gateway and event manager.

The new server is responsible for providing the web interface, which communicates with the user data, but unlike before, this interface may be more powerful and it may offer more services. Furthermore, more services may be designed, such as image processing, which can require large amount of processing.

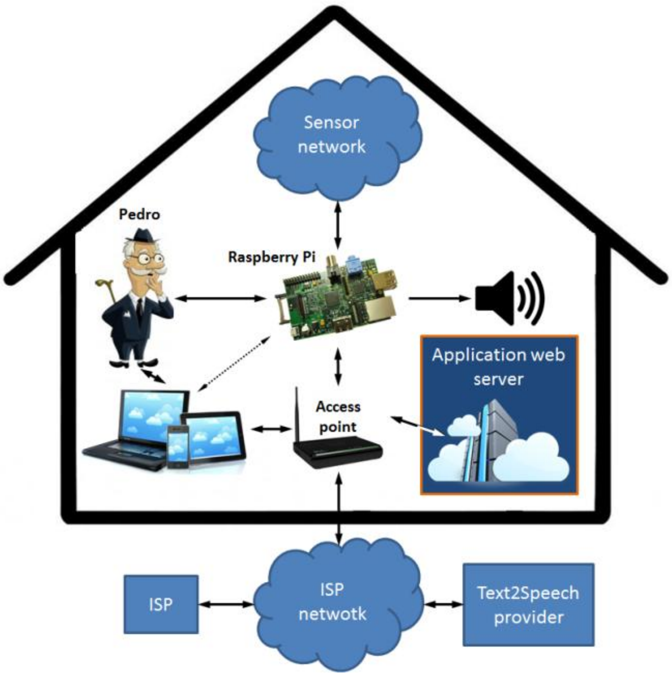

Figure 11. General scheme of structure-based cloud.

5. Costs

The final product is low cost, in Table 2 we have broken down the price of the necessary materials. This allows us to offer a very competitive product in the market, because for less than 150€ the consumer can obtain a base kit with which he can start to automating his home.

Table 2. Product material cost

Component	Price
Raspberry Pi	26.8 €
SD Memory 8Gb	7.75€
Wireless adapter	15€
Z-wave adapter	28.35€
Medicine drawer sensor	35.58€
Material for the circuit	5€
Housing (box for product)	10€
Total	**128.48€**

The modularity allows increasing the supply of services; which are purchased together with the required sensors.

A low cost product helps to reduce the amount of the bills at the end of the month, because of optimization of the household functionalities and it very welcome, taking into account the current economic crisis.

6. Conclusion

This product is aligned to the current economic, social and technological situation. This paper describes the design and implementation a home product that can be deployed in a sensor network. The environment allows building new services to improve the wellness of people, minimizing the user action in the management of systems. Furthermore, the evolution of society leads to the need in the near future, of access to these types of services to solve daily problems.

This product is based on a modular platform for orchestration of pervasive services, which admits to add medicines notification service, without any further modifications. It provides a mechanism for the configuration of the product at home, using a computer or smartphone, which transmits the data of wireless network to be connected, making it a plug&play system. A service for device management and one for handling events has been developed, with a simple and intuitive web environment, which offers great benefits with minimum efforts.

Future researches will strengthen the human-machine interaction by introducing, for example, recognition of movement patterns and machine learning schemes which will provide intelligence to the developed device.

7. Acknowledgments

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