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Creation of a voice-driven controller for home automation

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Granada, 9 de agosto de 2018

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Creación de un controlador domótico activado por voz

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Palabras clave: domótica, asistencia por voz, sistemas distribuidos, Raspberry Pi, software libre

Resumen

El objetivo principal de este proyecto es la creación de un controlador domótico activado por voz en un sistema embebido, como la *Raspberry Pi*, centrándose en el uso de software libre, obteniendo la máxima compatibilidad y el mínimo coste.

Para conseguirlo, se ha analizado la situación actual del sector, distinguiendo entre dispositivos domóticos, asistentes de voz y sistemas orientados a la automatización del hogar. A través de la Ingeniería del Software, se han estudiado las posibles necesidades de los usuarios, intentando suplir las carencias actuales del sector. Finalmente, se presenta una implementación de un sistema domótico en un entorno real, utilizable y extensible a cualquier situación cotidiana.

Por tanto, el proyecto trata de demostrar las infinitas oportunidades que habilita el reciente campo de la domótica, y la posibilidad de crear sistemas domóticos funcionales de bajo coste.

Creation of a voice-driven controller for home automation

David Vargas Carrillo

Keywords: home automation, voice assistance, distributed systems, Raspberry Pi, open source

Abstract

The main goal of this project is the creation of a low-cost, voice-driven home automation controller in a embedded system, such as the *Raspberry Pi*, using open source technologies and trying to obtain maximum compatibility with minimum cost.

To achieve this, I have analyzed the current state of the sector, distinguishing between domotic devices, voice assistants and home automation oriented systems. Through Software Engineering, I have studied the possible necessities of the users, trying to make up for the scarcities in this sector. Finally, I show an implementation of a home automation system in a real environment, usable and extensible to any daily situation.

Therefore, this project tries to demonstrate the infinite opportunities that the recent field of domotics enables, and the possibility of creating low-cost functional home automation systems.

Yo, **David Vargas Carrillo**, alumno de la titulación GRADO EN INGENIERÍA INFORMÁTICA de la **Escuela Técnica Superior de Ingenierías Informática y de Telecomunicación de la Universidad de Granada**, con DNI 76592492P, autorizo la ubicación de la siguiente copia de mi Trabajo Fin de Grado en la biblioteca del centro para que pueda ser consultada por las personas que lo deseen.

Fdo: David Vargas Carrillo

Granada, a 9 de agosto de 2018

D. **Juan Antonio Holgado Terriza**, Profesor del **Departamento de Lenguajes y Sistemas Informáticos** de la **Universidad de Granada**.

Informa:

Que el presente trabajo, titulado ***Creation of a voice-driven controller for home automation***, ha sido realizado bajo su supervisión por **David Vargas Carrillo**, y autoriza la defensa de dicho trabajo ante el tribunal que corresponda.

Y para que conste, expide y firma el presente informe en Granada, a 9 de agosto de 2018.

El director:

Juan Antonio Holgado Terriza

Agradecimientos

A mis padres, cuyo esfuerzo y dedicación han hecho que hoy esté escribiendo estas líneas.

A todos los compañeros y amigos que han estado conmigo en este camino, por haberlo hecho mucho más agradable y ameno.

Y, por supuesto, a Juan Antonio, por haber aceptado mi idea y haber hecho posible este proyecto.

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Chapter 2

Home Automation

Home automation, also known as domotics, has been a recurrent topic in Computer Science that has become a reality in the last decades, thanks to the growth and decrease in the price of embedded systems and wireless technologies, that have permitted to create distributed systems, the heart of this technology.

In this chapter, I am going to analyze this technology and its current state, including its implementation in commercial products.

2.1 What is Home Automation?

Although science fiction has represented the idea of smart houses since the past century, including in them an intelligence able to respond to all the dweller's needs and desires, it has never felt as close to real world as today.

The basic idea of home automation is to employ sensors and control systems to monitor a dwelling, and accordingly adjust the various mechanisms that provide heat, ventilation, lighting, and other services. By more closely tuning the dwelling's mechanical systems to the dweller's needs, the automated ïntelligent ̈home can provide a safer, more comfortable, and more economical dwelling.[9] For example, the automated system can determine the intensity and direction of the sunlight, and adequate the house according to its condition (which would include closing the blinds and adjusting the air conditioner).

Unlike many may think, we don't actually need a very modern house, since advanced systems can be perfectly integrated in older, traditional buildings. This fact makes domotics a real possibility in every situation. In fact, the number of home automation systems installed in Europe is expected to reach around 29 million by 2019.[6]

Figure 2.1: Example of a smart home with security-oriented devices

There is not an exact point where we can set the beginning of the domotics as a real concept, but during the last century there has been some remarkable efforts, and even before. In 1898, Nikola Tesla created a wireless control for a toy boat, the first of its kind [1]. That marks the beginning of wireless technologies, one of the fundamental parts of Home Automation.

In 1975, after lots of appearances of the idea of home automation in films, the first general purpose home automation technology, called X10, was developed. X10 defines a protocol for communication between electrical devices, which uses power line wiring for signaling and control, where the signals involve brief radio frequency bursts representing digital information. Therefore, it also defines a wireless radio based protocol. Surprisingly, the X10 technology is still widely used and available, with millions of units in use worldwide.

However, it was not until 1984 that the word Smart Home appeared, invented by the *American Association of House Builders*. After that, different inventions rapidly followed one another, with devices such as
The Clapper (which was operated through sound, like a clap or a bark) and interest from the biggest technological companies, like Microsoft.

Home Automation has not stopped gaining ground on our homes and now it is experiencing one of the best moments in its lifetime, with the unstoppable growth of the Internet of Things (IoT) and the simultaneous

Figure 2.2: The Clapper, a sound-activated switch

development of Artificial Intelligence for the general public, with the biggest companies, like Google and Apple, investing millions of dollars on it. Devices like Amazon Echo and Google Home, or assistants like Siri, Cortana, Google Assistant and Amazon Alexa are a good representative of this trend. I will talk in depth about them in the following sections.

We have always imagined that Smart Homes would bring us a whole world of benefits. And that is partly true, but they have ended up offering benefits that no one could imagine some decades before, when matters such as energy savings were not as important as today. These benefits are responsible for their increasing popularity, and they can be summarized in the following points:

- **Control anywhere:** Smart Homes can be completely controlled anywhere in the world from smart phones or other devices with Internet connection, so we can know the status of our devices at any time. That would allow us, for example, to stop worrying when staging out of home thinking if we have left the air conditioning on.

- **Safety:** there are tons of security systems ready to work on Smart Houses. They are capable of monitoring the people going in and out of home and send alerts to the owners if necessary. Like many other devices, there are also smart locks for the door and cameras that we can control from our smart device.

- **Accessibility:** Smart Homes can increase a lot the quality of life of elderly or disabled people, as they can be managed via voice commands,

making the interaction much easier to people which is not experienced with computers and improving their independence.

- **Energy efficiency:** one of the main goals of Home Automation is to work with the least amount of energy needed, and a big part of the research in this field is going in this direction. There are induction cooktop stoves that can be powered on only if there is anything placed over them (and even get the perfect cooking, powering off themselves)[2] or heating systems that power on and off depending on the weather and inner conditions of the home, or even a faucet technology that can maximize shower water usage by shaping the individual droplets of water, so the experience feels almost the same but with less water usage.

- **Money saving:** the last point leads to another benefit: saving money. Smart Homes can use less energy and water, making a big difference in how much we pay at the end of the month. Reports show that the savings on the energy bill for this reason range from 10% to 30%.[2]

- **Comfort:** Smart Houses can also help save time. Today, when everyone is trying to make the most of their free time, this technology is capable of doing housework, so that people can spend their time on things they enjoy most, or simply gain time to spend with their families.

This range of benefits has made possible to see home automation systems in many homes, but also in offices. Now, almost every new house that is built is prepared for domotics, including Internet access points in every room, a big amount of plugs, and a lot of space to extend its capabilities in a future. Indeed, the global home automation and security control market is expected to reach 12.81 billion dollars by 2020.[5] The following charts is a perfect example of how rapidly is growing the Smart Home sector and how powerful it is at this moment, showing the data for the most important Smart Home market at this moment: the United States.

Predictions are not bad either: they show that this trend will continue in the coming years, reaching 34.5 million of the US dollars, and this is just in the United States, although there will be similar situations in the rest of the world.

2.2 Home Automation System Design

After a look at the definition and history of Home Automation and its benefits, I am going to explain how these systems are usually organized. There is

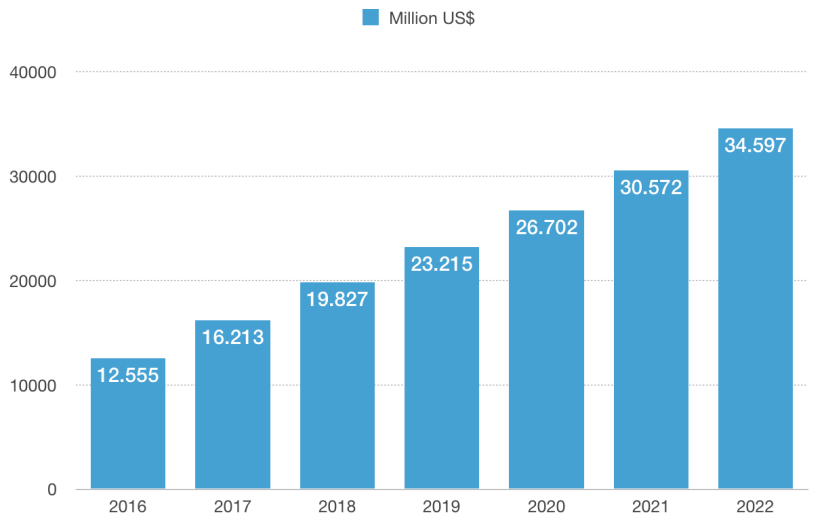

Figure 2.3: The Smart Home Market revenue from 2016 to 2022 in the US[7]

more than one valid way, and it will always depend on the requirements and conditions of the user, the home environment and of course the capabilities of its components.

First of all, from all the elements present in a Smart Home Environment, we can mainly distinguish the following ones:

- **Controller or controllers:** which are usually devices in charge of processing the data and take decisions, as well as communicate the devices between them and with other controllers, if any.
- **Sensors:** they are devices that are capable of perceiving changes in their environment by different means (audio, video, movement...). Examples of sensors are motion sensors or microphones.
- **Actuators:** these devices are the opposite of the sensors. They can inform of events, but they can also make changes in their environment. An actuator could be a light bulb or a speaker.
- **Communication mediums:** this is what devices and controllers use for communication. They can use the power grid, or by wireless protocols, like WiFi or Zigbee.

The figure 2.4 is a good example of a basic organization for Home Automation[3]. This organization has a name, indeed: centralized architecture.

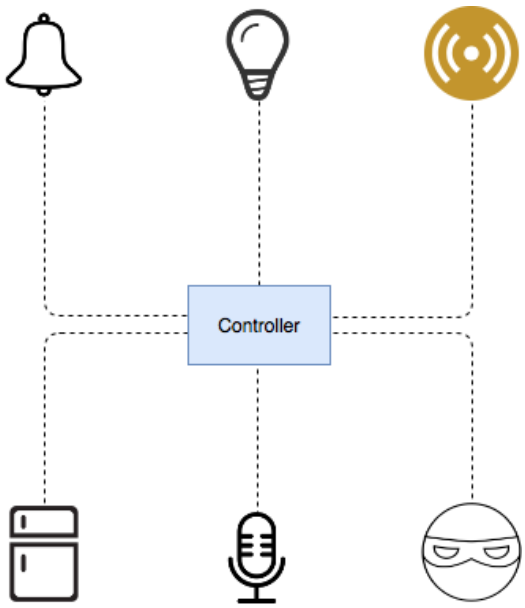

Figure 2.4: Centralized Smart Home structure

2.2.1 Centralized Architecture

In a centralized Smart Home Environment architecture, the Control System, which is realized by means of a computer system, is in charge of acquiring data from sensors, providing a user interface, and executing the control algorithms and sending instructions to actuators.[8] In the example in the figure 2.4, the sensor, in the upper right corner, could represent a smoke detector that can trigger the alarm (the actuator) to alert the householders.

The controller is often called Home Gateway, and in this case it is the central computer. It is also responsible of making accessible the system via Internet, as well as providing services to the home residents. An option to increase its performance while maintaining the same architecture is to limit the functionalities of the Home Gateway to data acquisition, software interfacing with domotic devices and basic processing, and to delegate to more powerful servers outside home the most part of the processing.

If they are placed in a powerful system, it is probably beneficial to use this architecture and get the maximum performance, which is ideal in big, complex systems.[4] However, there is only a controller and the system fully depends on it. If it failed, the whole system could be affected, which is a major issue in a Smart Home Environment.

This is the most popular architecture in home automation, partly because product manufacturers tend to centralize communications between their intelligent devices in a hub or gateway of the same brand, which users

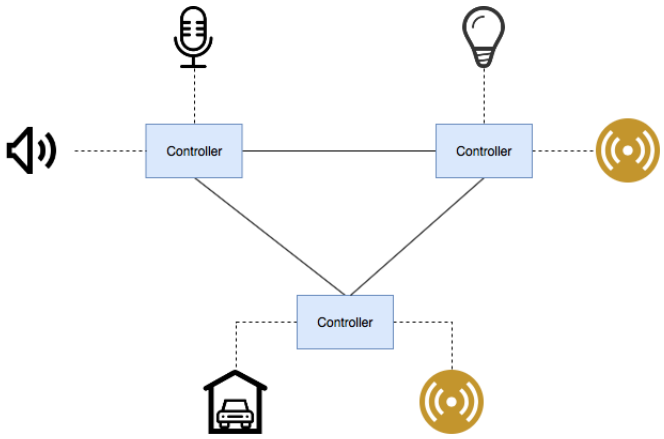

Figure 2.5: Decentralized Smart Home architecture

need to install to operate the rest of the devices.

2.2.2 Decentralized Architecture

In this case, there is more than one controller in the system. They are interconnected with a bus, so each one of them can interact and communicate with the rest. An example system that could use this architecture is a system with smart devices connected to hubs from different makers, and all of them interconnected thanks to a system that can work with all of them.

In the figure 2.5, we can spot three different controllers. Although the example shows a simple configuration, with this architecture it would be possible to interconnect big centralized systems, making one even bigger. Each controller is an independent system, and in this case they represent a lightning system, a voice assistant and a smart system for the garage.

2.2.3 Distributed Architecture

In a distributed Smart Home Environment architecture, the Control System software is conceptualized and implemented as a distributed computing system, that is, a series of intercommunicating devices working together to achieve an end, which in this case is running a Smart Home system. The integration and interoperability of heterogeneous domotic devices is achieved by an intermediary software layer called *middleware*.[8]

The distributed architecture benefits from the computational resources of smart devices to integrate software components into the nodes of the Home Automation network, which produces a big increase in autonomy and modularity[4]. However, the cost of this architecture is significantly

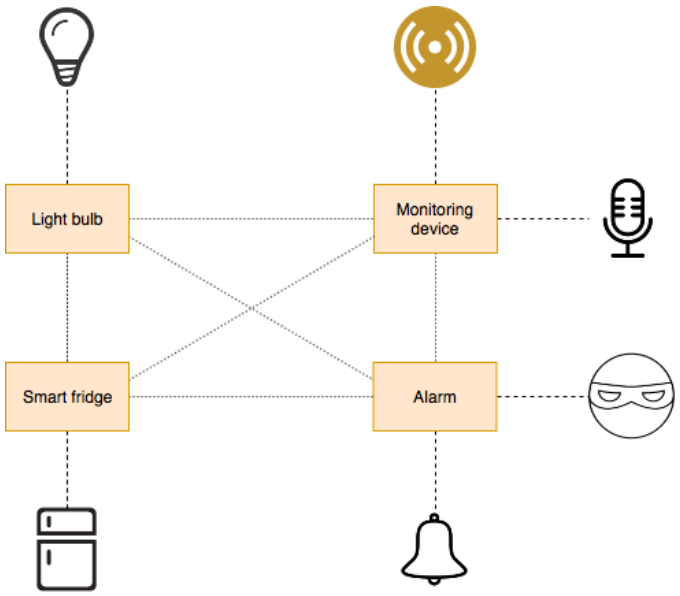

Figure 2.6: Distributed Smart Home architecture

higher compared to the centralized architecture, and therefore it is hard to achieve a fully distributed architecture. For this reason, this architecture is often applied conceptually, while still physically centralized into the Home Gateway.

In the figure 2.6 we can see an example of this architecture applied over a similar example as the one shown in 2.4. In this case, we can distinguish 4 independent but intercommunicated devices. For instance, the one at the upper right corner could contain a motion and a sound sensor, that could activate the alarm system located in the bottom right corner. The most important part about the distributed architecture is that each device acts as a controller as well, so there are not independent controllers anymore.

2.2.4 Hybrid Architecture

This architecture is a hybrid of the architectures mentioned above. In a system that follows this architecture, we may find a central controller (such as a centralized system), or a set of them (as the decentralized system), but also the end devices are controllers themselves, as it happens with distributed systems.

The main benefit of this architecture is that the devices are able to retrieve, process and communicate the information they get directly between them, so it does not have to pass through the controller. On the downside, this architecture could create an unnecessary mess in our system.

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