Beyond Smart Remote Controls

Developing a More Integrated and Customizable Implementation of Automation in a Building by Utilizing Tools and Concepts from Makers

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"Home Automation" describes the connecting of electronic household appliances to a centralized control unit like e.g. an app on a smart phone or some control panel. The overall goal of these efforts is to provide a general remote control for existing devices. By comparison a concept of home automation as part of a building design process has yet not come into shape.

Keywords: *Physical Computing, Arduino, Home automation*

INTRODUCTION

As technical term "Home Automation" describes homes in which electrical devices are connected and can be accessed and controlled without direct physical interactions. Devices range from single-switch devices, like lights and electrical outlets over isolated programmable devices, like thermostats and sprinklers, and household appliances to complete heating and cooling systems. In addition home security systems can be integrated. This includes an alarm systems and all the sensors that are linked to it. Magnetic sensors for doors and windows, smoke detectors, surveillance cameras, motion and light sensors, locks etc. formerly only used to trigger an alarm, are to be transformed into major input sources. All devices and sub-systems are linked to a network, which is accessible and controllable to some sort of centralized control unit like a dedicated control panel and, most important, provides an interface to the Internet. Based on this remotely controllable network users with mobile devices anywhere in the world could manage the local environment in their homes, the ultimate goal of every home automation system (illustrated in figure 1).

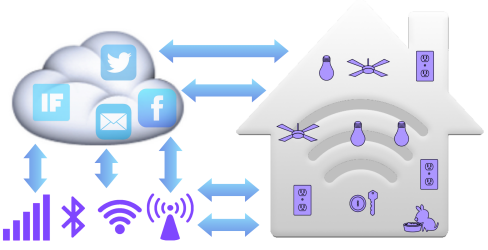


Figure 1
Possible concept of a home automation system

OVERVIEW

Common home automation systems consist of about four fields of applications: Lighting and home appliances, climate control combined with energy management, security systems with remote locks and sensors and entertainment systems with both Audio and Video. Besides that, singular devices like smart outlets and switches are introduced. All these devices are well known. In conjunction software

companies are developing packages or kits to provide access to these devices. All major operating systems of smart-phones have already some kind of home automation integrated. Apple includes its 'HomeKit' directly into iOS. Google has acquired 'Nest' and integrates it into Android. Since May 2015 they are proposing a reduced version of their operating system named 'brillo' for embedded platforms[7]. Microsoft is working with its acquired "Insteon"-solution on both the mobile and gaming platform. 'SmartThings', another startup dedicated to an open platform has now become a division of Samsung. This are only the big companies. There are still more drawbacks: To become Apple's permission to use devices on their Homekit-platform, only certain chips are allowed, the devices are tested and certified by Apple and yet an application needs to be written. As consequence we already see an amount of dedicated apps for singular devices, all going through Apple's cloud and maybe the vendor's as well, while the hardware is not available for some reason. On the other hand integrated solution are being develop, either based, as wired solution, on special bus-systems, or wirelessly based on Z-Wave, a low frequency below 900 MHz and different to many countries[5]. Integrated systems cover the most of the common scope of applications as drop-in solution like plug-in outlets and lightbulbs and specifically designed special purpose applications like a climate control system. Although the systems itself are well integrated, they usually fail when it comes to devices from other vendors. Furthermore such an integrated systems may bound customers to a specific vendor with no alternatives.

Missing standards

The name-dropping of brands points directly towards another issue: There is an emerging market with no defined standards generating a wealth of technically different concepts. Physically there are wired and wireless solutions. The different types of wired connections are either dedicated lines like serial cables or piggyback communication on powerlines. Wireless solutions are mainly differentiated by there frequency and based on them by designated protocols. Here in short higher frequencies resolves into higher bit-rates. Wifi, Bluetooth or specially assigned radio frequencies are not only physical different, they are also additionally split into several standards and protocols like e.g. 'Zigbee', 'Z-Wave' or 'Insteon' for the radio frequencies. The overall situation is chaotic and results in technical constraints, because simply a direct connection between devices featuring different standards is impossible, no matter what benefits a particular standard might present. There is only one point to consider: Wifi and Bluetooth might be favorited because these standards are wireless and available on mobile devices, which render their availability almost ubiqutious.

Clouds and privacy

As already mentioned, the ultimate goal of home automation is a mobile app controlling the system. Because such an app involves the Internet, hence requests some servers, dedicate cloud-services are established to channel the traffic and render it secure to the outside. As with all clouds, this applies only to the outside, not the inner side of the cloud. As consequence all interactions with the system are stored in data as actions with timestamps, when you enter your home, open a window, turn on the TV, the microwave or the light and flush the toilet. Without some sort of agreement all privacy is gone for good. As it appears, maybe not to only one cloud, but, like in the case of Apple's HomeKit, to two or more clouds.

Privacy is still an underestimated point of home automation. The only solution to resolve it is installing a cloud server under own control.

Mobile devices

Almost every home device on the market has an app both on iOS and Android to show its progressive status. There seems to be no future for home appliances without apps. As result mobile device as multipurpose tools carry a lot of different apps controlling the wealth of accessible devices from elsewhere. There is an app for the mood lamp, for the security

system, the fridge and so on.

Handling an app on a mobile device enforce special attention, a moment of concentration and focus either as eye-guided finger actions as defined touches or voice control. By comparison tapping on a switch on the wall while passing by seems just simple, even though it is a hand-eye coordinated action. However, this action is fast and for most people a no-brainer. Voice control solves this problem only at first glance. Speaking requires special attention as well and in addition it occupies a major channel of social interaction, the human speech.

Controlling the installations of a building only by handling a mobile device is not feasible. A general purpose remote control on a device that by design is a personal belonging has its constraints and limitations. Apps should be regarded as valuable option, especially when it comes to complex functions like controlling a mood lamp. Other concepts based on sensing of environmental data or natural requirements should be considered. Only local available access should be at least a feature.

At this point a strategy to customize potentially all parts of home automation is needed. The technologies, some of them are presented here as example, are evolving from the maker culture.

Integration

In architecture the layout of devices such as switches and light fittings and their associated electrical wiring is commonly integrated into the building's structure.

This is usually not a first priority. Commonly a standardized pattern based on some building codes is installed. This wired installation is fixed into the building's structure. The location of wall switches, outlets etc. are not about to be changed. As consequence clutter from power strips and extension coords on floors and behind desks has become a known phenomenon, if not to say problem, which might become dangerous as well.

The available remote switches are dealing with this situation. A typical remote outlet switch provides a plug that fits into the wall socket, then a volume like a small box as enclosure for the necessary electronically parts and a socket on the opposite side of the plug to simulate a wall socket.

The purpose is evident: the electrical wiring of the building remains untouched while the appearance of the socket is slightly changed in order to provide the additional functionality. This design gives the illusion that the installation is unaltered. As immediate consequence the clutter as mentioned remains unaddressed.

Obviously the issue that chunks are added onto the wall is not important. However what is supposed to be a flat surface with some sockets as minor holes is ruined with these devices, hence at some points their usage contradicts the architectural design.

The integration of smart devices into a building's structure like a traditional electrical installation requires for other techniques. By now this kind of customization is not available off the shelf.

MAKER CULTURE

The maker culture is a technology driven DIY-culture (Do-it-yourself) based on "electronics, robotics, 3D-printing , and the use of CNC tools, as well as more traditional activities such as metalworking, woodworking, and traditional arts and craft."[1]. It has a dedicate hands-on approach.

In the case of home automation the scope is reduced to electronics combined with some robotics and handcrafting and/or 3D-printing.

Physical computing

Physical computing has become widespread since the introduction of the Arduino and similar boards. Based on micro-controllers these tools can be used to take inputs from a variety of sources and control a wealth of physical outputs. They can both act as standalone computer or can interact with other computers. The platform is already explored and is especially well suited for rapid prototyping. A lot of people create individual projects with goals like to get an email sent once an egg is cooked. Even artistic concepts are emerging around this platform.

SIMPLE EXAMPLE

Electronics in architecture, in contrast to concrete, bricks and mortar, is an alien matter. In a standard building only outlets, wall plates and light switches are taken care off. Architects are not accustomed to deal with circuits and resistors or tiny chips as small computers. However, there is nothing to be afraid of. A simple example, a reactive light, should demonstrate the concepts and techniques.

Concept of a reactive light

A reactive light is a light that goes on when it is triggered by another light. It consists of a photocell as input source, an LED as output source, a battery as power source and a micro controller as processing unit. To complete the circuit, some resistors are inserted to protect the LED, the photocell and the micro controller. Using these parts often feels like applying a grammar. An LED cannot be used without a resistor, because otherwise it get burned and is lost. A photocell needs a potential divider. Almost all of the numberless tutorials are covering those basic issues like what pins to use, the choice of appropriate resistors etc. Once the basic concepts are covered, the real making process starts: Turn the light on only if it is dark and a decent threshold is hit, or more sophisticated, after a morse code is sent with the flashlight.

Experimental workflow

Experimenting with small and inexpensive parts is part of the workflow. After the start with a basic idea the hardware is assembled on a breadboard (figure 2) and the some coding applied to the micro controller. After evaluating hard- and software both may become more sophisticated while new ideas, like more colors, need some attention (figure 3).

Once a concept can be finalized, a more theoretical and schematic layout (figure 4) can be created, mostly for documentation and distribution. These diagrams then may be presented on some websites [1,2,3].

However, the process of making should not be marginalized. In case of home automation it is one of only few, if not the only one, way to create and evaluate samples of different concepts and ideas in a timely, flexible and affordable manner. To move from a white LED to a RGB-LED on a breadboard the hardware is partially ripped apart, exchanged and complemented in a jiffy, while adding some few more lines of code may add some minutes as well. Adding a servo-motor is slightly more complicated.

Limitations are the number of pins on the micro controller, which simply limits the total amount of hardware, and the mere computational power.

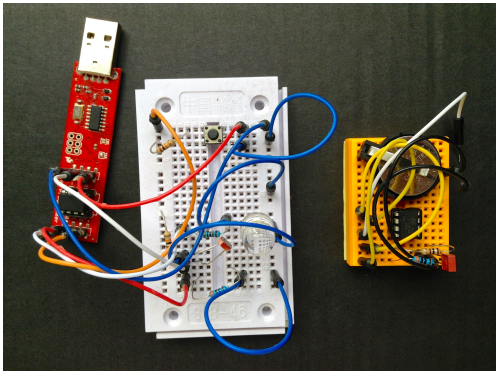


Figure 2
Breadboards with reactive lights, on the left with programmer, on the right standalone with battery.

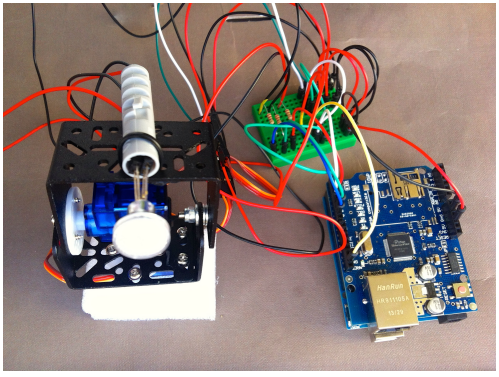
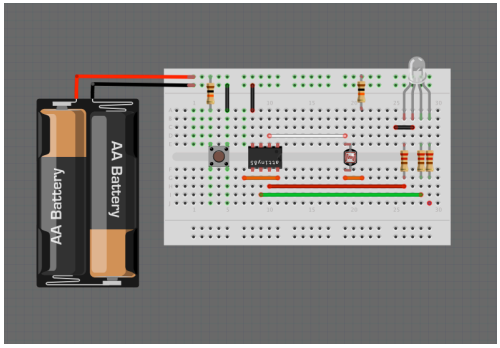


Figure 3
RGB-LED mounted on a pan-tilt-bracket with 2 servos and connected to an Arduino-board. The light can assume all colors while covering an hemi-spherical area.

Figure 4
Schematic layout of a reactive light.

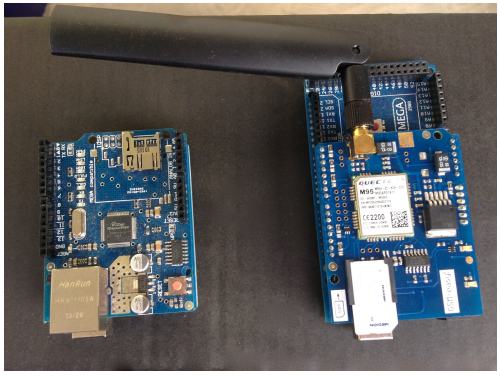


HARDWARE

Connecting some boards may overcome these limitations. By creating some relatively autonomous devices and interconnect them a type of meshed network can be established. The open-source Arduino-platform allows for all types of connections, wired with Ethernet or serial connection, wireless with WiFi, Bluetooth and cellular networks(GSM), and in addition Z-Wave.

The design of the Arduino board with its stackable shields allows for all types of connections. As results specifically designed shields are available for almost all of them (figure 5).

Figure 5
Arduino boards wih Ethernet shield on the right and GSM-shield (on a mega) on the left.



This concept delivers some degree of freedom between the connection on one side and the hardware layout combined with the specific code on the other side. The reactive light can be wired to both the board with the Ethernet-shield and the board with the GSM-shield, though in this case here the GSM-shield is not stackable, hence a mega-board is used and different pins are applied to the hardware. Just an implementation detail, but a common one.

More modern concept are the lately introduced Particle-devices. These are little Wi-Fi development board based on the Arduino which can be used to connect the hardware to the Internet. In general it follows a cloud concept: Every device has a unique ID and every user a single access-token. Once a user matches a core, in their language, a user has claimed a core, this core can be used for developing. All developments are done, this is kind of unique, in the cloud. A website is provided with an editor, access to documentation and libraries. The code is then compiled on their servers and as firmware transferred to the core, it is then flashed. As long as access is gained through device-ID and access-token a core could be anywhere as long as it is connected to the Internet through Wifi. However, for development a core can be accessed through a serial interface via USB, similar to the common Arduino developing style.

At first the concept of coding on a web page, compiling in the cloud and flashing the code at first feels uncomfortable and seems to be out of control, but once results are coming back those feelings are vanishing.

In technically terms a core can more or less all things an Arduino could do. All important libraries are already imported into the cloud's developing system. If not, they can be simply imported.

In addition 4 different functions can be called, with one single string as parameter. Assigned variables can be accessed directly through the cloud, or they can be published as based on HTTP as events. The latter is very useful for sensing devices like a temperature sensor, if those data needs to be broadcasted.

Future hardware

In the nearby future two new boards, a GSM-core and a board with Bluetooth will be available. They are already developed and funded through Kickstarter. They are expected in October 2015. With then 3 different kind of integrated wireless communication ports (out of 4) this platform uses the same code and hardware layout for all different types of connections depending on what type of device is used. Besides that the small footprint is really an asset.

Cloud and local cloud

As with others Particle provides a global cloud service on its own, hosted on servers by a big Internet-seller. They also provide a local cloud service. The software can be installed on all major platforms like Windows, Linux or Mac OSX and all local cores can be directly connected to this service. All devices would then connect to the local cloud and all network traffic remains inside the local network. No Internet traffic is generated, no uplink is needed. Unless there is a need to control some devices remotely the local cloud may stay in isolation. Nevertheless the response times should be short.

By now the concept of a local cloud is the only feasible concept to obtain some privacy, or to regain it. Although it is opened source the only known working solution by now is the local cloud from Particle.

HAND CRAFTED HOME AUTOMATION

After introducing the overall concepts some projects are presented which can demonstrate how a maker's approach transforms home automation into a flexible and affordable tinkering process.

Lighting

Lighting in electronics is a special case, while LED are used. They can be addressed directly. This makes it very easy to work with, but limits the overall brightness.

LED-ring

It has become some common practice that some prefabricated devices are available for training and testing purposes. One of them is the so called 'Internet button' a ring of 11 LEDs, 12 with the one provided by the core, 4 buttons, a gyroscope and an accelerometer (figure 6).

Spark, now Particle, distributed them for a hacking marathon in November 2014.

Here the ring is used to establish a user-interface on an iOS-device to demonstrate how a mobile device can be used to control 12 lights, and furthermore to control a group of these buttons simultaneously. Figure 7 shows the results.

It should be mentioned, that both connection the cloud and direct UDP-connection are tested. While the cloud's transmission usually results in delays of one to 2 seconds, the direct transmission was very fast. At some point three color flashing rings could be synchronized to less than 1/10 second. Dealing with large amounts of LEDs, like as part of a wall, pixel based illuminations of all different kind can be imagined. A mood lamp would be the simplest one.

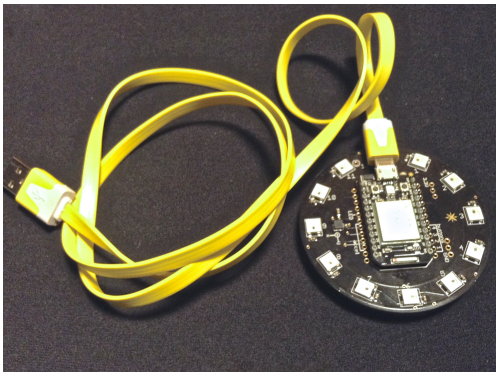


Figure 6
The Internet Button, 11 LEDs, 4 buttons and some sensors wit a core in its center

Figure 7
iOS-device with user interface and the real LEDs with mtaching colors on the right.

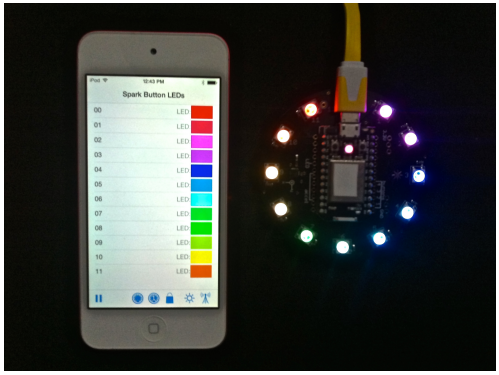


Figure 8
Outlet spider: 4 outlets wired to a relais shield inside a junction box.

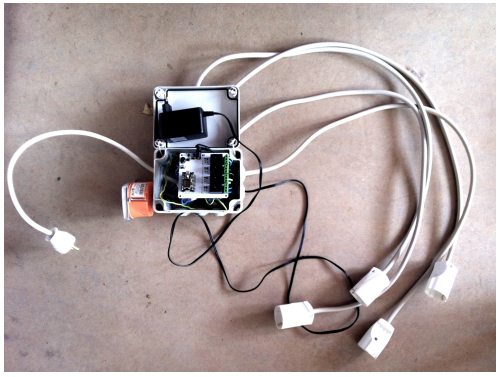


Figure 9
Outlet spider: Detailed view of the relais shield with WiFi-enabled microcontroller [Particle Core].

Outlet spider

This is our first project dealing with high voltage. The outlet spider is a power strip with extension coords (figure 8). It should avoid spacing conflicts on the strip by providing some flexibility. In its center is a junction box containing the connectors and the devices of the home automation.

Relay shields

No micro controller can control high voltage on its own circuits. Instead relays are needed to trigger a switch for the high power devices, the single purpose of a relay (figure 9).

For micro controllers special relay shields have been designed. They provide some relays with screw connectors, power regulation for the complete board except for the high voltage and a dedicated socket for the micro-controller.

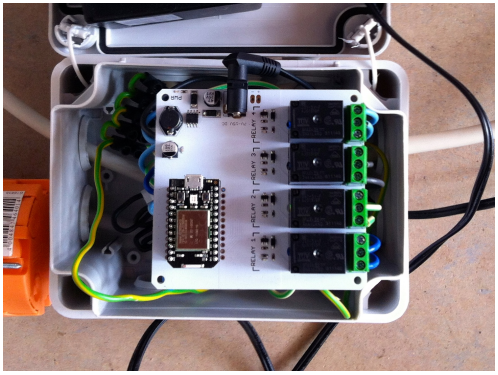
The controller itself can be exchanged. The shield is only bound to a specific pin layout, but not to a special hardware itself.

In fact this provides two options: The type of hardware can be modified, but also the implemented software on the controller simply be replacing it with an identical chip with different software.

Modifying and uploading software on micro-controllers is repeatable pattern of the workflow. Usually the same controller is used and enhanced. In case of home automation an update of the software can be like a simple replacement, if the really shield, once installed inside a building's structure, remains maintainable.

Wiring

All wires are connected to the screw terminal connectors on the relays shield inside the junction box and to the outlets (figures 7, 8). The main problem was a junction big enough to for all components and an additional outlet for the transformer of the shield.



Usage

Because a ready made shield is used, where the core simply plugs in its socket, no further hardware composing is done, and the related software remains unaltered. Particle provides a simple app to control all

pins of a core. By now this app is sufficient. A relays just switches buy a push of a button, and because it is on the Internet, the switch could be triggered from elsewhere.

There should be no doubts, that some pins of the controller are still open and some sensors like a photocell or a temperature sensor can be added. There is a lot of room left for customization both in hard- and in software.

CONCLUSION

Although they do not demonstrate a complete home automation project the presented examples give an insight of possible realization concepts. The outlet spider is at first an architectural or design project. It replaces a power strip with all its clutter with access points at extended lines to provide 4 power outlets freely inside the radius of the extension coords.

The LED-rings demonstrate fast switching and changing light arrangements, the servo-contoled LEDs show a more sophisticated light concept. The brightness and intensity of LEDs directly connected to micro-controller is still not really useful for lighting purposes. The provided power and voltage is simply too low. It is however only a technical shortcoming, which may be overcome once the necessity of enhanced controlling becomes evident.

By conquering and adapting to methods of the makers' culture the simple usage of devices from mass production can be overcome. One of the key benefits of products of makers is the transfer from serial production to batch or even job production. It correlates with the architectural design process as a typical job production but almost never a serial production process.

If the architectural design raises the claim as an creative process to establish a building, and if home automation becomes an integrative part of the process, and there are no doubts about it will, then the tools and techniques from the makers' culture should be at least considered when it comes to the design of a building with an integrated home automation system.

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