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# Universal Central Control of Home Appliances as an Expanding Element of the Smart Home Concepts

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**Abstract.** With the development of the electronic appliances, there is an increase in the usage of the so called Smart Homes concept. Nowadays, many standards and technologies exist which enable the control of the related home appliances. However, the common devices that support only the handling via a controller on the basis of infrared transfer are not possible to be operated by these systems. In practical environment, the suggested solution is able to replace the function of such controllers and enable the user to operate the given devices using a website application that is available for example through a smartphone. The part of the solution is the interface for the connection of the application to current Smart Home systems and an intelligent recognition and an automatization of user's actions with controllers. The result of the implementation is a functional prototype.

**Keywords:** Smart Home, Infrared, Remote Control, Automation, Mobile, Multimedia

## 1 Introduction

The recent fast development in the field of electronic appliances also accompanies the development of the systems which contain elements of so called Smart Homes [1, 10-11, 13-15], the methods for the cooperation with electronic devices enabling the basic functions of a house. Originally, Smart House technologies were developed for the control of energetically advanced systems, such as heating or lighting. However, the

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current level of electronic equipment enables the connection of almost any components into the Smart Home system. Moreover, this is not only bound to switching on and off devices, it is also possible to create actions which would simplify the inhabitation of such environment and save time on the basis of pre-defined or intelligent algorithms. This is due to the instruments for monitoring of the presence and user's activity [2]. [3]

In relation to the intelligent buildings, recently the controlling and monitoring of their energy usage became a popular topic. The reason for the interest is for example the fact of up to 40% of spending on energy is in commercial buildings which can be reduced to 70% [4] using automated systems for controlling of lighting. An example of an active operation in this field is the research of wireless control of lighting [5], technologies of smart transfer networks (Smart Grids [6]) or general usage of Smart Homes [7].

Current systems for intelligent homes usually contain a central controlling unit to which using star or bus line topology there are attached end nodes – sensors or action members. In relation to the supplier of the given solution, these nodes must support a specific standard of communication. The common representatives of such standards are for example C-Bus which communicated using the Ether network, international standard KNX [8] or a wireless system ZigBee [9].

The purpose of the project described in this paper was to suggest and implement a hardware and a software which would contribute to the centralised solution of the home appliances that are operated using the infrared controllers and do not support any of the standards for central controlling. The solution contains a website application which introduces a Human-Machine interface (HMI) and provides API for integration of current Smart Home systems.

Moreover, the system continuously monitors the usage of current controllers and on the basis of the user's activities suggests for example the unification of commonly consequential steps into mass actions (macros) or automatic implementation of regular actions. The result of this function should be the time saving and simplifying of everyday activities related to home appliances, which according to [3] corresponds to basic requirements of Smart Home technology users.

## **2 Problem Definition**

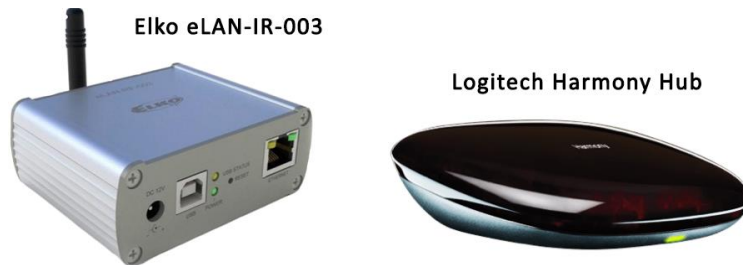
The main reason for this project was the absence of the connection of most common multimedia appliances with current Smart Home solution. Some models support the standard HDMI CEC [20] that enables the operating of interconnected appliances using the HDMI cable. However, for the usage of such standard it would be necessary

to connect to each device an individual module for its maintenance. This is technically, but also financially a very demanding solution. On the other hand, the traditional infrared remote controls are used by most multimedia home appliances. Moreover, the hardware for the transmitting and receiving is favourably priced. For example, the article [21] is concerned with the processing of the signals from IR controllers. This article suggests the system of automatic switch off of unused electric plugs and their repeated awakening using the IR signals.

Currently, there are a few products on the market which enable the functionality of the central controlling of the appliances using the IR signals. The product line Harmony from Logitech contains a wide spectrum of universal remote controls, from which Ultimate Hub, Smart control and Ultimate models have the Hub unit that provides similar functions as the suggested solution. For this solution, the company also offers applications for iOS and Android which are very well built and intuitive. Unfortunately, the Harmony product line is very closed and does not allow the connection with other systems. The prices range from 100 to 300 USD, depending on the specific model.

Moreover, the Open Source Universal Remote application is also worth mentioning when considering the open-source solutions. This application can be installed on any PC which contains IR controller and enables the transmitting of commands to appliances from any web browser in the network, for example even a smartphone. The disadvantage of this application is that it does not offer the possibility to record signals of the current controller and consequently emulate them.

None of these above mentioned solutions has the ability to monitor the user's activities with the current controller and also does not suggest the optimisation of regular activities. The first two are introduced in the in the Fig 1.



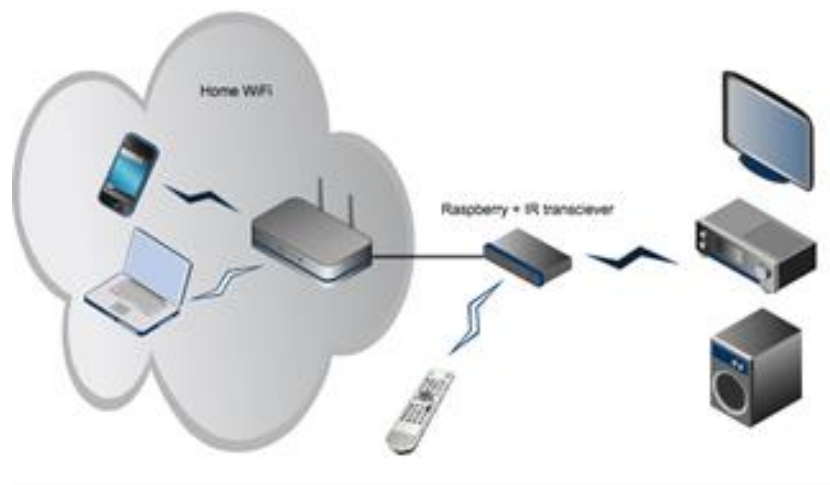
**Fig. 1** Commercial device enabling the central control of IR appliances.

### 3 New Solution

This chapter introduces the suggested solution for controlling of end devices. The schema (fig 2) shows the architecture of the whole system. It is important to notice the 3 basic communication directions:

- Through the web application, user can operate the end devices using the IR transmitter in the central point of the system.
- Central point captures commands which are sent from the original controller into the end devices.
- On the basis of the manual command, it is possible to duplicate the current controller and use it from the web application.

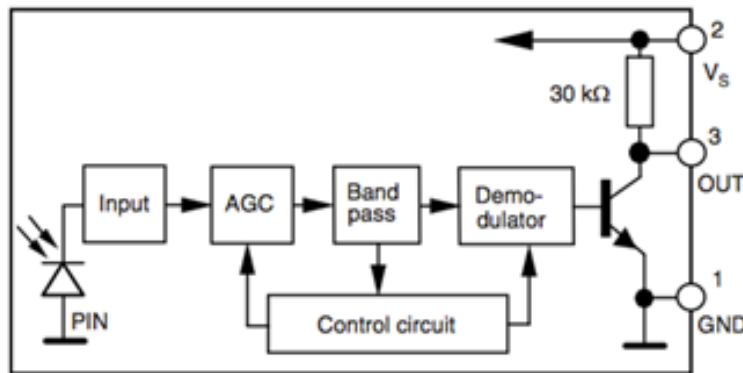
The requirements for the central point included the ability to receive and transmit IR signals which are compatible with remote controls and communicate with other devices using the HTTP protocol and LAN home network.



**Fig. 2** Devices present in the system for the central control of the appliances.

Most of the remote controls use the IR transfer with coding on the 38 or 36kHz frequency. Manchester, Pulse distance or Pulse length coding is used for the modulation. In order to decode these signals, it is possible to use a completed three-

pin receiver that contains a demodulator and control circuit due to which the generated digital signal is corresponding to the transmitted value. In comparison to the simple IR phototransistor, it is not necessary to manage the demodulation. The inner schema of the used receiver is shown on the Fig. 3.



**Fig. 3** The inner connection of the IR receiver TSoP 31238 [12].

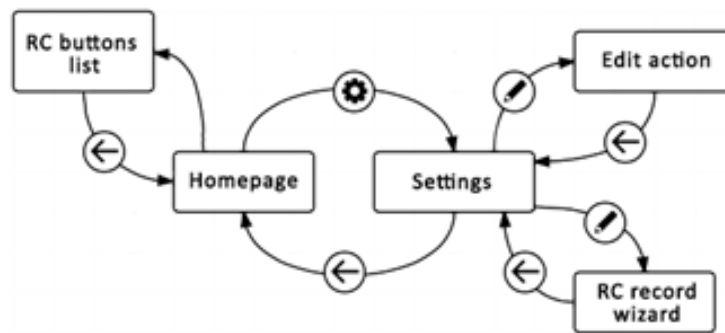
The suggested transmitting circuit contains two IR diodes and a switching transistor (in order to not overwork the data pin by too much current). Two of the used diodes with the combination of wide-angle transmitting should provide the coverage of all appliances in an average room.

The next task was to ensure the recognition of correct coding of digital signals which come from the receiving module, the subsequent transfer to HEX representation of the pushed button and the possibility to code the value back and send it through the IR transmitter. The LIRC library was used to uncover the coding. It is composed of numerous basic sub-programmes:

- Irrecord – an interactive console application which enables to “record” the current remote controlling; the final product is a configuration file liircd.conf which contains for each operation a description of used coding signal and mapping of individual HEX codes of symbols into their aliases
- Liircd – system demon which acts on each defined end device with connected IR transmitter and using the socket enables other applications to send the previously recorded IR commands
- Irsend – associating console application which resends the entered saved command into the liircd socket
- Irw – simple utility which reads the liircd aliases of the received codes from the socket that is created by the demon and sends them to the standard output

Before the actual implementation, the structure proposal the user's interface of the application was conducted. The frequency of the expected usage of individual tasks which should be implemented was used for the distribution of the most important elements to the best reachable places. The most significant service of the application is the simulation of the push of the buttons for recorded controllers. Therefore, the accomplishing of the mass actions was placed at the original page.

The special page for recording of the controller functions on the basis of interactive navigator with simple commands. It can obtain text data from the users, such as the names of the recorded buttons, show the progress guide or the countdown of the remaining time. Physically, it is an interface which in real time [12,16-18], using the WebSockets communication technology [19]) conveys the commands of the irrecord application to the user and immediately returns to it the obtained data. The structure of the application and possible paths between individual functions are shown on the Fig. 4.



**Fig. 4** Diagram of the transfers between individual pages of the application.

The unique function of the suggested solution is the detection of the common actions. It is an implementation of an algorithm for searching of repeated sequences in the recorded time row. There are many papers which cover this problem, for example [24-27]. Most of them suggest the usage of algorithms based on the Markov chains or decision trees. However, in regards to their intended purpose for continuous data or even multi-dimensional data, they are too complicated for the needs of this paper.

The commonly used model of decision trees was used during the suggestion of a simpler algorithm which enabled the recognition of samples in recorded binary data that represent the buttons' push of the controllers. The recorded time line is processed by the algorithm for the detection of clusters and then each cluster and its metrics (for example the average delay between individual commands) are recorded in the form of



a sequence into the graphic database. This obtains a system of sets of trees from which each represents a sequence of commands with identical first node. Therefore, each recorded sequence is connected to the current tree or there is a new tree created. When repeating the sequence, a counting mechanism is incremented only in the database.

From this continuously maintained database, it is possible to simply obtain the sequences which are most commonly used and may be for example suggested to the user for establishing of macros.

#### 4 Implementation of the Solution

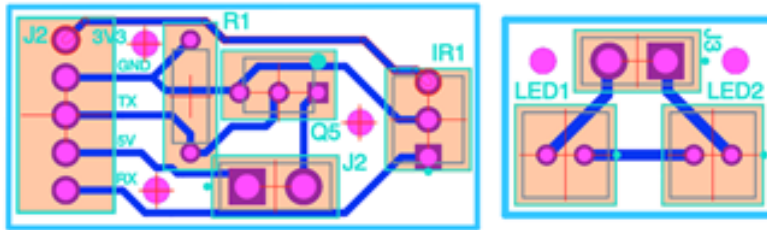
The compact computer Raspberry Pi [28] which functions on the platform ARM was used for the prototyping of the central point of the system (see Fig. 5). This platform is sufficiently powerful in order to carry out all the tasks and it has better dimensions and battery than common x86 PC platforms. It has the dimensions similar to the ones of a credit card and its price is around 25EUR. Moreover, it contains an integrated processor with 700MHz frequency and a 512MB RAM memory. In comparison with the simpler and cheaper device, such as Arduino, it has a significant advantage due to its support of fully-functioning operating systems on the basis of Linux which enable the usage of many software technologies.



**Fig. 5** The finished prototype of the central point.

For the creation of the main application which contains all the functional logistics and offers the possibility of controlling through HTTP, the Node.js platform was chosen [30]. It is a server solution which functions with the JavaScript running

environment V8 and is used in the Google Chrome browser. Its advantage is the orientation on the asynchronous utilisation of events and high power, even with a weaker hardware.



**Fig. 6** The proposal PCB of IR module with separated transmitting part.

The existing library was used for calling LIRC sub-programmes from Node.js on which even the competing solution Open Source Universal Remote is built. Unfortunately, it supports only the sending of the commands. Therefore, it was necessary to add the support for irrecord which enables the initiation of the record of the existing remote control from a smartphone or a PC. This was a significantly difficult task due to the fact that the given sub-programme has an interactive interface from which it is necessary to transfer all events from console through Node.js and into the browser, as well as back.

The whole structure of the application, described in the chapter III, was implemented in a way which enables a fully valuable and comfortable control from a web browser, as well as from a smartphone, independently of the resolution. An example of the application run from a smartphone which was adjusted to the resolution of the display is shown on the Fig. 7.



**Fig. 7** Web application is responsive and adjusting its settings according to the type of device used.

## 5 Comparison with Competing Devices

The result of this paper is the functional prototype of the device which ensured a centralised control of home multimedia appliances using the IR signals. In this chapter, the suggested solution is compared with competing products. The following table 1 shows the main advantages of the individual solutions which are comparable with the suggested one. The purpose is not to give a detail description of each product, but only to compare the important characteristics.

TABLE 1. COMPARISON OF COMPETING SOLUTIONS [33-35]

<b>Name</b>	<b>Characteristics</b>	<b>Suggested solution</b>
Logitech Harmony	Native application for Android and iOS. More expensive versions also have a hardware controller. It does not have API and does not learn according to the user's behaviour.	Instead of the native application, it is possible to use a web application which is optimised for mobile devices.
ELCO eLAN-IR-3	The closed solution with a non-intuitive application. Does not read the user's behaviour.	Open API for the linkage of services of 3 pages and algorithm for the detection of common sequences of commands.
Open Source Universal Remote (OSUR)	An intuitive web application even for mobile devices. But non-intuitive recording of the controller using command lines.	An interactive guide for recording of the controller. Princip web application originated from OSUR.
Traditional Smart Home solutions	Large selection of expensive specialised appliances which are able to be centrally controlled, but the inability to control common appliances	IR signals enable the controlling of most multimedia appliances with low expenses. For controlling of more advanced elements, it is necessary to link another system.

It is clear from the table that the main advantages of the suggested solution are the possibility of the linkage to other services using the public API and the ability to automatically recognise the most commonly used sequences. The commercial products offer more functions, but they are usually dependent on the hardware of the particular manufacturer.

Furthermore, the user testing on 10 sample subjects in the age 15-55 was run. It contained following tasks:

- Connect devices into the multimedia home system and run it,
- record the current controllers,
- try to use web application in a smartphone instead of controllers,
- let it create and name a mass action which is automatically suggested after a certain time period of usage.

After the evaluation of the results, it was found that users were able to fulfil given tasks with the success rate of 80% which shows a correctly designed users' interface and generally the principle of the solution. The created reminders were used for further improvement of the application.

## 6 Conclusions

This paper suggests an open-source solution for centralised control of multimedia appliances which use IR controller. The suggested solution can be used as a supplement to the current Smart Home systems. Using the web application which is accessible from even a smartphone, it is possible to record commands of the current controllers, emulate their function using an individual approach and on the basis of long-term activity of the user, it suggests the unification of frequent sequences of commands into macros. This functionality can save time of the user and increase the comfort of working with multimedia appliances. The functional prototype was compared to the competing solutions and tested with users. One of the next directions of the development could be for example the improvement of the algorithm for detection of common usage patterns, independent of the order of carrying out the particular commands in the case when it does not matter.

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