How Blind People Can Manage a Remote Control System: a Case Study

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Abstract. Remote Control Systems (RCSs) are increasingly being installed in homes and offices. Technology evolves very rapidly and sensors and devices are becoming smaller, smarter and more powerful. Mobile and Web apps are commonly used to remotely configure and control devices. Home control is especially valuable for blind people, since they can benefit from technology to control and turn on/off devices autonomously. Remote control can offer meaningful support, especially when devices are not directly accessible (e.g,. thermostat to manage heating temperature). Therefore, if RCS interfaces are not accessible via screen reader, blind users may miss a great opportunity to achieve greater autonomy at home. This paper investigates the accessibility of the web user interfaces offered by RCSs for blind people. To do this, the Fibaro, a popular Remote Control System, was tested as a case study by analyzing the interaction via screen reader. Results indicate that accessibility and especially usability need to be improved to make interaction easier and more satisfying for blind people. To this aim, some suggestions are offered to aid developers in designing more accessible RCS user interfaces.

Keywords: Home Automation, Accessibility, Blind Users

1 Introduction

The last decade has been characterized by great advances in Home Automation and Remote Control Systems (RCSs), increasing the power of devices and sensors while decreasing their size and costs. These smart systems are a great opportunity for the autonomy and safety for elderly and disabled persons, enabling one to control lights, shutters, doors, alarm systems, smart TV, cameras, sensors, devices, and so on. Visually impaired people, and especially the blind, can increase their autonomy enormously, thanks to technology that supports controlling and handling devices via smartphone, tablet or computer. Many devices that are not directly accessible can today be handled via mobile or Web-based applications also by a blind person, making possible various activities, such as programming a washing-machine or setting the household heating temperature, if the user interfaces (UIs) and functionalities are appropriately designed. Briefly, Home Automation Systems (HAS) are today easily controlled via smartphones, tablets or computer with customizable apps. However, to offer benefits and enable everyone to take advantage of the full potential of these systems, the Web-based or mobile apps for remote control should be accessible and usable also via assistive technologies, such as a screen reader for blind persons.

In this paper we investigate the accessibility and usability of a Web application used to remotely control components of a Home Automation System. A popular HAS was selected as a case study. Of several commercial systems, we selected the Fibaro (https://www.fibaro.com), relying on Z-Wave protocols, which offers a system for managing a building accessible via browser through a graphic user interface (GUI) or via the native mobile app. It includes an extensive library of preinstalled plugins for third-party smart TVs, cameras, thermostats, alarm panels, media players and control systems. An easy-to-use visual scene builder can be used to configure the system. The Geo-Location feature enables the creation of GPS triggers for all users anywhere in the world. Different degrees of personalization can be achieved by advanced users who are able to write scripts with Lua, a powerful and efficient scripting language (http://www.lua.org).

Our goal is to investigate (1) the main components of an RCS suitable for simplifying interaction for blind people, and (2) the problems a blind person might experience when interacting via screen reader with a HAS. Regarding the main components of a remote control system, blind persons have different or additional needs compared to sighted people. Since a blind user cannot have an overview of the interface, a sequential reading via a screen reader is necessary. This can require considerable effort. Therefore, appropriate UI design can improve interaction via screen reader as well as via keyboard. For example, a functionality designed for making a list of the only rooms with open shutters could dramatically simplify and shorten the interaction via screen reader when the user wants to close the opened shutters. Such a functionality might not be available in a common HAS since a sighted person spends a very short time exploring the UI at a glance to check the rooms that still have open shutters. Other similar functionalities could be very useful to greatly improve the usability of the interaction for the blind. Concerning interface accessibility, to ensure simple interaction for anyone, regardless of his/her disability, it is important to first implement the Web Content Accessibility Guidelines (WCAGs) including structured content, accessibility tags, and the possibility of managing any actions via keyboard, in order to avoid obstacles or difficulties experienced by a blind person. For example, links and buttons should be context-independent and auto-explicative (e.g., “Turn light on” rather than simply “Turn on”). In the following, we analyze the Fibaro web user interface to investigate the aforementioned aspects. The paper is organized as follows: section 2 reports related work, section 3 defines the methodology and introduces the study. In section 4 results of the inspection via screen reader of the Fibaro Web interface are discussed and some suggestions are proposed for developers of Home RCSs. Conclusions and future work end the paper.

2 Related Work

Nowadays, low-cost Home automation and security systems can be implemented using Android (the popular Operating System for mobile devices) and Arduino (Arduino is an open-source electronics platform based on easy-to-use hardware and software, www.arduino.cc), to control home appliances and provide security via phone or tablet [4]. However, since it may be difficult for blind users to deal with these open systems and considering that the market offers low-cost built-in solutions, such as Fibaro, relying on open languages, we selected this system in our study.

Smart Houses take advantage of the Internet to make home automation smarter and easier to use anytime, anywhere. The inclusion of health systems to assist elderly and disabled people furthers technology's progress toward the Health Smart Home (HSH) [6, 10]. As suggested more than a decade ago by Stefanov et al., "Some innovations in smart houses designed for people with disabilities (such as advanced health monitoring systems) may be transferred to non-disabled people. Wearable monitoring systems will become important tools for prolonging life expectancy" [10]. Actually, simplifying eye-free interaction with home RCS systems could benefit anyone in specific conditions (e.g., no light or temporary disability).

With this in mind, Santos et al. introduced B-Live, a Home Automation System specifically designed for disabled and elderly people, to enable a conventional home to become an HSH. The system has been tested with motor impaired users (tetraplegic, paraplegic and in wheelchairs) at their homes [9], enabling users to simply carry out operations such as turn on/off the room lights and open/close room blinds and doors. Sandweg et al. designed a telephone-based interface (TBI) in the development process of a home automation system, collecting user requirements in focus groups and applying general guidelines for TBI design. The introduction of no-speech sounds may improve the user experience [8].

An accurate review on AAL is carried out by Al-Shaqi et al. Specifically, authors analyzed the last 15 years of research, discussing the current practices for developing AAL systems and identifying future research directions, commercial, technical and social challenges [1]. Portet et al. carried out an experiment for assessing the acceptability of a smart home equipped for vocal interaction (audio processing technology) with a sample of autonomous elderly people living alone in their home. Results showed that speech technology has a great potential to ease everyday life. However, the system encourages a lazy lifestyle, provoking a rapid degradation of health. Smart home technology design must promote a healthy way of living [7].

Domingo offers an extensive view of the potential of the IoT (Internet of Things) in different scenarios, including the smart home. Home devices include sensors and actuators embedded in goods, home appliances or furniture. Smart homes for people with disabilities provide accessible interfaces to manage the home devices for automation and control and include assistive devices to improve autonomy, to counter their social isolation and monitor their health [3]. As previously stated, many studies investigate AAL systems. Several of them focus on solutions for the elderly, and those with disabilities in general. The needs of blind people have been thoroughly investigated and solutions have been designed to help them in everyday life (VizWiz Social) [2]. However, accessibility of interaction with RCS and HAS have still not been thoroughly investigated in all aspects (i.e., screen reader interaction).

3 The Study

The Fibaro system was configured to remotely control sensors and devices installed in the house of one of the authors. Some main functions have been selected in order to test the interaction via screen reader to investigate the following factors, valuable for a blind person. The user should be able to quickly and easily (1) check which devices/sensors are on/off; (2) turn the devices/sensors on/off; (3) get an overview of information about the home/room/device status. To this end, we selected some of the view modalities offered by the system: by (a) rooms, (b) devices, and (c) a single room (we selected the kitchen). Through each modality, the user should be able to obtain various data and have different opportunities to check and handle the home sensors' status. We focused on aspects to consider when simplifying interaction for a blind user. To interact with the user interfaces, the screen reader Jaws for Windows 18.0.2530 and Internet Explorer 11.00 was used. With regard to the screen reading interaction with the RCS, we specifically focused on the usability principles and not only on mere accessibility technical requirements. According to the usability and accessibility criteria proposed in [5], we selected some of them to evaluate the UI: Buttons and links labels, Page title, Page structure, Main content identification. The evaluation was conducted by the authors (one is blind) and two blind users with long experience in using the screen reader Jaws while surfing the Internet.

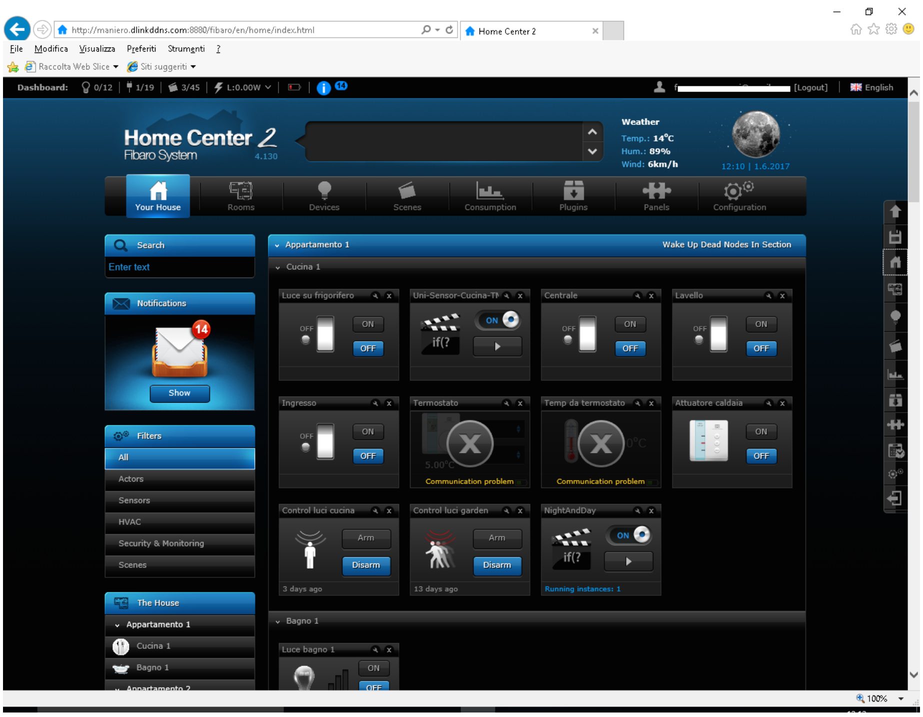

Fig. 1. Fibaro Home Page for a logged user

3.1 Case Study: The Fibaro System

Exploring the home page (Fig. 1), no particularly useful information can be accessed via screen reader. At the beginning of the page the user can obtain general information on the environment (like that reported in Table 1). Unfortunately, the information is not very clear; i.e., content like "Link Dashboard: 0/ 12 | 1/ 19 | 3/ 45 | L:0.00W | 14" results somewhat meaningless if not presented in a more user-friendly way. In addition, the screen reader user only encounters a list of rooms with no useful information associated. Therefore, the home page does not deliver helpful information. Besides, the graphical buttons in the main area of the interface are not detected as buttons but as links. Although this does not significantly affect the interaction, it is not semantically correct. Modern web pages rely on HTML and Javascript. To make images used as buttons to be perceivable via screen reader, a role should be associated using a specific ARIA tag (Accessible Rich Internet Applications) and the state of the object has to be managed programmatically [11]).

Case 1: Rooms View (Fig. 2): Table 1 shows how the screen reader Jaws interprets when one clicks on the link "rooms". The page is rich in elements. The sequential reading may take a long time. The user perceives a "long" list of the available rooms in the house. First, only a list of the rooms is available to allow the user to define a showing order to the rooms. Two links Up and Down are used for this purpose. This is not particularly useful for a blind user since when navigating via Tab key, too many Up and Down links are encountered; to know to what they refer to, the surrounding needs to be explored. Links should be more self-explanatory. Locating this function in a setting panel could make the system more usable. Moreover, on the page there is also information on the rooms. Each room is reported with some information: the name of the room followed by some numerical data. To reach each room the user needs to explore all the content sequentially. No mechanism for partitioning the content has been used (e.g., headings level, wai-aria regions, etc.). Moreover, the numerical data could be unclear for unskilled users. Analogous considerations about clarity are applicable to the similar Edit and Delete links.

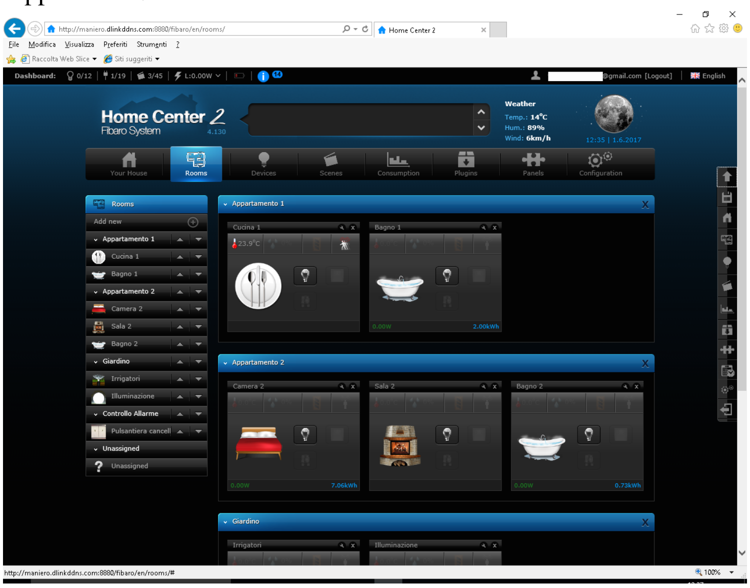

Fig. 2. Rooms View

Table 1. Rooms view read by Jaws: a fragment

Home Center 2 **Link** Up Save Your House Rooms Devices Scenes Consumption Plugins Panels Events Configuration Logout *list of 6 items* **Link** Dashboard: 0/ 12 1/ 19 3/ 45 L:0.00W 14 *list end* name.surname@gmail.com [Link Logout] English **Link** 4.130 Weather Temp.: 14ºC Hum.: 89% Wind: 6km/h 12:38 | 1.6.2017 **Link** Your House Rooms Devices Scenes Consumption Plugins Panels Config *list of 5 items* Rooms **Link** Add new *list of 4 items nesting level 1* **Link** Appartamento 1 Link down Link up *list of 2 items nesting level 2* **Link** Cucina 1 **Link** down **Link** up **Link** Bagno 1 **Link** down **Link** up ... Appartamento 1 rooms/# Cucina 1 Edit Delete 23.9ºC 0% light/light0 roleta/roleta0 alarm/alarm_grey

Case 2: Device View. In Table 2 a portion of the page "Devices" content read by Jaws is shown. The available devices per room are listed (e.g., Bathroom 1 | list of 1 item | Bathroom 1 light | down up list end). No information about its status is available. Such a functionality is useful just to know the devices available in the room, but the user cannot do anything. The two links near each device (Up and Down) enable one to set up the device order. Therefore, when interacting via screen reader a blind person cannot obtain appropriate information or perform specific actions. A list of the available devices could certainly be useful to obtain an overview, but more useful information has to be captured via screen reader.

Figure 3 shows an overview of the sensors available on the house. All devices are listed and reported without a classification. The user needs to read all of them. If there are many sensors and devices, to check and manage a specific sensor or verify home parameters like the lighting status could require a lot of effort. Probably a sub-classification according to the type of sensors or devices could improve the usability of the remote automation system via screen reader.

Table 2. Devices page read by Jaws: a fragment

Link devices/# Visibility **Link** Show visible **Link** Show hidden **Link** Show all Devices

Link Add or remove device
Link Cucina 1
list of 9 items
Link Luce su frigorifero **Link** down **Link** up
Link Centrale **Link** down **Link** up
Link Lavello **Link** down **Link** up
Link Ingresso **Link** down **Link** up
Link Termostato **Link** down **Link** up
…
Link Bagno 1
list of 1 items
Link Luce bagno 1 **Link** down **Link** up
list end

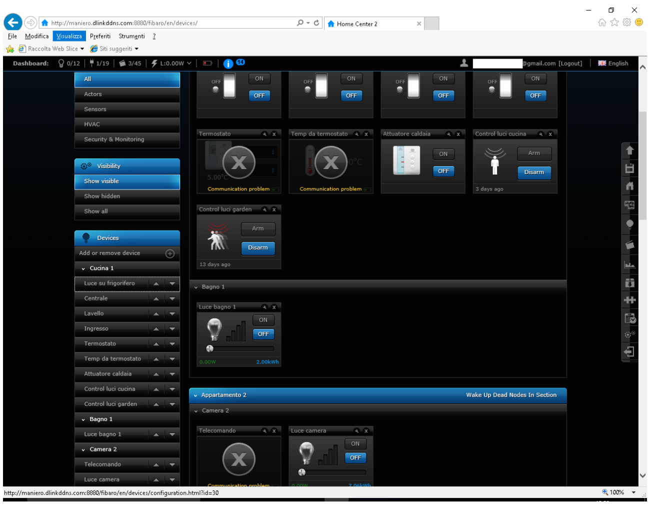

Fig. 3. Devices view

Case 3: A Single Room View. The information shown by the system when a specific room is selected is shown in Fig. 4a.

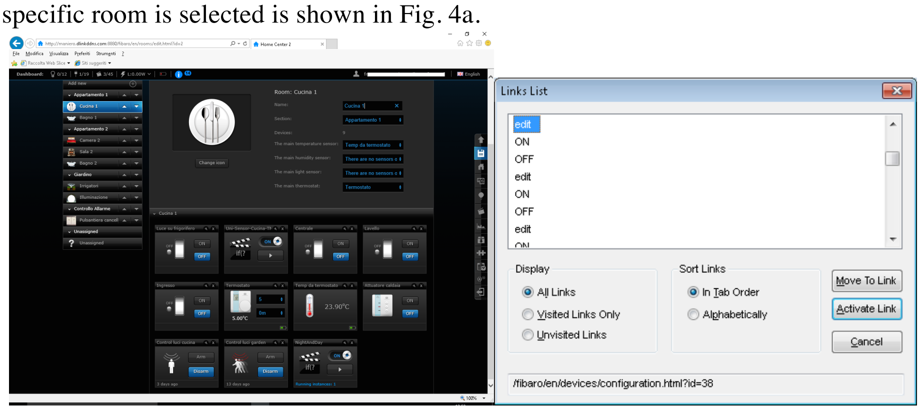

Fig. 4. a) Single room (kitchen) view **b)** List of links provided by Jaws

Even when choosing a single room, the interaction is not interesting due to too much content, no content partitioning, context-dependent links (Edit/Delete or On/Off), and unclear information. The editing of each room should be demanded in a setting panel. Moreover, although the two links On/Off associated to a lighting sensor allows the user to switch it on/off, no information on the current status (if the light is on or off) is detectable via screen reader. Often blind users navigate interactive elements via Tab key or select links by a specific screen reader command (e.g., Insert+F7), moving via arrow keys. In Fibaro web interface labels are context-dependent; the element they are refer to is not clear and thus it is necessary to explore the surroundings, increasing the interaction effort (Fig. 4.b).

Table 3. Single room (Kitchen) view read by Jaws: a fragment

Cucina 1 **Link** rooms/edit
Link Change icon
Room: Cucina 1
Name:
Edit Cucina 1
Section: *Combobox* Appartamento 1
Devices: 9
The main temperature sensor: *Combobox* Temp da termostato
The main humidity sensor: *Combobox* There are no sensors of this type in the room.
…
Cucina 1
Luce su frigorifero **Link** *edit* **Link** delete
Link ON
Link OFF
Uni-Sensor-Cucina-TM **Link** *edit* **Link** delete
Centrale **Link** *edit* **Link** delete
Link ON **Link** OFF

4 Results and Suggestions

The following usability and accessibility issues emerged from the inspection analysis:

- Logical content partitioning: no content grouping/partitioning mechanism has been applied to the interface. This implies an "excessive sequence reading" and several difficulties to identify the main content of the current page. All the content is shown sequentially with no separation tags or main content identification.
- Meaningful page title: the page title (i.e., <title> tag) delivers useful information to screen reading users about the page content. The screen reader immediately reads the page title: if it is significant, the user can quickly get an idea about the page's main content. All the Fibaro explored pages have the same title.
- Labels: several links with the same content-depending labels, like "Edit", "Delete", "On", or "Off", are used. When the user navigates via Tab key, the links are not clear at all; the user needs to explore the nearby content to understand what those links are referring to. More significant and self-explanatory labels could help the user understand the link goal without exploring the surrounding. This makes the interaction more comfortable and effective.

These drawbacks negatively affect user interaction in satisfactorily handling the main functionalities such as:

- Check which devices/sensors are on/off: no dedicated button or filter to obtain a list of only the devices "on" is available. Also from the list of all the devices, the status information is not available since it is not provided in an accessible way.
- Turn on/off the devices/sensors: there is no function allowing one to set a specific category of devices (e.g., lighting). As a consequence, the user has to list all devices and one by one click "Off" (or "On"). This can require a lot of effort.
- Get an overview of information about the home/room/device status. Information on a given element can be difficult to obtain or can be incomplete. The pages are rich in information and focalizing on the desired topic may require a lot of effort or be difficult or impossible.

For blind people, home remote automation can be a valuable way to check and manage daily activities autonomously. For this reason, the interface should not only be accessible but also, and especially, usable. How the information on the devices as well as on sensors is presented may be crucial to facilitating the blind user's interaction.

Some access keys might facilitate the interaction, for example to activate the main push buttons, to obtain the device list, etc. In general, the interface is content overloaded, requiring a lot of effort during screen reader interaction. The configuration features should be grouped in a setting panel to lighten the interface.

Summarizing, using the standard interfaces a screen reader user is unable to obtain information about the status of devices and sensors, and to easily perform any action on them. Based on the results, we can offer some suggestions to keep in mind when designing the interface and configuration panel of a home remote system:

S1. Make the UI more readable and easy to interact with, i.e., by partitioning the content into several meaningful areas (WAI-Aria attributes and roles).
S2. Create self-explanatory links and buttons (labels), so that it is clear what they refer to. Use links "Kitchen light on" (or "Kitchen light off") rather than "edit", "on", or "off" as described in Example 3.
S3. Make different views available, such as by devices and rooms. For each view modality, the status of sensors and devices, as well as all types of contextual information should be presented in a clear and accessible manner.
S4. Provide functionalities to make some actions simpler, such as a button to set the status of all devices in the same typology (e.g., turn on all the lighting).
S5. Arrange all type of settings in a specific panel so that the user knows exactly when the content, links and buttons refer to a configuration.

5 Conclusions

The Results of this study pointed out some usability issues experienced by blind people when interacting via screen reader with the user interfaces of a home remote control system. Some information is not clear at all when announced via screen reader; the UI arrangement is not particularly useful for providing the required data and simplifying interaction. However, certain functionalities offered by a HAS system could be very useful for a blind person in handling home activities (e.g., a button to set on/off lighting or open/close shutters). For overcoming observed limits and issues, some suggestions have been proposed to support developers of home automation systems to create more usable products.

Our analysis is limited to the Fibaro web interfaces; it would be extremely valuable to extend this investigation to other systems and to the interaction on mobile devices (gesture-based). Future work will further investigate the needs and expectations of blind people in order to better customize the interface to empower the user by improving their experience.

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