

# Smart Mirror - A Home Automation System Implemented Using Ambient Artificial Intelligence

Joshua Roshan Dhamanigi<sup>1</sup>, Nidhi Srinivas<sup>2</sup>, Vaibhav Sharma<sup>3</sup>, V. Suraj Reddy<sup>4</sup>

U.G. Research Scholar, Department of Computer Science and Engineering, New Horizon College of Engineering,  
Bangalore, India<sup>1,2,3,4</sup>

**ABSTRACT:** This paper presents the design and the development of an interactive, futuristic Smart Mirror with artificial intelligence for the ambient home environment as well as for commercial uses in work and public environments. The project collects real world machine data based on user requirements, and this data is displayed to the user. The entire working of the Smart Mirror system is controlled and managed by a Raspberry Pi. The Smart Mirror implemented, is a personalised digital device equipped with peripherals, namely - a microphone, speakers, an LCD monitor covered with a sheet of two-way acrylic mirror, and is powered by a Raspberry Pi. It provides basic common functionalities such as weather of the city, latest updates of news and headlines, and local time corresponding to the location. Using speech processing techniques the user, therefore, interacts with the Smart Mirror through verbal commands. A Remote Configuration Tool (RCT) is also created to help the user with the working of the Smart Mirror when the user's voice commands result in false positives and true negatives. The Smart Mirror listens to the user's commands and performs the corresponding functions.

**KEYWORDS:** Smart Mirror, Raspberry Pi, Internet of Things, Ambient Artificial Intelligence, Web Programming, Home Automation

## I. INTRODUCTION

The world and everything around us is constantly changing. With the advancement of science and technology, we are moving towards a more automated lifestyle. We have smart cities, smart homes, smartphones, smart cars, and more. This fast way of life requires further development of home automation projects. home automation systems are mainly created using Internet of Things (IoT) devices. IoT is an integrated system of communicating devices in which each device has the ability to carry out tasks autonomously. IoT is an interconnection of Wireless Sensor Network (WSN) devices.

Using IoT for home automation has many real-world applications, for example, we can build a smart home which will automatically close or open the windows based on the weather conditions outside or even turn the lights on and off in a particular room. This paper presents the implementation of a Smart Mirror using IoT with the help of a Raspberry Pi.

A mirror is an essential part of everyone's daily routine. What if they could look into the mirror and see something more than themselves? What if your mirror could let you to know that you have an important business meeting at 4 PM today? What if the mirror could tell you that it's cold outside and recommend you to wear a sweater? For this purpose, we introduce an interactive Smart Mirror.

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A Smart Mirror is capable of displaying the date, time, weather and traffic conditions on its reflecting surface. These features will be obtained from the internet and implemented using the Raspberry Pi. The Raspberry Pi runs Raspbian Jessie with PIXEL Operating System (OS). A common approach to building a Smart Mirror is to use a sheet of two-way acrylic mirror, a monitor, a frame to hold the glass and monitor, and a web browser with JavaScript to provide the software features and drive the display. A browser is used as the main method of displaying information. A browser creates a sandbox for the code that runs within it, that is, all interactions and processes are isolated from other running processes and hardware interactions on the computer. A web browser is still a necessary feature for providing and displaying information, as it has built-in support for multiple media formats, such as text, images, and videos. The information presentation can be made interactive with JavaScript and is customizable with Cascading Style Sheets (CSS).

It also incorporates a Remote Configuration Tool (RCT) that enables customisation of the mirror to a specific user preferences and thus provides ease of use. The RCT is developed using web programming to provide the customisation details for each of the feature that has been implemented. This RCT and the Smart Mirror share the same IP address to provide ease of access via a browser that can be opened on the user's laptop or smartphone that is connected to the same network.

There are many benefits of using a Smart Mirror. It makes life easier as the need to look at phones every time we need to check the date or weather, is reduced. We have all the information that we need right in front of us. The Smart Mirror can also be upgraded to display browsers and social media websites. Adding a motion sensor to the mirror will further increase the speed, ease of use, and will provide another interface for interaction. Now we can get dressed and read the news or watch YouTube videos all at the same time and from a convenient place. The Smart Mirror can also help in developing smart houses with embedded artificial intelligence, as well as finding its applications in industries.

## II. THEORY

The vision of Ambient Artificial Intelligence (AmI) has brought a new twist to the decade old research and industry initiatives in realizing Smart Environments. The AmI vision, as proposed by the European Consortium, promotes a paradigm where humans are surrounded by intelligent and natural interfaces offered by the interconnected heterogeneous computing devices embedded into everyday objects. The environment thus created is capable of recognizing and responding to the actions and presence of individuals. Therefore, AmI can be seen as the driving force toward a more user-friendly and user-empowered smart environment for providing effective support to human interactions. The AmI aware smart environments and surrounding, whether it is the home environment or the distributed environment, uses a variety of smart technologies. These technologies integrate sensing, processing, reasoning, and networking capabilities in addition to heterogeneous applications, services and digital contents [1]. With all of these rich technologies involved, AmI faces challenges on how to integrate them with the everyday objects. Often unobtrusively, in order to provide computing intelligence in the surrounding environment.

## III. RELATED WORK

The Smart Mirror is designed to perform several functionalities. It will mimic a natural mirror interface through a flat LCD monitor used for the display. A two-way acrylic mirror is used in front of the LCD monitor thereby mimicking the function of a regular mirror. For personalised information services the users will be able to obtain minute updates of latest news and public headlines, weather reports as well as get reports of their interests.

The proposed Smart Mirror represents an interactive interface that enables access to personalized information and services. This is to contribute to this design of a Smart Mirror-like interface as well as the smart environment in which the interface is used for interaction. In the following, we briefly discuss on some related research in this field.

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Philips HomeLab [2] is a test bed for creating perspective and context-aware home environments. Among several projects, their work on creating an intelligent personal care environment uses an Interactive Mirror [3] in the bathroom to provide personalized services according to the user's preferences. The mirror can provide live TV feeds, monitor the latest weather, and so on. The mirror is a combination of one or more LCD flat screen displays specifically combined with a mirrored surface and connected with a central processor to provide the intended services. In addition, we use open standards like web services to communicate with the devices and customize various personalized services for the user.

Interactive Mirror is a touch and gesture functional mirror created by Alpay Kasal and Sam Ewen of Lit Studios [4]. The user touches the mirror, which has a built in touchscreen, to interact with it. Also, this mirror is less about data and more about artsy visuals. Users in the demo video show off different types of drawing and 2D games that are displayed using a projector. The fact that it emulates a mouse is nice because of the expandability and the range of functions capable. Yet, this still differs from our Smart Mirror since this is used only as a source of entertainment but our Smart Mirror also provides solution to many problems faced by a user on a daily basis.

The HUD Mirror was designed by five students for a course at the Chalmers University of Technology in Sweden [5]. They used a two-way mirror to allow the LEDs they mounted behind to illuminate information through the mirror. This mirror was made for the bathroom and displayed time, weather, outside temperature, and a toothbrush timer by use of the LEDs. Also, instead of using a touchscreen for interaction, they used Light Dependent Resistors (LDRs) as buttons behind the mirror. When "touched", the light changes and can perform a function specified in the Arduino software. Despite being simpler, the HUD Mirror has a lot of the same ideas as the Smart Mirror.

The Magic Mirror was developed by the New York Times Research and Development Lab [6]. It uses a TV with a mirror finish and uses a Microsoft Kinect to track movement and take in voice recognition. Also, it integrated a RFID reader to identify certain bathroom products. The whole system is run from a Windows PC. The fact it can keep track of prescriptions and use the Kinect to "virtually" put clothes on the user are very inspiring features. The Magic Mirror also allows the ability to check email, calendars, and social media, which are implemented in our Smart Mirror as well.

The Smart Mirror is definitely not a true consumer product yet. There are very few truly manufactured and ready for sale Smart Mirrors in the market. Those that are there are very different in terms of functionality, development, and price. It is certainly going to take a large smart home company to get behind this product and make it mainstream to the consumer. Our Smart Mirror has combined a few features that have been stated in the above paragraphs yet it stands out as we have incorporated voice activation to access said features and their customisation through a Remote Configuration Tool (RCT) that is designed and developed through the help of web programming.

## IV. SYSTEM ARCHITECTURE AND DESIGN

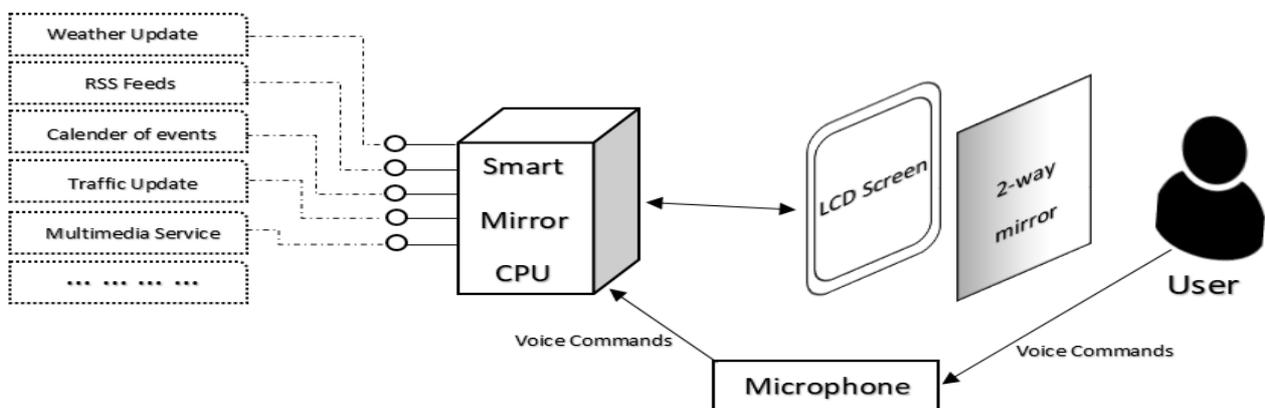


Figure 1: System Architecture of Smart Mirror

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The mirror interface is decorated with several widgets. A widget is a simple window frame that contains an embedded browser. Unlike a window, widgets do not overlap nor do they contain complex interface elements. The mirror interface contains two categories of widgets, one that enables remote device control (e.g. light on/off, and home temperature control), and the other enables access to various information services (e.g. news feeds, weather updates, etc.).

The widgets in the mirror UI instruct the Raspberry Pi of the Smart Mirror system to control a requested device or to access other personalized information services.

The Raspberry Pi is configured to always listen for a voice command and perform the task associated with it. The Smart Mirror is powered by the Raspberry Pi and the output is seen on a monitor that's connected to it, which in turn is placed behind a two-way acrylic mirror with the same dimensions as that of the monitor. This system of devices implements the Smart Mirror and can be used in home, work, or public environments.

The Smart Mirror widgets are customizable to meet the user's requirements. They have been implemented in a building block manner, thus, the user can choose the widgets they wish to have displayed and functioning on the Smart Mirror at any point in time.

Since the Smart Mirror is voice activated and controlled, there is a lot of chance for false positives and true negatives when the user gives a voice command. In order to overcome these challenges, we have developed and designed a custom Remote Configuration Tool (RCT) that the user can use to customize the settings of the widget as well as input commands through a text input interface.

The RCT is designed keeping simplicity and high functionality in mind, along with ease of use for any user of the Smart Mirror. It enables the user to customize the functionality and visibility of the Smart Mirror's widgets with ease and also to adjust the microphone sensitivity. All this is done through a web page with various options and interfaces for the user to interact with and make the changes they desire.

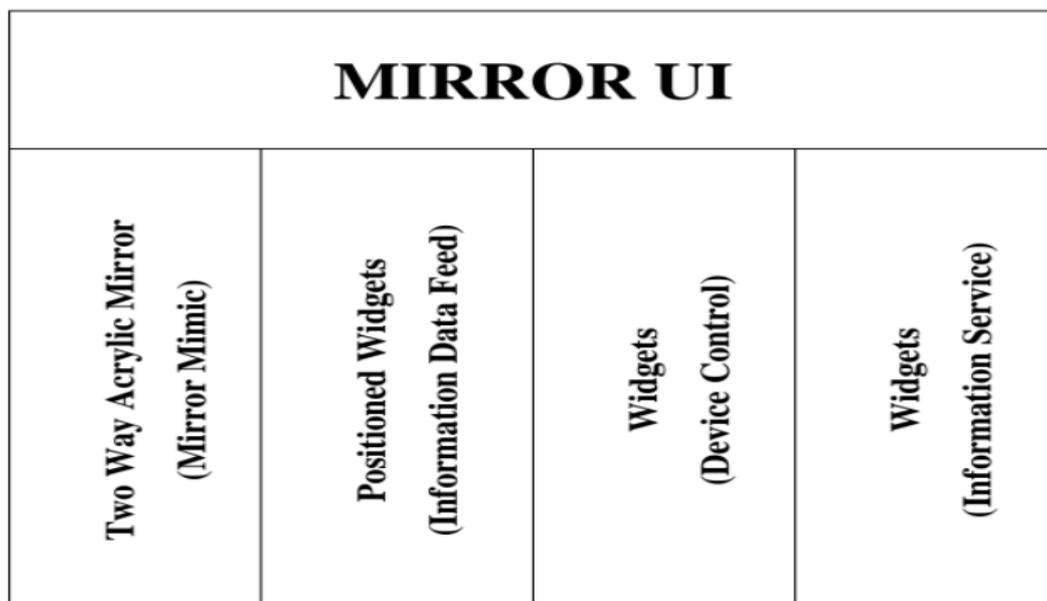


Figure 2: Mirror User Interface

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## V. METHODOLOGY

The proposed Smart Mirror has various functionalities implemented and is designed and developed using a building block architecture. This therefore prepares the Smart Mirror for future scalability as it can support extended home automation. This means that through the Smart Mirror interface, in the future, other home automation IoT devices can be controlled like ambient lighting systems, centralized air conditioning systems, and even other modular home automation systems like Google Home.

Our Smart Mirror is designed to mimic a natural mirror interface. A two-way acrylic mirror is used for the mirror display, thereby mimicking the function of a regular mirror. A flat LCD monitor is used to provide real time display of the content on the Smart Mirror which is powered by a Raspberry Pi, thereby mimicking the function of a Smart Mirror.

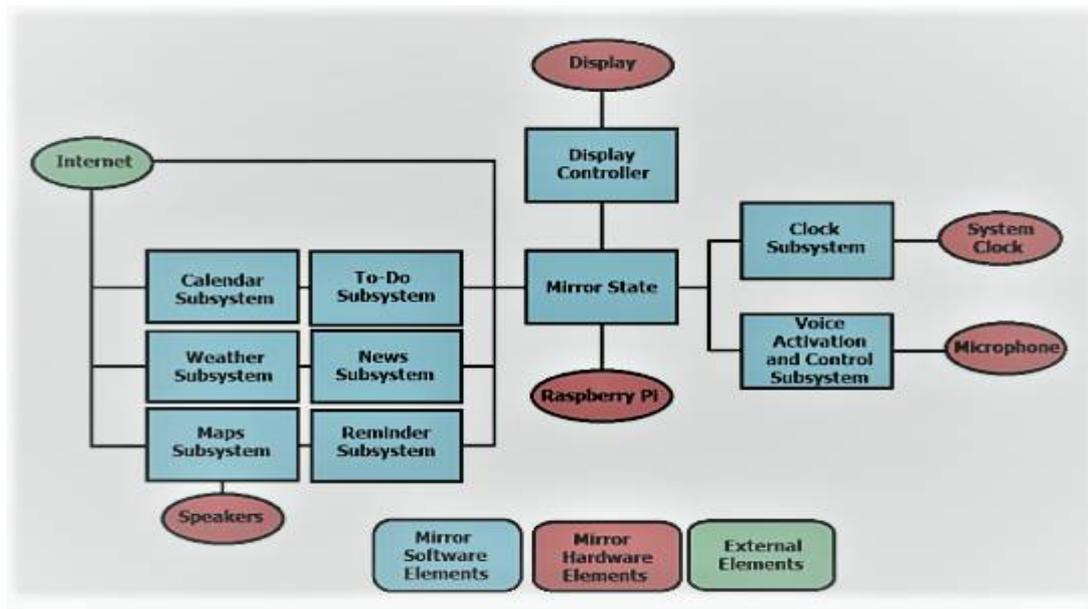


Figure 3: Data flow in the Smart Mirror

The Smart Mirror has the functionality of many modern day smartphone applications implemented on it in the form of widgets. Some of the applications incorporated into the working design of the Smart Mirror are those of Bing Maps (Along with real time display of traffic in a particular location), YouTube (Functionality to play videos along with the audio output), a Date and Time widget (Displays the current system date and time. It can also update this information by obtaining it from the internet), a Weather widget (Displays the weather information based on either automatically detected location, or manual location information fed to it in terms of Latitude and Longitude). The temperature units system (Fahrenheit or Celsius) displayed in the widget is based on the popular units system used in the location. This too can manually be changed by the user based on the user's units system of choice.

Users will be able to obtain minute updates of latest news and public headlines, with the Rich Site Summary (RSS) feed widget. Along with the aforementioned widgets and applications, the Smart Mirror also has application functionality. These functionalities are those of a Countdown Timer which counts down from a user specified time measurement, a Reminders application which displays the user's manually set reminders. There is also a To-Do List which has a list of to-do items that the user manually inputs, and a widget that displays the next-air date of a list of the user's favourite television shows.

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A Remote Configuration Tool (RCT) was also developed to help provide ease of use of the Smart Mirror to the user. The RCT is a remote web application that provides widget and application customization and visibility options to the user. This RCT is designed to be simple, easy to use, and provide all the functionality of the Smart Mirror that the user has through voice commands, through a text input interface. The RCT is a very useful tool that helps the user overcome the challenges of voice command input like false positives and true negatives.

The RCT has a variety of options for each individual application and widget that has been implemented in the Smart Mirror. The user has the ability to enable/disable any or all of the widgets of the Smart Mirror through the RCT. The RCT is an extension of the Configuration File where the aforementioned settings can be manually edited by programming them accordingly there. The user can also alter the sensitivity of the microphone through the RCT and help improve the Smart Mirror's ability to accept true positives when a voice command is given.

## VI. SIMULATION AND RESULTS

The main functional modules of the Smart Mirror were simulated and tested upon, prior to completion of the entire Smart Mirror system. Each aspect constituted a test case for simulation of the Smart Mirror. The test cases were documented in a systematic manner and each test case contained the following fields of information - A serial number, the name of the functional module to be simulated upon, the description of the simulation, the input data and conditions for the module to be simulated upon, the output of the simulations on the module based on the input data and conditions, and a results section which indicated whether the particular simulation was successful, partially successful, or unsuccessful on the module in consideration.

The input data given to the modules for simulation and testing consists of module-specific data and conditions. The input had to be relevant to the module being simulated and tested, in order for an accurate result to be obtained. The test cases were used as a means to check the correctness of the development process of the Smart Mirror system and to verify and validate that each functional module of the Smart Mirror system performs its required task independently as well as all together as one combined functional unit. The following table represents the simulation process on the different main functional modules of the Smart Mirror system as well as the results obtained from each simulation case.

Serial Number	Module to be Simulated	Description	Input	Output	Results
1	USB Microphone and Audio Output Jack on the Raspberry Pi	Advanced Linux Sound Architecture (ALSA) needs to be configured and explicitly notified about the input and output devices for sound. This is because manipulating sound input/output in Linux systems is complex. Hence, Raspbian (Operating system used) needs to be explicitly informed about the audio input and output devices (USB Microphone and Audio Output Jack on the Raspberry Pi).	Using commands in the terminal, the hardware information of the devices are determined and used to alter the operating system files and configure ALSA.	The hardware device information was detected, the files modified correctly, and the devices were recognized and usable as required. When the hotword "Smart Mirror" was given while testing the USB Microphone in the terminal, it was detected correctly.	The simulation was successful.
2	Node Package Manager (NPM) Database Connection	When the Smart Mirror program is executed, it tries to connect to NPM Database (SQL server) using the data source and catalogue. If the connection details are correct, the Database is connected, else an error is displayed. Successful connection results in execution of the Smart Mirror application.	The command "npm start" is used to initialize the Smart Mirror application.	The connection was established and the Smart Mirror application executed and run successfully.	The simulation was successful.
3	Speech to Text and Hotword Detection	When the user inputs a voice command, it must be recognised and interpreted. A voice training method is adopted to enable the mirror to get activated when the attached microphone picks up on a voice command. Sonus, Sound Exchange (SoX) Libraries, Snowboy, and Google Speech API are used to detect voice commands and convert speech to text.	User's voice is input for interpretation.	Sonus uses SoX Libraries to convert raw audio input into 16-bit binary files that are sent to the Google Speech API for conversion to text. Snowboy is responsible for the Smart Mirror to always listen for an output as well as for detection of the hotword. Once the hotword is detected, the bottom of the Smart Mirror screen lights up, indicating that the user can subsequently input a voice command. If the voice can be decoded, the speech is appropriately converted to its respective text format and displayed and its associated command is executed.	The simulation was successful.
4	Module and System Functionality	The functionality of individual modules as well as the combined functionality of all the modules implemented into the system are simulated and tested.	User gives voice commands to activate the functionality of the various modules implemented in the Smart Mirror system.	The individual modules like Maps, YouTube videos, Countdown Timer, and others that have been implemented, display the appropriate outputs to the user based on the input commands. The entire system works correctly as one cohesive unit.	The simulation was successful.

Table 3: Simulation and Results

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## VII. RESULT

The Smart Mirror system we have developed combines the concepts and methodologies that have been implemented in other systems like smartphones. It is a novel method of creating a smart interactive system that is reliable and easy to use. We have concentrated on an interactive and user friendly home appliance that is beneficial to the user. The architecture has been adapted for the development and deployment of various services which all use web service communication mechanisms. These services of the Smart Mirror can be further extended to support future enhancements and developments. This means that features such as extended home automation (control ambient lighting systems, centralized air conditioning systems, and other modular home automation systems/devices like Google Home) and additional applications and widgets can be implemented.

A user's personalized data such as calendar, news feeds, and other information relevant to their lifestyle have been implemented and displayed. The Smart Mirror uses voice commands to switch between each view, and performs the functions corresponding to the input voice command. Rather than become confined to a home, we can implement the functionality of our Smart Mirror system to commercial work, and public environments.

Each widget and application has been developed using a building block approach, keeping the aspects of future enhancement and scalability in mind. The main advantage of using this building block approach is that any new application or widget can be implemented and put to functional working by developing them as plugins and using them as required to meet the environment and user's needs.

The Smart Mirror we have developed takes an average of 15 seconds to begin execution once the command to initiate its process has been input into the Terminal window in the Raspberry Pi. On initiation, when the Raspberry Pi is connected to the internet, a unique IP address with the port "8080" suffixed to it, is generated. This IP address is displayed in the terminal window and can also be viewed in the Smart Mirror process by saying the command "Show Remote Link". The IP address is used to connect the user's laptops, smartphones, or any other device capable of connecting to the internet, remotely to the Smart Mirror. That is, the Remote Configuration Tool (RCT) is initiated whenever a device uses the generated IP address to connect to the Smart Mirror. As a prerequisite, the device running the RCT needs to be connected to the same network connection as that to which the Raspberry Pi of the Smart Mirror is connected.

When the Smart Mirror is running, voice commands can be masked by background noise that is present in the environment in which the Smart Mirror is placed. This therefore can result in false positives and true negatives of voice command input to the Smart Mirror. In order to overcome this, the user can either manually alter the Configuration File or use the RCT to alter the sensitivity of the microphone.

The voice command to activate the Smart Mirror is user defined and was set to "Smart Mirror" in our implementation. Once this command has been given, the Smart Mirror actively listens for the user's command, and once the subsequent voice command is input, the Smart Mirror performs the function associated with it.

## VIII. CONCLUSION

We have designed a futuristic smart mirror that provides natural interaction between users and the ambient home services. The core of the mirror is based on a home automation system, which we developed to demonstrate the various functionalities provided by the mirror. These functionalities include the control of household appliances and access to personalized information services. The mirror display is provided by a flat monitor, which listens continuously from a web camera connected to the mirror to mimic a traditional mirror function. In addition voice activation technology has been used to authenticate a user to provide personalized service access. We have developed a functional prototype to demonstrate our work. Overall, the prototype provides an easily extendable framework that can

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be utilized to provide even more functionality to the user. In our future work we will investigate how the surrounding context of the user and the environment can be utilized in order to provide optimal service experiences in the home environment.

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