Intermediate Report

My Assistant Pal - Smart Home Device Using 3D Printing

COMP4801 Final Year Project
Department of Computer Science
The University of Hong Kong

Project by
Arun Kaza (3035435618)

Supervisor
Prof Chuan Wu,
Department of Computer Science,
The University of Hong Kong

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Abstract

In recent years, there have been considerable advances in the fields of 3D printing and IoT in terms of technology, cost, and speed. Taking inspiration from the potential offered by them in various sectors including manufacturing and healthcare, this project aims to build a smart home gadget with 3D printing.

The smart home device will have a speaker with a pan/tilt turret on top which will be used to hold a smartphone. Its functions will be controlled using an Arduino board which will receive instructions from a mobile app through Bluetooth. The device will be able to take voice commands, play music, and perform various other functions.

For this project, Android Studio will be used to develop a mobile app for Android devices and CAD software will be used to design models for 3D printing.

Acknowledgement

I would like to extend my gratitude to Prof. Wu for support and guidance as my supervisor. I also wish to thank Mr David Lee from MakerLab for helping me acquire the necessary knowledge and skills for this project.
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Abbreviations

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<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>CAD</td>
<td>Computer-Aided Design</td>
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<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
</tr>
<tr>
<td>UI</td>
<td>User Interface</td>
</tr>
<tr>
<td>OS</td>
<td>Operating System</td>
</tr>
<tr>
<td>SDK</td>
<td>Software Development Kit</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>UX</td>
<td>User eXperience</td>
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<td>RTSP</td>
<td>Real-Time Streaming Protocol</td>
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1. Introduction

This report serves as an overview of the project for the development of a smart home device using 3D printing. It will first introduce some background information on 3D printing and smart home devices and how their progression over the years has inspired this project. It will then set a scope for the project along with the components and functions of the deliverables. Finally, it will give the reader an outline for the rest of the report.

1.1 Background

1.1.1 3D Printing

3D printing is the construction of physical objects from 3D models. Also known as additive manufacturing, it has many advantages including producing lesser waste and providing more freedom in design \[1\]. While the technology was developed in 1986, Ngo, et al. \[1\] note that its adoption was slow, despite its benefits, due to its high cost and patents. But this has changed with newer machines being developed in the last decade which have given rise to many commercial applications of 3D printing.

The process involves making a 3D model using CAD software, after which suitable materials are chosen to print the model. With 3D printing, it is possible to create highly customised objects or parts quickly. This is why rapid prototyping, a term referring to creating prototypes using 3D printing, is an increasingly popular method for prototyping while the expensive and time-consuming traditional methods are being abandoned. Some manufacturing sectors have moved to additive manufacturing entirely. Many companies especially those in aircraft and related industries and healthcare equipment manufacturers are using 3D printed components in their products. In the US, hearing aids manufacturers moved to 3D printing completely by 2015 \[2\]. While it cannot yet compete with large-scale manufacturing in terms of costs, 3D printing can offer flexibility and countless customisation options.

1.1.2 IoT and Smart Home Devices

IoT or Internet of Things is a term describing a network of gadgets, connected to the Internet, which communicate with each other \[3\]. These can include everyday items such as a refrigerator or a light bulb to state-of-the-art components in an aircraft’s engine. A smart home gadget is one such IoT device capable of accepting voice commands, accessing the Internet, and communicating with other smart devices in a household. There are many such
popular smart speakers available commercially such as Google Home and Amazon Echo (see Figure 1). These speakers have been experiencing rising sales, with 409.4 million units expected to be shipped in 2025 [4]. Santoso and Vun [5] believe such smart home devices have great potential with Wi-Fi capabilities and smartphone access in many modern homes.

![Smart speaker unit shipments from 2014 to 2025* (in millions)](image)

Figure 1: Increasing sales of smart speakers worldwide [4]

1.2 Motivation

This project aims to demonstrate the advancement in these fields by making a smart home gadget using 3D printing. There is a huge potential for the application of IoT and 3D printing in many fields. Ota et al. [6] demonstrated this by creating a 3D printed smart glove with interconnected sensors and components. The glove included a temperature sensor and a built-in heater. This can be worn by patients with injuries on which the glove can apply heat to increase blood flow and reduce pain. This glove can be created to fit each patient’s hand dimensions with all its components including sensors and actuators being 3D printed. While
outside this project’s scope, the glove serves as an inspiration for the development of embedded systems using 3D printing.

1.3 Scope and Deliverables

Through the course of this project, the device consisting of a pan/tilt turret, an outer shell and a speaker system will be created using 3D printing. A smartphone will be held in place by the turret. Apart from this, a mobile app will be made to control the functions of the gadget. The app will be able to change the orientation and positions of the turret to rotate the smartphone attached to it. It will also be possible to play music, set alarms and take hands-free calls on the device with the help of a voice assistant. The smartphone attached to the turret can also be used as a surveillance camera using its rear and front lenses. This footage would be streamed to the app.

While the pan/tilt turret component of the device is already printed, it has trouble with overshooting when turning and needs to be programmed to return to the home position when turned on.

1.4 Outline

Next, this report will examine the methodology in section 2 that will be used to develop these deliverables and then in section 3, explore the schedule for the project along with its current status and challenges expected. Finally, in section 4, it will conclude the project with the discussion of the immediate next steps.

2. Methodologies

The section on methodologies is divided into two parts for each deliverable: the mobile app, and the smart home device. It will examine the various tools and software that will be used to develop them.

2.1 Mobile App

The app will be written primarily in the Java programming language for Android devices. A major reason for choosing Android is that it is the most popular operating system for smartphones with an 85% market share [7]. It also offers more flexibility in terms of the features that can be accommodated in an app. This flexibility would be
required to implement, for instance, the streaming of surveillance video feature as mentioned in 1.3.

Android Studio, the official IDE for Android, will be used to develop the app. Using Android Studio has many advantages. It has pre-built UI elements which follow the material design style of the OS. App maintenance is also quick and easy as Gradle scripts get regular updates and re-building the app is all it takes to adapt it for a new version of Android. The IDE also has an in-built Android emulator to test the app during development.

Choosing the right minimum SDK version for the app is an important step before beginning development. While newer API versions are more feature-rich, they may not support as many devices as older versions. To meet a balance between better features and compatibility, the minimum SDK version has been set at API 21 (Lollipop 5.0), making the app compatible with 94.1% of Android devices.

The app will communicate with the smart home device using Bluetooth. As mentioned in 1.2, it will have many features that will improve the user experience with the smart home device. When opening the app, there will be a prompt to connect to Bluetooth and pair with the device. The app will revert to this prompt if the connection to the device is lost at any point. Once this requirement has been met, the Home screen of the app will be displayed with arrow buttons which can be used to control the movement of the pan/tilt turret. To easily move between features, there will be a bottom navigation bar with icons that represent each of them. These include the voice assistant, the surveillance video stream with controls and a section with other miscellaneous options. Each of these sections will be built as fragments and connected using the NavHostFragment container. A flowchart visualisation of this design is presented in Figure 2.
Figure 2: The app’s UX flowchart

The surveillance stream from the smartphone on the device will be streamed to the app using the RTSP protocol. This would allow the phone to send the video stream to the app while also enabling the app to communicate commands in the opposite direction, making it possible, for instance, to switch between the rear and front camera (similar to Figure 3). A web server is necessary to facilitate this function as the user needs to be able to view the footage remotely.
Figure 3: Communication with RTSP protocol

2.2 Smart Home Gadget

The smart home gadget will be operated by an Arduino board, programmed to receive instructions from the mobile app via Bluetooth. As they are low power and inexpensive microcontrollers, Arduino boards are ideal for embedded devices. The problem with the turret, mentioned in 1.3, will be solved with the installation of end-stop switches by determining its initial position using the readings of the switches.

The 3D models for the outer shell and speaker will be designed using CAD modelling software like SketchUp (see Figure 4), while 3D printing will be done using the facilities at MakerLab.

3. Project Status

This section will first give a detailed overview of the expected timeline of this project. It will then examine the current progress and preliminary results, and finally, explore the challenges faced so far and what has been done to overcome them.

3.1 Proposed Schedule

Stage 1 (October to December): Android App Development

This stage will begin by conducting required research on Android app development, Android Studio and UI designs. Then the work on the app will begin and feature from 1.3 will be incorporated. The app will be tested using Android Virtual Device (AVD).

Stage 2 (January to February): Design and 3D Printing of the Shell and Speaker System

Firstly, the 3D models of the required components will be designed using CAD software. These will then be printed using the printers at MakerLab and be tested. Then, end-stop switches will be added to the turret to fix the problem of overshooting mentioned in 1.3. Finally, all the parts of the device will be assembled to complete the hardware build.

Stage 3 (March to April): Final Implementation
In the final month of the project, thorough testing of the app and the device will be done to fix any bugs.

3.2 Preliminary Results

The UI of the app has been worked on using Android Studio’s in-built editor. Research has been conducted over techniques and good practices in designing UI.

![Figure 4: Screenshots of the app](image)

Many features have been implemented in the app. These will be navigated using a bottom toolbar. The turret rotation and movement control will be done using arrow buttons like in Figure 4 (left). There will also be a button to reset the position of the turret to its home position. A speech recorder widget is placed in the second section for the voice assistant function. In the third section, the video streaming widget is being
worked on. App development is expected to be completed soon after testing with the Arduino.

3.3 Difficulties Faced

Due to the COVID-19 pandemic, restrictions on travel have prevented me from travelling to Hong Kong. While working remotely is a challenge itself, the designing and printing of 3D models require access to the facilities at MakerLab in HKU. This has meant postponing all work on 3D printing to January (Stage 2; refer to 3.1). The major disadvantage of this is not being able to test the app during development, with the Arduino. However, until then I have attempted to test the app on my own using the emulator on Android Studio.

4. Conclusion

This report has presented an overview of the project to build a smart home device using 3D printing. It has explored some background information related to the technologies involved and the deliverables expected at the end: the mobile app, and the smart home device. The methodologies involved in the project have been discussed in detail. The app will be developed for Android devices using the OS’s official IDE: Android Studio. It will consist of a bottom navigation bar that will allow for easy movement between its features. The parts for the smart home device, powered by an Arduino board, will be mostly constructed using 3D printing. The timeline of the project has been examined with a summary of the current progress and findings. The challenges faced so far like not being able to access MakerLab have been reviewed and solutions were considered. The app is expected to be finished soon, after which, work on the smart home device will begin.

References


