The Disconnected Universal Controller

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Fig. 1. Image of the Prototype and Fig. 2. Render of Controller

Abstract:

This paper presents a "Disconnected Universal Controller" which can be used to adjust smart home devices using ArUco markers. A prototype, which allows adjustment of the brightness of a lamp and temperature of a thermostat, was built to demonstrate this capability. Whilst no user testing was conducted, initial explorations appear promising and recommendations for future work are made.

Additional Key Words and Phrases: IoT, Smart Home, ArUco Markers

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1 INTRODUCTION

Homes are becoming evermore connected as technology in the smart home IoT sector improves. For most devices at home, there is now a 'smart' version on the market, which is meant to make the life of users easier, by allowing them to communicate with each other and also making their control easier for the user. In many cases, these 'smart' devices can be controlled from a central app on a phone such as the Apple 'Home app' [1]. Having such a central control panel can be very convenient for users as they don't need many different remote controls anymore, and they can easily adjust settings for the different 'smart' devices from a distance. This can bring many benefits; however, experts also see a

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range of drawbacks of a 'smart' home where everything is connected. In an article by Rainie and Andersen [2017][5], Christopher Owens, an adjunct professor, is quoted as saying "Being connected is less and less of a choice so even if someone wanted to disconnect, they would not realistically be able to."

An increase in smartphone use has been giving more attention to the unintended consequences of excessive use [3]. Being constantly connected means users are always receiving notifications either from their work or social media platforms. Therefore, disconnecting from the online environment can have a range of benefits. A study by Lee and Katz [2014][4] showed that after participants disconnected from mobile communication, they had an entertaining and satisfactory experience which even aided social aspects.

To not lose the benefits a 'smart' home system brings with it, in particular, having the ability to remotely adjust different functions from a distance, in this paper, the 'Disconnected Universal Controller' is presented and discussed. The goal of this controller is for the user to retain the functionality of remote controlling functions of the 'smart' home, whilst allowing them to disconnect from the digital world. By using ArUco markers, the controller can adjust the settings of the 'smart' devices without having to contain any technology. Using the abilities of the ArUco markers the user could adjust different settings simply by pointing the controller at the device and twisting it, making it possible to also retain the ability to control different devices with one controller, just as the Apple 'Home app' does.

Such an interface would come in at a relatively low cost as the only technology needed is the processing unit and a few cameras since the actual controller would not contain any electronics. Whilst cameras could lead to certain privacy issues, as discussed in the related works, there will be options in the future to safeguard data on private networks which are not connected to the internet.

For this project, a prototype was built visualising the possibility of one controller adjusting the settings of two different 'smart' devices. The brightness of a lamp and the temperature of a thermostat. In the following sections, first some related works are discussed, then the setup of the prototype is explained and lastly, the concept is evaluated.

2 RELATED WORKS

Smart home devices usually only work when online and connected to the internet. Therefore, installing cameras in the home whilst knowing they are connected to the internet and could potentially be hacked is an uninviting thought for many. A model proposed by Thalhammer et al. [2023][7], explains the possibility of having different stages of connectivity for smart home devices. The universal controller presented in this paper could work with Stage 3 (Network Mode), where the cameras detecting the ArUco markers would be connected to the private network of the user which would then communicate with the other smart devices in the home.

A project called the Intelligent Room, proposed the use of gesture recognition with cameras in homes to control a variety of devices, for example, the television [2]. Using gesture recognition instead of ArUco markers brings benefits such as not having a "remote control"; however, it also means that users are constantly being tracked and more confidential data about their current position and activities are being collected instead of just information regarding the ArUco markers.

Other projects have also proposed using everyday objects which are familiar to users to control different interfaces. For example, Suzuki et al., [2020][6] propose to use cushions as interfaces, since they blend easily into the lives of the users. However, there are two downsides to this. Firstly, using ArUco markers is much more economical as less technology is needed to realise the interface control. Secondly, the interaction with the disconnected universal controller is much more direct and universal as the user simply has to point at the device to be controller and turn it.

3 DESIGN AND IMPLEMENTATION

3.1 Design

The Disconnected Universal Controller is a concept where a handheld device containing an ArUco marker on the bottom can be used to interact with different devices in the 'Smart' home. To demonstrate the functionality of such a controller, a prototype was built which shows an interaction between the controller and a 'smart' lightbulb such as a Phillips Hue and a 'smart' thermostat. The controller would simply have to be pointed at the devices and by twisting it, a change would be achieved. In the case of the lightbulb, the controller would adjust the brightness, and for the thermostat, the controller would adjust the desired temperature in the home.

The controller, which can also be seen in Figure 2 has a set of distinct features which is meant to make the user experience and usability better. Firstly, the controller was designed to resemble a doorknob as it was assumed that due to developed mental models, users would associate a doorknob with a twisting motion. Secondly, by having a flat bottom (where the ArUco marker is located) and a spherical top, users should be more likely to set it down on the flat part which would prevent accidental detection of the ArUco markers when not in use. Lastly, there is an indentation in the spherical part of the controller which is meant to give the user a better indication of where the 'midpoint' of the settings is. This way they can easily feel which way the controller is twisted and twist it into the desired position.

3.2 Technical Implementation

As this project had a relatively short timeframe, the demonstration was not realised with the actual 'smart' devices connected to a home network. Instead, an Arduino was used to visualize how the adjustments made with the controller would affect the 'smart' devices. The prototype consisted of a computer running the ArUco marker detection, an external 1080p camera, and an Arduino.

On the computer, a Python script detects the ArUco markers whilst at the same time creating a server that provides information regarding the ID of the ArUco markers, their position on the X, Y and Z axes and the rotation of the markers around these axes. This data can be accessed using a processing sketch provided by Liang Rong-Hao. For this project this processing code was left mostly as it is, however, some changes were made which allowed the marker information to be sent to an Arduino using the COM ports.

The Arduino was used to make the demonstration come to life. To imitate the lamp, an LED strip was connected, and to imitate the thermostat, an LCD and a stepper motor were used. From the available data about the markers only the ID, the position of the markers on the X-axis, and the rotation of the markers around the Z-axis were needed. The Z rotation values of the marker ranged from -3.2 – 3.2 and were mapped to either the brightness of the LED strip or the 'desired temperature' in the home. This desired temperature was displayed on the LCD display, and depending on whether it was increased or decreased, the stepper motor reacted accordingly by rotating either to the right or the left.

As can be seen in Figure 1 the prototype was set up so that the lamp and thermostat are placed next to each other along a wall with the external camera in between them. The position of the marker on the X-axis was required as this value would determine whether the brightness or the temperature would be adjusted. When standing in front of the lamp and thermostat, pointing at either one of them would result in the marker on the controller being either to the right or the left of the camera. Hence, the X-axis values would either be above or below 0, which could be used as a threshold to either adjust the one or the other. The Arduino code used in this project can be found on GitHub https://github.com/LucasLichtPradillo/DUIET.

4 RESULTS AND DISCUSSION

The use of ArUco markers to make adjustments to the settings of smart devices in the home environment appears to work quite well. The brightness and temperature levels are easily adjustable and since in this setup, there is visual feedback about the changes that are being made, it appears user-friendly as there is immediate feedback to the user. However, there are different considerations that need to be made before generalizing these results. Most importantly, there was no user testing conducted in this project due to time constraints which is why all described results are subjective.

Looking at the different considerations, firstly as mentioned, the visual feedback was helpful to understand what changes were made as there was no inherent feedback in the controller itself, despite the small indentation. Therefore, if there was no visual feedback, or this feedback was visually obstructed, it could be quite hard for users to understand what exact changes were made.

Secondly, selecting the devices to adjust simply by pointing at them seems to be a very easy and intuitive process. As described above the prototype does not yet determine whether the ArUco marker is pointing at the devices but uses the X-axis values to select which settings to adjust. Whilst realizing the prototype, it was attempted to use the Y-axis as a way to identify which direction the markers were pointing in, however, this led to interference. To further explore this concept, it will be necessary to find a way to determine accurately which direction the ArUco markers are pointing in.

Thirdly, this prototype focused solely on showcasing the functionality of a universal disconnected controller. Hence, the camera was visible on the prototype and there were no privacy concerns as it was not filming anyone in a private setting. However, one must consider that such a system would be used in a home environment where privacy is more important. This could impact the willingness of users to install such a system if data safety cannot be ensured, or if the cameras seem intrusive.

Lastly, different devices might not have as easily adjustable settings as brightness and temperature and hence cannot simply be adjusted with a twisting motion. Potentially more complex gestures are required which could make the whole controller more complex and therefore less desirable.

5 CONCLUSION

This project explored the concept of a "disconnected universal controller" which could be used in a smart home to adjust the settings of different smart devices using ArUco markers allowing users to disconnect from the digital world. Overall, from this exploration, it appears that such a controller could indeed be used to allow users to disconnect from the digital world. This prototype proves that adjusting 'smart' device settings with this controller is intuitive and easy to use and therefore this could be a desirable addition to the smart home of many in the future.

6 FUTURE WORK

As mentioned above, other gestures besides twisting should be investigated with such a controller as this could open up the possibilities of interactions with other devices. A gesture elicitation study could be conducted to explore in more detail what exact gestures are associated with different actions and devices. Furthermore, to evaluate this concept user testing should be conducted which could reveal insights into the usability of such a controller. This should be followed with a full technical realization after which a in-context user study could be conducted.

REFERENCES

[1] Apple. n.d.. Home app. https://www.apple.com/home-app/

[2] Kota Irie, Naohiro Wakamura, and Kazunori Umeda. 2004. Construction of an intelligent room based on gesture recognition: operation of electric appliances with hand gestures. In *2004 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)(IEEE Cat. No. 04CH37566)*, Vol. 1. IEEE, 193–198.

[3] S. LaMotte. 2017, December 1. Smartphone addiction could be changing your brain. CNN. https://edition.cnn.com/2017/11/30/health/smartphone-addiction-study/index.html

[4] Sun Kyong Lee and James E Katz. 2014. Disconnect: A case study of short-term voluntary mobile phone non-use. *First Monday* (2014).

[5] Anderson J. Rainie, L. 2022, September 15. Unplugging isn't easy now, and by 2026 it will be even tougher. Pew Research Center: Internet, Science Tech. https://www.pewresearch.org/internet/2017/06/06/theme-2-unplugging-isnt-easy-now-and-by-2026-it-will-be-even-tougher/

[6] Yuri Suzuki, Kaho Kato, Naomi Furui, Daisuke Sakamoto, and Yuta Sugiura. 2020. Cushion interface for smart home control. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 467–472.

[7] Philipp Thalhammer, David Müller, Alexander Schmidt, Michael Huber, Albrecht Schmidt, and Sebastian Feger. 2023. ConnectivityControl: A Model Ecosystem for Advanced Smart Home Privacy. In *Proceedings of the 22nd International Conference on Mobile and Ubiquitous Multimedia*. 550–552.

7 APPENDIX

7.1 Appendix 1: Circuitry of the Prototype

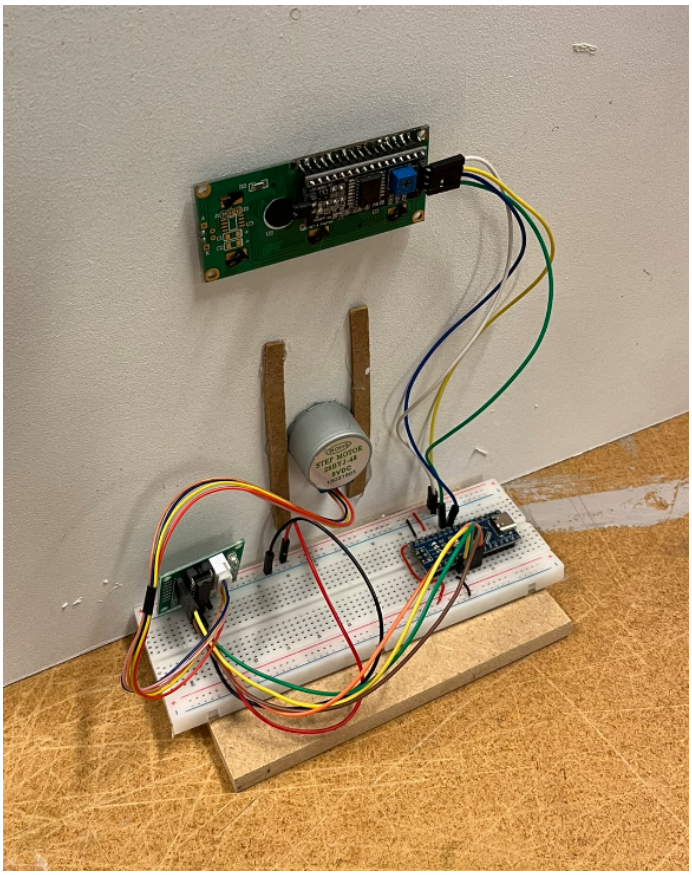

Fig. 2. Image of the circuitry. (The lamp is not connected but would simply be attached to pin 9)

7.2 Appendix 2: 3D Printed Controller

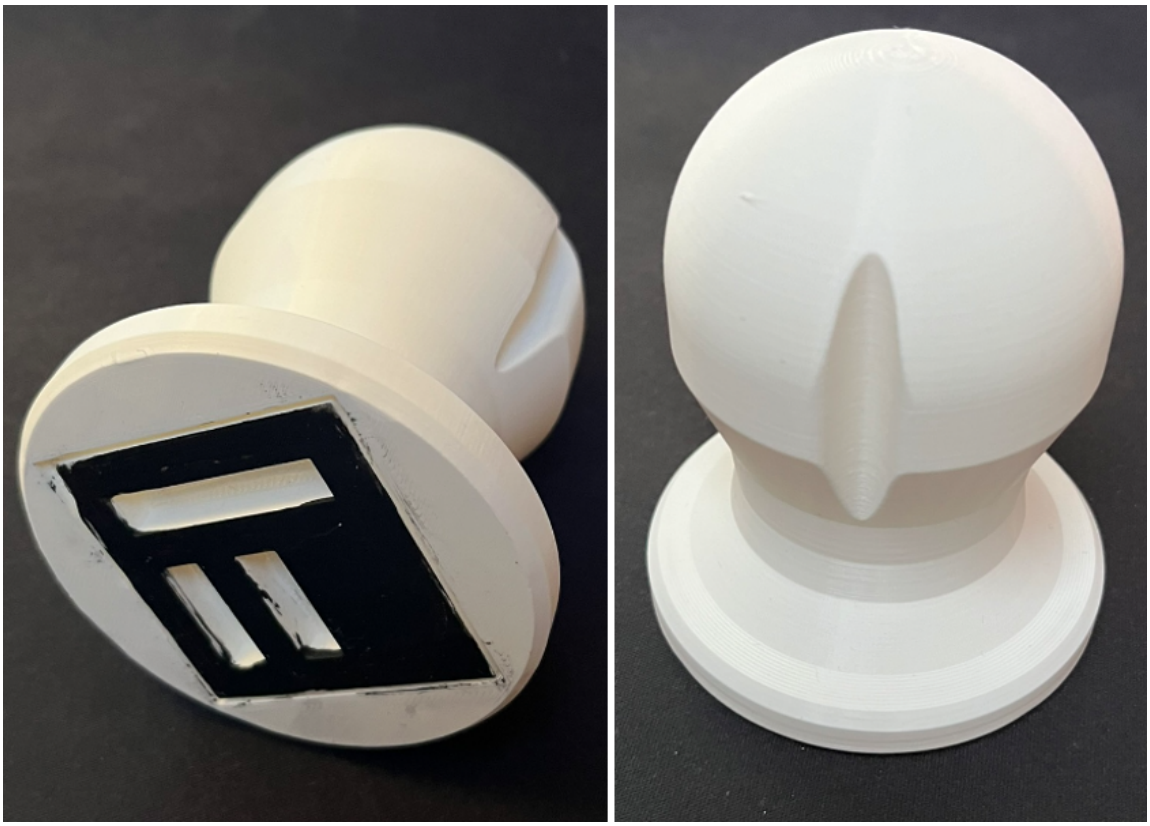

Fig. 3. Image of the 3D printed controller with the CV marker on the bottom