Doorstep: A doorbell security system for the prevention of doorstep crime

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***Abstract*— Safety and security rank highly in the priorities of older people on both an individual and policy level. Older people are commonly targeted as victims of doorstep crime, as they can be perceived as being vulnerable. As a result, this can have a major effect on the victim's health and wellbeing. There have been numerous prevention strategies implemented in an attempt to combat and reduce the number of doorstep crimes. There is, however, little information available detailing the effectiveness of these strategies and how they impact on the fear of crime, particularly with repeat victims. There is therefore clear merit in the creation and piloting of a technology based solution to combat doorstep crime. This paper presents a developed solution to provide increased security for older people within their home.**

I. Introduction

The ideology of "successful" or "active ageing" has been presented as a potential panacea for the challenges faced due to population ageing [1]. Active ageing, as defined by the World Health Organization's Policy Framework [2], is "the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age. It allows people to realize their potential for wellbeing, throughout their lives and to participate in society according to their needs, desires and capabilities, whilst providing them with adequate protection, security and care when they need assistance" [2]. Within the active ageing policy framework health, participation and security are considered to be the three main pillars to sustaining the needs of the ageing society [2]. Security concerns activities designed to ensure the protection, dignity and care (for example: meeting and respecting the physical, social and financial needs and rights) of those older people unable to guarantee themselves. This covers areas such as, social integrity, social justice, elder abuse, shelter, crises and consumer practices. Consumer protection within the framework is defined as the need to "protect consumers from unsafe medications and treatments, and unscrupulous marketing practices, particularly in older age" [2]. It is not surprising that the framework gives specific mention to the need for consumer protection for older people given the increase in vulnerability which has been associated with older age. Doorstep crime has been highlighted as a priority within the Consumer Protection Partnership (CPP) Priorities Report 2013-2014 as an area which is currently or has the potential to cause, the greatest detriment to consumers and would most benefit from a co-ordinated CPP response. A recent review [3] has indicated an attrition of studies addressing doorstep crime since 2006 [3]. This paper considers the nature and prevalence of doorstep crime, in addition to prevention strategies and proposes a novel technology based solution to aid in prevention of doorstep crime.

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II. Background

The term doorstep crime covers a number of offences including, distraction burglary, rouge traders, pressure sales and scams. It includes cases where the offender first enters the premises and subsequently uses distraction burglary methods in order to remain on the premises and/or gain access to other parts of the premises in order to commit burglary [4]. Several intelligent doorbell systems already exist on the market, that have a varying range of features and available functions. All of these solutions make use of a smartphone app to interact with and receive notifications from the doorbell.

The current market leader is Ring [5] which has features such as motion detection, mobile access, an HD wide-angle camera and night vision. Nevertheless, to the best of the authors knowledge, this solution lacks the ability to do face detection or recognition, which would determine if the movement was caused by a person or just an animal, for example. The Ring doorbell is targeted at the general home owner to simply replace their standard doorbell, with something more intelligent to allow them to receive doorbell alerts when they are not at home.

Skybell [6] is another product available that is very similar to Ring. I-BELL [7] is again, targeted at the general home owner, however, they specifically mention that it can be used for older or disabled people. This is facilitated by the family members or carer's smartphone displaying details on an app, so that they can monitor when someone is at the older person's door.

All of the current intelligent doorbell systems investigated are all controlled by a smartphone app. The solutions did not provide any means to connect to third parties for providing assistance. All of the systems are also self-contained eco systems with no APIs to integrate with. This makes them to a

certain extent limiting and unable to provide a means for the older person to contact a carer for assistance.

In this paper we present an intelligent doorbell solution, hereby referred to as DoorStep, that can detect when a caller is at the front door and push notifications to the older person in the home. The older person can review the captured image of the caller and also has the opportunity to seek assistance from a carer. The carer can then respond with a recommendation to let them in or not. The DoorStep system differs from the other intelligent doorbells because it focuses on providing security to the older population and disabled communities by enabling them to review who is at their door and request a carers assistance, before approaching the door. It also enables the older person to keep their freedom and control of their own home by notifying and asking them if they need assistance, therefore not bypassing them and going directly to the carer. Unlike other proposed solutions that send notifications directly to a family member. Nevertheless, if they feel they need assistance, then the DoorStep system provides this functionality and connectivity to provide peace of mind and a feeling of safety to them. DoorStep improves and advances the current state of the art in intelligent doorbells by enabling face recognition, logging of visitors and the ability to push educational information, such as showing the elderly person how to ensure they have placed the door chain, locked the back door, etc. before answering the caller.

Section III discusses the system architecture, Section IV presents the hardware and software of the developed solution, Section V discusses the Conclusion of the study and presents areas for future work.

III. System Architecture

The system architecture, outlined in Figure 1, presents the main components of our system and how they interconnect with each other. The central component in the system is the Windows Universal Platform (UWP) app built on Windows 10 IoT, running on the Raspberry Pi 2 hardware. This is known as the DoorStep Server, shown in Figure 1. This component's purpose is to detect and capture faces from the wide angle camera and notify connected clients of doorbell events. The Home App is a Windows 10 UWP application that runs on a Windows smart phone or tablet device. The purpose of the Home App is to provide the home owner with a means to receive notifications from the DoorStep Server, request carer assistance and display doorstep etiquette. A background task is created by the Home App, which is used to handle the long lived TCP socket. This allows the Home App to not be running, but still receive doorbell events. This is explained in more detail in the Implementation section. The Face Recognition component is external to the components within the home. This is partly due to the computing resources required to accurately and quickly process face recognition tasks. It is also external because the system will build a centralized inclusion and exclusion list of known people. It enables a face captured by the DoorStep Server to be sent and processed to determine if it is a known person or not. The results from this analysis are then sent to the carer to assist with their decision. We are currently testing OpenCV and Microsoft's Project Oxford to determine which meets our requirements the best. From initial testing Project Oxford provides additional face features such as estimated age, gender and emotional expression. This extra information enables the carer to make a more informed decision, rather than just from a photograph. The Carer App enables the carer to receive assistance requests from their patients. The notification consists of the face photograph captured from the DoorStep Server, date and time of event and the face recognition results. The app then provides a way for the carer to review this information and make an informed decision of "Yes" let the person in, or "No" do not let them in. This response is then sent back to the Home App to display the response to the home owner. Since the carer app is external to the home, there needs to be an intermediary relay for both apps to communicate with each other. This is achieved by the Patient/Carer Communication Server (PCCS), shown in Figure 1. This server provides an end point for both the Home App and the Carer App to communicate with and relay information. It also enables the Home App to send a Google Cloud Message (GCM) whenever the patient requests assistance from a carer. A database on the PCCS stores the carer's google cloud ID for GCM messaging. It also stores which patients a given carer is responsible for, so that assistance requests can be routed to the appropriate carer.

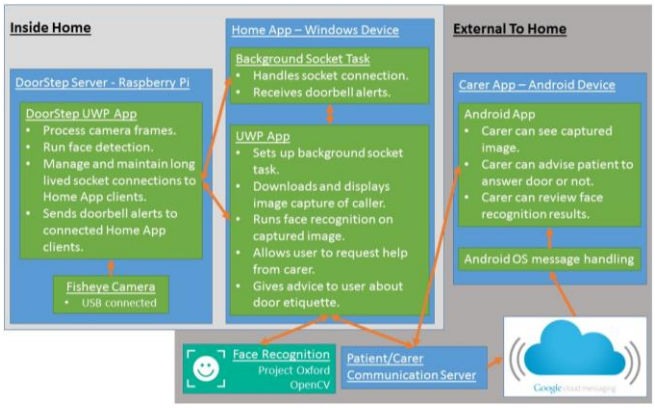


Figure 1. Diagram detailing the system architecture of the developed DoorStep system.

IV. Developed Solution

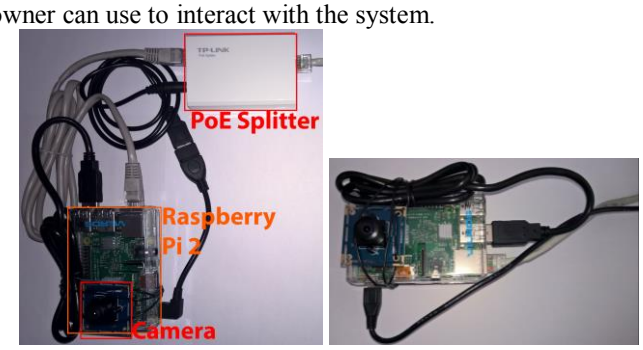
During the development of the prototype system a number of both hardware and software decisions were required.

A. Hardware

We choose to develop the DoorStep Server on the Raspberry Pi 2 because of its small form factor, which enables its placement outside of the home at the doorstep. It can also be housed as a self-contained unit, including the camera. The Raspberry Pi 2 also has the capability to connect a doorbell switch via the General-Purpose Input/Output (GPIO), therefor allowing it to operate just like a traditional doorbell. The Raspberry Pi 2 also has the flexibility to have either an Ethernet, Wi-Fi or 3G data connection. If Ethernet is used, then the Raspberry Pi 2 can be powered by POE (Power Over Ethernet) using a splitter. This means only a single Cat5 cable needs to run from inside

the home to the DoorStep Server, as shown in the DoorStep Server setup in Figure 2.a. Otherwise a single 5v power cable can be run, if Wi-Fi or 3G is used, as shown in Figure 2.b. For the purposes of testing a wired Ethernet cable has also been attached.

For the camera hardware we selected a wide-angle camera with a fisheye lens (Model:ELP-USBFHD01M-L180), as shown attached to the Raspberry Pi 2 in the bottom of Figure 2.a and to the left in Figure 2.b. This gives the device a 170-degree field view, of the doorstep area, meaning a person cannot avoid being detected by our system, by standing to the side of the doorway. Provided the DoorStep Server is positioned in a suitable location at the door. The cost of all the components used in the DoorStep server was under £100. The hardware for the Home App can be any smart device that is capable of displaying notifications and interacting with to enable the carer requests. We have developed the current Home App in the UWP framework, which enables it to be deployed on a Windows 10 smart phone, Windows 10 computer, Xbox One connected to a TV, or even another Raspberry Pi 2 connected to a TV. This provides great flexibility over the devices that the home owner can use to interact with the system.



(A) (B)

Figure 2 - DoorStep Server setup with POE adaptor supplying power and data to Raspberry Pi 2 (A). Setup with 5v direct power supply and wired Ethernet to the Raspberry Pi 2 (B).

B. *Software*

As discussed previously, there are three main hardware components to the DoorStep system, namely: DoorStep Server, Home App and the Carer App, meaning that we needed to develop three main software components for these. The DoorStep Server and Home App both were developed in the Microsoft UWP framework which allows easy deployment to many types of devices in the UWP family. The Carer App for testing and evaluation purposes was developed in Android. The Home App makes use of a face recognition service to identify who the person in the captured photograph is. We have currently implemented against Microsoft's project Oxford for testing, as it has an accurate face recognition algorithm and can also provide other characteristics of the face such as emotional and gender classification, and age estimation. These other characteristics could be helpful for the carer to make an informed decision about their response for letting a person in or not. With our system being able to perform accurate face recognition, this allows for the creation of both an inclusion and exclusion list of known people. For example, known carers or family members face profiles can be added to the inclusion list and the home owner will be notified that e.g. "Samuel is at the door". The exclusion list would allow the police service to add a face profile to the system of a person that has been known, or previously convicted for doorstep crime or wanted in a nearby area. Our system can then inform the home owner to stay away from the door and the carer and police service will be notified. This system then becomes a very big deterrent to any person that attempts to carry out doorstep crime against a house fitted with the DoorStep system.

C. *Implementation*

The Home App is the main interface that enables the home owner to interact with the DoorStep system. To ensure the setup is as simple as possible, the Home App auto discovers the DoorStep Server via multicast, as shown in Figure 3. Failing that an IP address can be manually entered, if multicast is not supported. A long lived TCP socket connection is established between the DoorStep Server and the Home App, to receive the alerts. The advantage of using a long lived TCP socket is that the connection is permanently established and instantly ready to send/receive data, however uses minimal bandwidth. This means the Home App does not have to continuously poll the DoorStep Server to ascertain if there has been a doorbell event. The DoorStep Server will tell the Home App when an event has occurred, therefore also minimizing communication delays. When the Home App is terminated, the TCP socket is handed over to the socket broker, which continues to listen for any socket activity. If there is activity then the socket broker executes the Home App background task, which handles the socket data. This approach uses the minimal amount of system and bandwidth resources and is very efficient. Once the Home App is connected, it is clearly displayed to the user at the top of the App, as shown in Figure 3.

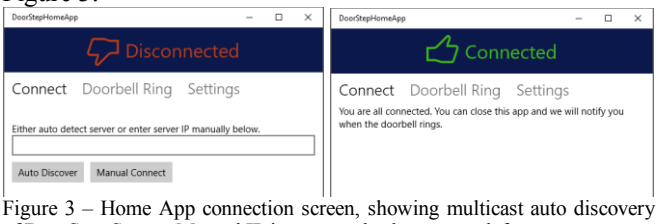
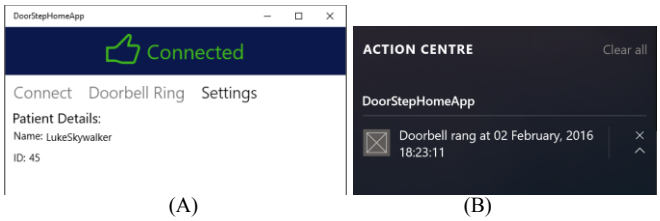


Figure 3 – Home App connection screen, showing multicast auto discovery of DoorStep Server. Manual IP input can also be seen on left.

The settings page, shown in Figure 4.a, supports the patient details to be configured and their device registered with a carer. A unique ID, assigned by the PCCS, is used to configure the carer app's GCM so that the Communication Server knows which device to contact when the associated patient requests assistance. When a doorbell ring event is triggered, the Home App displays a notification in the Action Centre, shown in Figure 4.b, which the user can tap and the Home App will be launched to display to details of the doorbell ring event.



(A) (B)

Figure 4 – Home App settings page show patients details (A). Action Centre displaying doorbell event notification for Home App (B).

When the app opens from a notification, the Doorbell ring event details are displayed, which include the date and time of the event and the photograph captured by the DoorStep Server, as shown in Figure 5. If the face detection has recognized the face then it will tell the home owner who it is, for example "Your carer Marry is at the door". If the face is not recognized, then the home owner has the option to request assistance from their assigned carer. If the face profile matches a known person in the exclusion list then this information is relayed to the carer, so that it can be reviewed by the carer and then if needed the police services can be notified by the carer. This way the home owner is not panicked and the police can intervene without distressing the home owner.

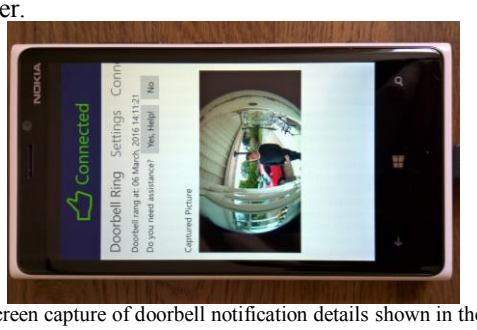
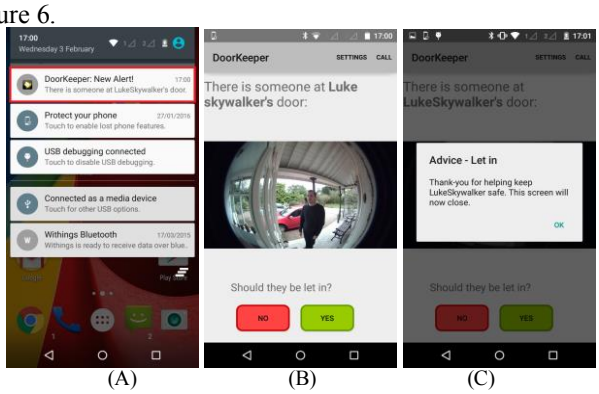


Figure 5 – Screen capture of doorbell notification details shown in the Home App.

The Carer App will receive a GCM notification which is associated with the Carer App. When the carer taps the notification the Carer App is lunched and the name of the patient and the captured photograph is displayed, as shown in Figure 6.



(A) (B) (C)

Figure 6 – Screen captures of Carer App showing notifications and interface allowing carer to review the doorbell event and respond to the patient.

The carer can then select "Yes" or "No" to let the person in, shown in figure 6.b. This simple yes or no means there is no vagueness about the answer given to the home owner. The decision selected by the carer is sent back to the home owners Home App and displayed to them, so that they know if it is ok to let the person at the door in, or to take measures to not let the person in. Based on the response, the Home App will display several doorstep etiquette steps to ensure the older person will be safe when approaching and opening the door. For example, "Ensure the back door is closed and locked, before approaching the front door." and "Ensure the door chain is applied, before unlocking the front door." etc.

V. Conclusion

In conclusion we have presented our doorbell security system for the prevention of doorstep crime, using low cost and easy to install technology, to support and further enhance the home owner's ability to thwart potential doorstep criminals. Our solution is targeted at the older population, of age 70 and over, who maybe more vulnerable to becoming a victim of doorstep crime. Having the DoorStep security system installed, can make an older person feel less vulnerable and give them more confidence when answering the door, because they know that help is just a few clicks away. This paper has presented the technical implementation of the system and shown that the technical aspects of the system can provide assistance to an older person through the use of technology. We have shown that the system can be interacted with in an unobtrusive way, using a simple smartphone app, and there for keeping the complexity of technology hidden from the home owner.

In our future work, we will evaluate the system with a cohort of older adults who have been previously targeted by doorstep crime in the past and would be potential users of the solution. This will help us to improve the mobile app interface and system from the feedback. We also will finalize the implementation of the face recognition and implement a backend system to enable both carers and the police service to add to the inclusion and exclusion lists. It is also to be noted that the actual face of a person will not be stored, but only the facial profile. We will 3D print an enclosure, along with improving the wiring for the DoorStep Server, which will be water proof and more elegant than the current prototype.

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