GUIDed: An Augmented Reality Assisted-Living and Social Interaction Platform for Older Adults

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Abstract. The demographic trend causes a rising pressure on health and care systems. Information and communications technology (ICT) provides many appliances that may support older people in prolonging independence while reducing the pressure on health and care systems. Research provides insights into the needs of older people as well as insights into the suitability and usability of ICT appliances for older people. As a result, this work presents the GUIDed system that aims at supporting the independence and quality of life of older people by using augmented reality as the central element of the user's interaction, whereby the paper's focus is placed on the technical development. The system is comprised of five services that are related to older people's daily activities or issues and social needs. These include the intake of medication, navigation, communication, smart home control and safety. Finally, a mobile application is included that allows older people to access all the services in an Augmented Reality (AR) interaction mode, while a conventional accessible user interface (UI) is also provided in the case an older adult prefers this as an interaction method.

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1 Introduction

The demographic trend predicts a rapidly aging population in advanced economies including the European Union, which comes from advances in health care, higher incomes, shrinking fertility, improved education and increased gender equality. One

effect of the rapidly aging population is the rising pressure on health and care systems [1]. Therefore, the need for self-care of older people will continue rising. Information and communications technology (ICT) including smart home technology has the capability to decrease or in a few cases almost eliminate older people's dependency on caregivers [2]. However, some research [3], [4], [5] shows that older people tend to be fearful of adopting new technologies. Augmented Reality (AR), a technology that adds computer-generated objects to the real world, enhances and facilitates the possibilities of designing user-friendly services, which may lead to a reduction of fear and usability issues, especially among older people, when adopting a new technology. Some authors examined the acceptability of an AR-based virtual coach for home-based balance training with older people. Their results suggest that the participants in their study find the AR system encouraging and stimulating [6].

Rosales and Fernández-Ardèvol describe that older people enjoy using mobile applications such as WhatsApp, a medium for exchanging messages, images, audio or video[1], as they offer services that correspond to their needs while providing a good and intuitive user interface (UI). They summarize the older people's needs as: basic communication, security and safety, support of personal interests including social interaction, personal management such as pill management and entertainment [7].

The GUIDed AAL EU project aims at supporting these needs by offering five services accessible through a mobile application, while also providing the AR interaction mode as an alternative UI layer in order to reduce usability issues. The first service represents the "Medication Planner" service which supports users with taking pills by offering the capability to set appointments and receive reminders. The second service, "Smart City Navigation", helps its users to navigate to places they select. The third and fourth services, "Smart Home Control" and "Smart Home Safety", support older people's safety and control needs. Furthermore, a smart home system is established that facilitates the integration of many different smart home devices from different vendors. The fifth service, "Social Communication", helps the users stay connected to their family and friends offering a medium for video calls in order to counteract loneliness. Furthermore, the "call a stranger"-function offers the capability to get to know other users from the GUIDed community that also use this system.

The goal of this paper is to describe the development of the GUIDed system from the ICT perspective, which places AR as the key technological element that aims to reduce usability issues. This includes the examination of challenges faced and consequent solutions adapted. Previous research, the experience gained from previous ICT projects, literature reviews, technical documentations as well as insights from the development process itself served as the input for this article's examination.

The remainder of this article begins with describing related work examined in existing literature which provide recommendations that were followed in the design and development process. These include the engagement of older adults in the design and usability testing, and the consideration of best practices for design and development of mobile applications and web applications suitable for older adults. Then a synopsis of the GUIDed system's architecture is presented. Next, each service is described in

[1] https://www.whatsapp.com/?lang=en

more detail. Initially, the "Medication Planner" service is examined which shows the implementation of a medication planner for pill taking. Secondly, the "Smart City Navigation" service is described. It includes the integration of a system called "Mapbox" for requesting routes by providing coordinates. Thirdly, the "Social Communication" service is presented. It shows how a communication between two users can be established over a peer-to-peer network using WebRTC[2]. Then, the last two services, "Smart Home Control" service and "Smart Home Safety" service, are examined. These services illustrate how cost-efficient and more open smart home systems can be designed by using mainly open-source systems. Finally, this article concludes with a summary of the work conducted for implementing and integrating the services and directions for future research.

2 Related Work

2.1 Related Projects and Systems

In terms of EU funded projects aiming to offer ICT solutions for enhancing and supporting the home living of older adults we have the following:

- The IOANNA (Integration of All stores Network & Navigation Assistant) project aims at developing ICT-based solutions for seniors for everyday facilitation in shopping management and navigation, focusing on assistive mobility and social engagement through crowdsourcing [15].
- The FrailSafe project aims to better understand frailty and its relation to other health conditions to develop a set of measures and tools, together with recommendations to reduce its onset [16].
- The MedGUIDE project offers an approach to social networking and e-learning focused on polypharmacy management, where seniors will be supported in their medication adherence via sensor technology and smart pillboxes [17].
- The Many-Me project builds a social interactive care system to help people with dementia, their relatives, informal and formal carers [18].

The above present the main projects and systems relevant to this work, while additional work is presented in the previous work of the authors that focused on the needs analysis and requirements for the definition of the GUIDed app and system using a co-design and participatory approach [13].

2.2 Lifestyle Problems faced by Older Adults

Medication Reminders

Stuck et al. examined some of the most downloaded medication reminder applications concerning their suitability for the usage by older people. Their findings reveal issues

[2] https://webrtc.org/

including unintuitive navigation, poor visibility and a lack of transparency. Furthermore, the authors inferred guidelines for application design from their findings. These include the inclusion of older people in the design and usability testing phases of the development process, as well es the compliance with standard age-specific design guidelines [8].

How Older People Struggle with Maps

In a recent research Yu and Chattopadhyay examined the accessibility of current mobile maps from the perspective of older people. They classified the issues encountered by older people into motor issues and non-motor issues. In this context, motor issues represent interaction problems where a user failed to successfully execute an intentional action such as tapping or swiping. Non-motor issues include for instance the unwilling ignorance of UI components due to inadequate visual saliency, ambiguous affordances or low information scent. They concluded that non-motor issues were more critical as they often resulted in frustration and resignation among users [9].

Social Needs of Older People

As loneliness tends to increase with age [10] communication applications such as WhatsApp or Viber have gained a strong popularity among older people. They enable them to stay connected to their family and friends that are not nearby. Bruggencate et al. examined the social needs of older adults. These include active involvement, respect for individuality, stimulating social contacts including close and peripheral relationships, and the sharing of knowledge [11].

Smart Home for Older Adults

Yusif et al. conducted a systematic review of empirical studies concerning the adoption of Assistive Technologies (AT) including smart home. Their findings suggest that older people are mostly concerned about privacy, costs of ATs, ease of use, suitability for daily use and the general benefit, which some older people assess to be low. However, their results also suggest that older people in general have a positive attitude towards ATs as they see it as a means to maintain independence [12].

2.3 Previous Research in the Context of GUIDed

Mettouris et al. describe the user-centered design approach with the focus on the co-creation aspect in the context of the GUIDed system. This includes the evaluation of high-fidelity (Hi-Fi) paper prototypes (i.e., the designs) for the GUIDed services. The hi-fi paper prototypes are based on the recommendations from the literature and the authors' goal was to validate them and the proposed additional AR UI. The Hi-Fi prototypes were tested by older adults and their caregivers using focus groups in four European countries, namely Austria, Cyprus, Norway and Poland. The results show that the users found the GUIDed system understandable and easy to use [13]. This

represents an encouraging finding considering older participants' low technological literacy.

3 GUIDed System – overall architecture

The architecture of the GUIDed system is depicted in Fig. 1, which is described shortly as follows, whereas more details are described in the report from the GUIDed EU AAL Project [14]. The architecture of the GUIDed system consists of three entities: the Android client for the users, the cloud instance for configuring, relaying and processing data and the Raspberry Pi 3B+ for the smart home services at the user's home. The cloud hosts a Drupal content management system (CMS) instance for configuring the five services and saving user data (Services 1-5), a spring boot application for handling smart home operations and smart home safety functions such as sending push notifications to specific users when an alarm is triggered (S1, S2), as well as a WebRTC signaling server to keep track of all connected and available GUIDed users and for establishing a communication channel between two users within the "Social Communication" service (S5). The GUIDed system exposes the services through REST APIs which enable the use and manipulation of information through the mobile application. The Drupal CMS, which is accessed over a web browser, allows users including older people to use a mouse, a keyboard, bigger user interfaces and clearer navigation structures that simplify the configuration process in contrast to using a mobile application.

4 Medication Planner Service

Compared to existing medication planner mobile applications that in almost all cases perform data management and data access on the mobile application and interaction through restrictive user interfaces, the "Medication Planner" service enables data management via the GUIDed CMS that offers usable and clear navigation interfaces, enables data access for the mobile application via the exposed REST API and allows interaction using either intuitive AR interfaces or standard UIs to serve all different older adults' requirements and needs.

Specifically, the primary user (i.e., older adult) or secondary user (e.g., family, caregiver) assisting the older adult can use the CMS accessible over a web browser to manage the drug and prescription data. This allows defining and managing medication, vitamins and supplement data using larger user interfaces, with clearer navigation and easier interaction, rather than administering data on the mobile application.

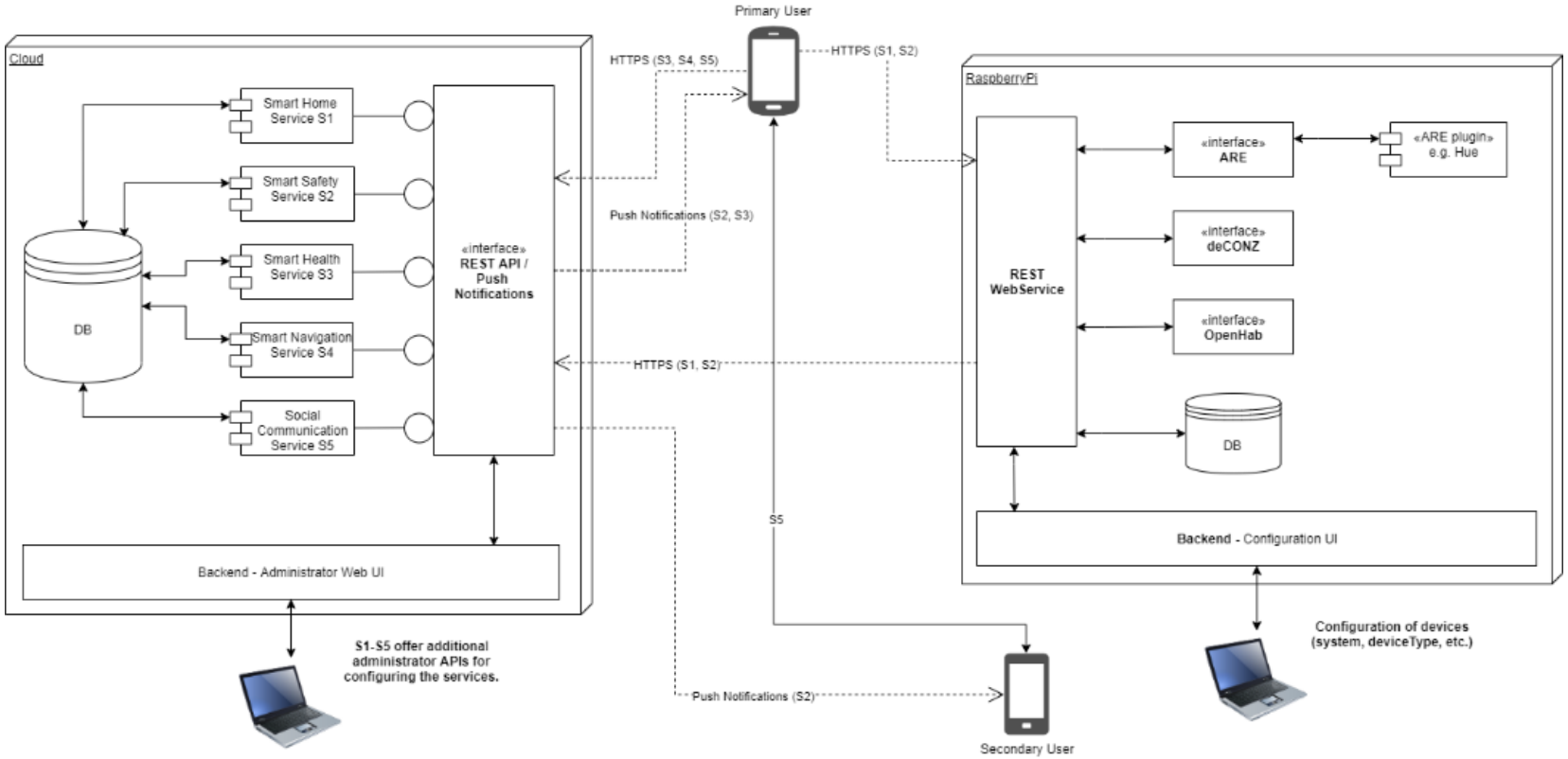

Fig. 1. High-level Architecture for the GUIDed System

Moreover, Headless Drupal is used on the backend framework to expose the required REST APIs that provide remote access to the medication data from the mobile application. The mobile application provides the capability to the primary user to select the “Medication Planner” service using the tiles-view, which loads the camera view of the phone. The Android ARCore framework and the TensorFlow machine learning (ML) model are initialised, which allow detecting respectively either a 2D image of a pillbox or a 3D physical pillbox object. As soon as the 2D image or 3D physical pillbox object is detected the REST API is invoked, which returns the matrix with the medication information augmented on the camera view, including intake times and dosages of the prescriptions. Furthermore, it allows to tick the checkbox when the medication is taken (see Fig. 2). However, the checkbox is only enabled 15 minutes before and after the intake appointment. The user can also click on the maximize-button to expand the augmented matrix view and see the complete list of medication to be taken for the current day (see Fig. 3).

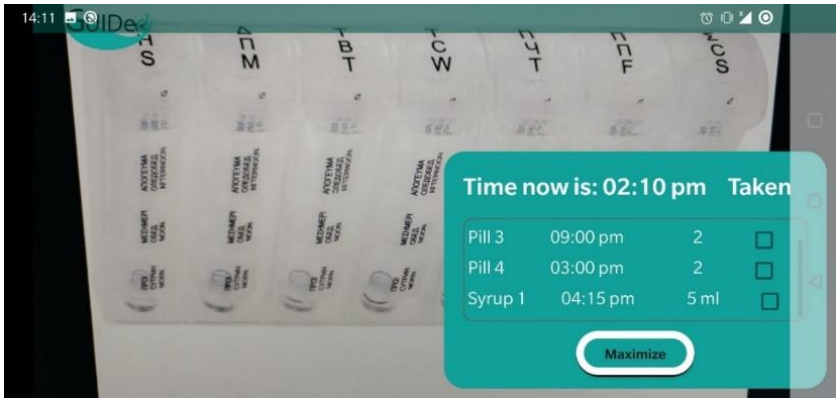

Fig. 2. AR Medication Planner Pillbox Detection - showing next intake information.

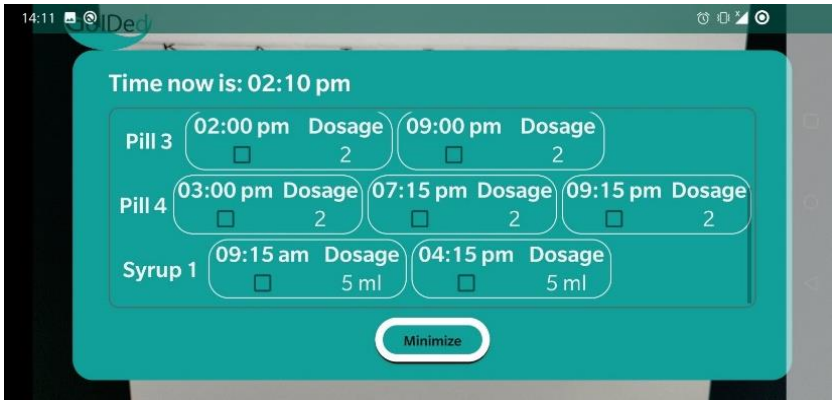

Fig. 3. AR Medication Planner Pillbox Detection – expanded view.

5 Smart City Navigation Service

The AR navigation service also requires the use of the CMS and the Android application. The primary or secondary user can also use the CMS to manage the favourite places (unique name of the place, the coordinates of the place, etc.) of the older adult. Moreover, the exposed REST APIs provide remote access to the places data from the Android mobile application. On the frontend, the tiles-based view is shown that allows selecting the navigation service, which loads up the camera view in AR mode, presents a dropdown menu with the user's favourite, from which the user can select the location to navigate (e.g., home) and then clicks the Go button that initiates the AR navigation (see Fig. 4).

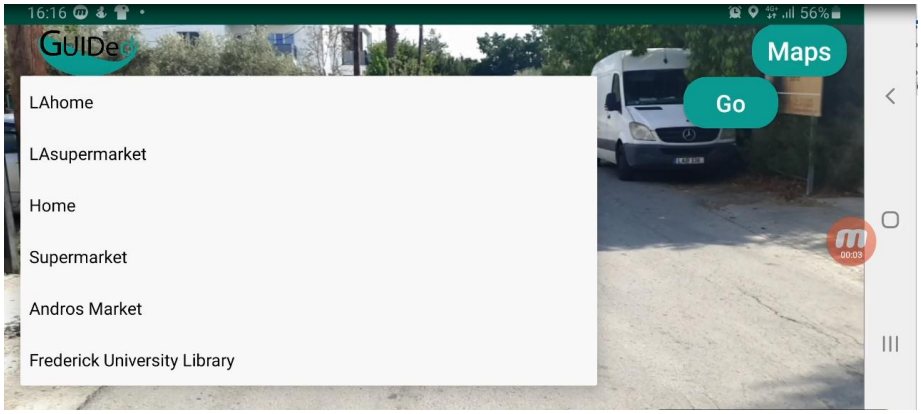

Fig. 4. Selecting the Navigation Place.

The implementation of the Android application is based on the ARCore technology and the Mapbox APIs, which enable to detect the current location of the user, getting navigation instructions and rendering this information as augmented visual cues (i.e., direction arrows), providing an augmented reality navigation experience to the users (see Fig. 5). The user is also able to click the "Maps"-button on the top right, in case the map-based navigation is preferred, to open the map view. The location of the user is detected, and the user can select any location on the map as the destination. The route is plotted, and the user clicks the "Start"-button to begin the map view navigation. This enable users that are technology-oriented and accustomed to the map view to use this mode of navigation.

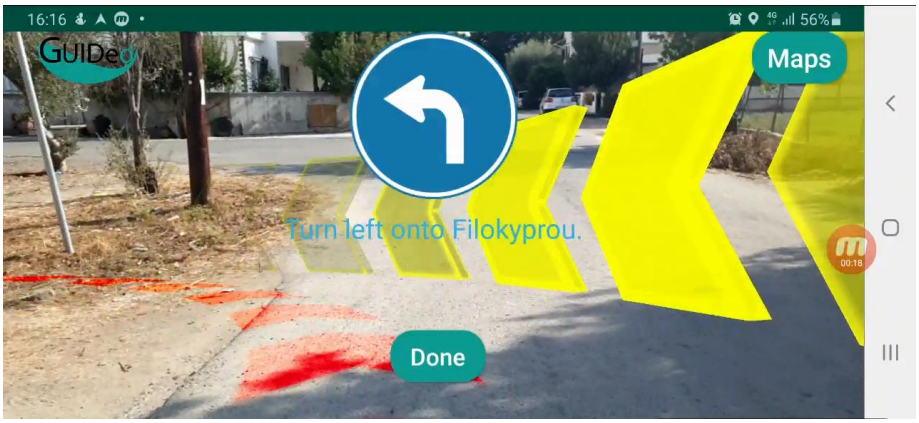

Fig. 5. Navigating in Augmented Reality View.

6 Smart Social Communication Service

The Social Communication Service aims to address the issues of social isolation and loneliness that older adults experience, by offering a sense of real-life physical presence between the older adults and the communicating family members, healthcare providers, friends and even a stranger (explained further below). This is achieved by providing a video calling service with a simple (yet functionally complete), minimalist design and easy-to-use UI, that is also appropriate for use by older adults. Using the service, older adults can remain in contact with family and friends while engaging in everyday activities, such as eating together, drawing with the grandchildren, knitting and much more.

The Social Communication Service differs from existing similar apps in the market in three fundamental aspects: 1) it targets older adults, making thereby the appropriate design decisions in terms of UI elements' size and colors, 2) the workflow of the service and the architecture of the various functionalities have been designed and developed having in mind HCI (Human Computer Interaction) related parameters like usability and ease-of-use, targeting at the same time older adults, and 3) it offers the "Meet Others" functionality, an innovation of GUIDed (please see paragraph below).

Besides conducting video calls, the service offers a secondary functionality called "Meet Others". This functionality enables primary users, through the push of a virtual button, to conduct video calls to another GUIDed primary user in a random fashion. The remote user belongs in the GUIDed community, i.e., he/she is a GUIDed user as well, and is randomly selected by the GUIDed system, provided that the preferred languages of the two users match, and that the remote user has agreed to the communication request at the moment of the call.

The GUIDed services, including the Social Communication Service were briefly described in [13]. In that paper, the architecture and technical information about the service were provided in detail. In this paper, the focus is on the "Meet Others" functionality as an innovation in this service and of the GUIDed system overall.

6.1 Architecture

The Social Communication Service was developed using the WebRTC framework. WebRTC is a free, open-source framework that enables Real-Time Communications with audio and/or video, by providing web browsers and mobile applications with the means for real-time communication via its APIs. The Social Communication Service includes two different architecture designs: a Client-Server architecture between Android devices (smartphone/tablets clients) and a signaling server that is used for setting up the connection between two communicating users, and a P2P (Peer-to-Peer) architecture between two Android devices for conducting the video call. It is important to note that the signaling server does not retain any information about the two clients during a video call, thus ensuring the user's privacy and data security. All WebRTC clients' data are deleted as soon as the signaling process is terminated. Apart from the signaling process, the server listens and handles any special case events e.g., client disconnection, client reset and client network changes. More on the Social Communication Service architecture and the WebRTC can be found in [13].

6.2 Workflow

The Social Communication Service can be divided into two main features, the video call process and the process of adding new contacts to a primary user. The former is mainly handled by the WebRTC API and the signaling server, as previously explained in section 6.1. The latter takes place through an appropriate Web UI on the GUIDed web platform, where the primary user (active user) or a helping secondary user can add other GUIDed users as contacts to the active user, by initiating a pending contact request to another user. Users can check their pending contact requests and accept or decline each request. In addition, adding a new contact to a primary user can be done during a video call with a stranger in the "Meet Others" mode (more on this below).

Through the Android application, the user can enter the "Meet Others" mode by clicking a virtual button on the contact's list screen so that the process of finding a suitable candidate begins. Based on the user's preferred language, the algorithm run by the Signaling Server will respond with a random GUIDed user that meets the language requirement and is also currently online and available for a video call. Fig. 6 shows the incoming call from the "Meet Others" process. When both users agree to the video call, it initiates. During the video call between the two strangers, there is an option to send a contact request to the communicating user. Then, a pop-up appears on the receiving user's screen notifying him/her of the contact request and providing an accept/decline option to immediately notify the sending user of the result. Fig. 7 shows the workflow for the "Meet Others" functionality.

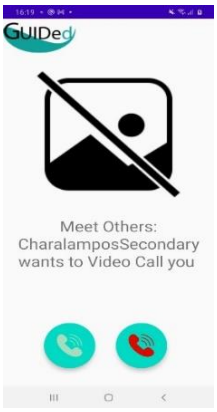

Fig. 6. "Meet Others" process: the receiving user's incoming call.

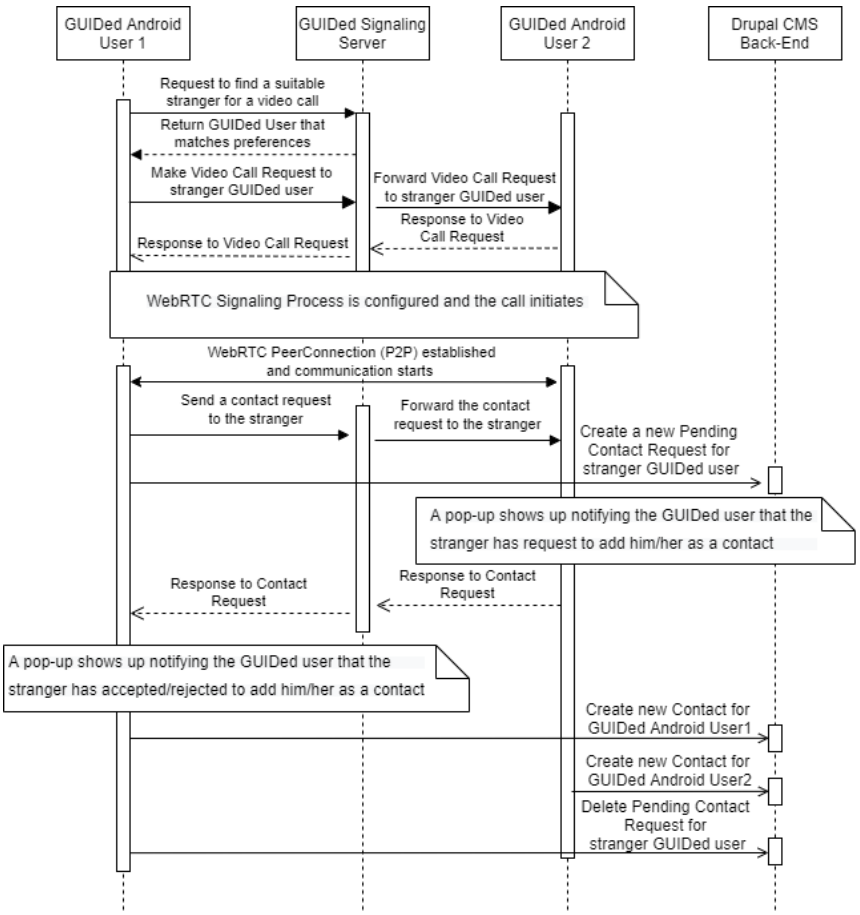

Fig. 7. Sequence Diagram for the "Meet Others" Functionality.

7 Smart Home Control Service and Smart Home Safety Service

The GUIDed services “Smart Home Control” and “Smart Home Safety” offer solutions to mitigate concerns related to ATs discussed in chapter two. Fig. 8 summarizes the concerns and their respective solutions via a non-formal mind map. On the left side the model summarizes four issues for ATs: hard to use, high prices, vendor lock-in and privacy. The right side of the model proposes approaches to reduce or eliminate the issues. The links between issues and solutions are depicted as green arrows. These approaches were incorporated into the implementation of the services for the GUIDed system. In order to make the usage of the system easier, the GUIDed system relies continuously on accessibility for the user interface parts. Furthermore, the AR mode in the camera view offers an additional way of operating smart home devices.

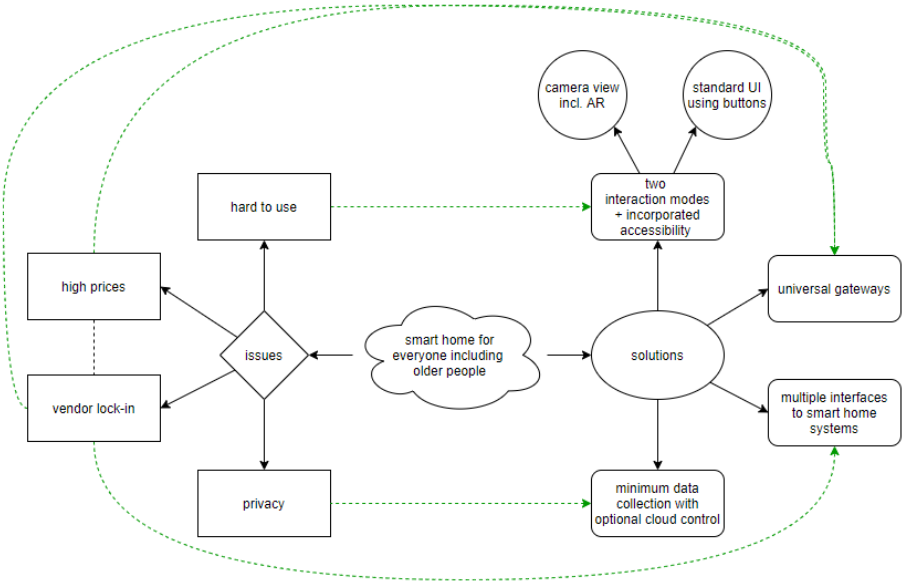

Fig. 8. AT’s Issues and GUIDed’s respective Solutions

For the issues of high device prices and vendor lock-ins the GUIDed system incorporates different application programming interfaces (APIs) for operating smart home devices. These APIs include deCONZ[3], OpenHab[4] and the ARE from the AsTeRICS[5] project. This strongly reduces the dependence on vendor-specific or expensive devices as it facilitates the integration of different technologies including devices with a specific protocol such as ZigBee. Concerning privacy, the data collection is kept to a minimum, which includes configuration data locally stored on a Raspberry Pi in the

[3] https://www.dresden-elektronik.com/wireless/software/deconz.html
[4] https://www.openhab.org/
[5] https://www.asterics.eu/

user's home in order to have the ability to control and read device states. However, for users that wish to control their devices over the cloud, additional data related to the configuration and states of devices would need to be stored which would be fetched or uploaded by the Raspberry Pi for synchronization.

From a user perspective the two smart home services can be described as follows. The "Smart Home Control" service allows users to control their home environment. It provides features such as control of lights or power sockets. The "Smart Home Safety" service monitors the users' homes and alerts the primary user when a threat is detected. Furthermore, push notifications are sent to linked users including primary and secondary users. In the current implementation the "Smart Home Safety" service can track the presence of smoke and carbon monoxide. Door or water leak sensors for example could also be supported. Fig. 9 shows the AR view for the services, whereas a user can also choose a standard UI to check and operate devices.

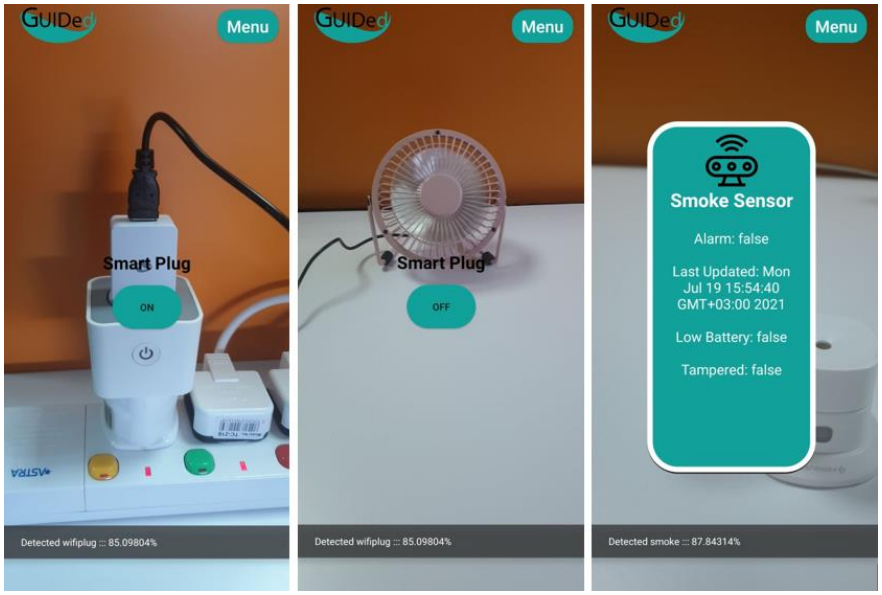

Fig. 9. Augmented Reality: Smart Home Control & Safety

7.1 Architecture

The Raspberry Pi is the central hardware component responsible for the "Smart Home Control" and "Smart Home Safety" services, which together with a set of sensors and actuators need to be installed in the user's home. The Raspberry Pi connects over a REST API to the proprietary Drupal instance running remotely on the cloud, and to the third-party smart home systems deCONZ, OpenHab and ARE installed locally. Furthermore, a proprietary front-end application ("Configuration Client") is served by

the Raspberry Pi. It enables the configuration of smart home devices (naming, room configuration, device type - e.g., light, smart home system - e.g., deCONZ).

8 Conclusion

This paper presented the GUIDed system including its five services from a technical perspective. The services were chosen to support the daily activities of older people supporting not only their independence but also incorporating their social needs. The development was conducted after and while considering recommendations from the literature including the results presented from the evaluation of the GUIDed Hi-Fi prototypes [13]. In terms of the usability aspect, the recommendations include for example the consideration of the navigation, transparency and visibility of UI objects, which is incorporated using design guidelines from the literature as well as the user feedback. Moreover, AR was incorporated as the integral part and the differentiating point of the GUIDed system compared to existing systems offering similar services. The described results of the development process represent the GUIDed prototype. Future work will test this prototype extensively as it will be installed in so-called living labs at the users' homes. The feedback will provide valuable insights that will allow a profound evaluation of the GUIDed system. To be more precise, the system will be examined on how well recommendations from the literature and user feedback were incorporated. Most importantly, the effect of AR on usability and user experience will be evaluated since this is the main goal and the contribution of the prototype built in this work.

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