Evaluating the Possibility of Integrating Augmented Reality and Internet of Things Technologies to Help Patients with Alzheimer's Disease

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Abstract— **The independent life of the individuals suffering from Alzheimer's disease (AD) is compromised due to their memory loss, and as a result they always depend on someone by their side to help them lead their daily life. In this situation, generally, either the family members or the caregivers extend their helping hands; they attach notes on every single object or take out the contents of a drawer, the family might need to make those visible when they leave the patient alone at home. The goal of this study is to provide some helping means for the patient and the family members through existing science and technology. This study reports preliminary results on an Ambient Assisted Living (AAL) real-time system, achieved through Internet of Things (IoT) and Augmented Reality (AR) concepts, to fulfil this goal. The system has two main sections: the first one is the smartphone or windows application that allows caregivers/family-members to monitor a patient's status at home and be notified if patient are at risk. The second part allows patient to use smart glasses to recognize QR codes in the environment and receive information related to the tags in the form of audio, text or three-dimensional image. This work presents preliminary results and investigates the possibility of implementing such a system.**

Keywords: Augmented Reality; Internet of Things; Alzheimer's Disease; Ambient Assisted Living; Distributed Mechatronics

I. INTRODUCTION

Alzheimer's disease (AD) is the main common cause of dementia. Approximately 5.8 million Americans are suffering from AD in 2019. By 2025, the number of people over the age of 65 with AD is predicted to rise to 7.1 million [1]. Loss of memory is the main difficulty experienced by patients with AD. In fact, they have problems in remembering recent information. Thus, they need to be reminded of the tasks to be performed, and that have a considerable effect on their confidence and quality of life. This can disrupt the patients' life and their family's daily life. In this situation, caregivers try to use best architectural design to create simple environment. For instance, they use clear plastic boxes to make objects more visible or leave reminder notes (e.g., "Take your medicine at noon" or "Don't leave the home"). Unfortunately, these methods have not been entirely effective in most cases [2].

Recently, Augmented Reality (AR) has been used as a cognitive aid tool to help people suffering from AD, specifically in the early stages [3]. In early stages, they may experience memory failure, such as forgetting how to deal with routine tasks or the location of their belongings [4]. The *ARCoach* system has been designed by researcher at Chung Yuan Christian University, which was based on using personal computer with an external web camera to add information to a real object [5]. The *Ambient aNnotation System (ANS)* [6], was included two main sections, first one allowed the caregiver to create new AR tags by selecting objects or locations, and then annotating them with information that could help the person with AD. The second one, ran on a smartphone, was used by a person with Alzheimer's disease and alerted the existence of tags in the environment. Despite their useful features, these systems could not be used in daily life easily, furthermore they did not have any monitoring option, so family consternation still remained.

During the last few years, development of Internet of Things (IoT) services have drawn a considerable interest in the scientific association. However, few researchers have addressed the development of a model designed for seniors with chronic diseases and particular demands, such as dementia and AD. Ambient Assisted Living (AAL) is an IoT-based service that supports care of elderly or debilitated patients [7]. AAL not only contributes a safer environment but also provides independency and encourages the user to be more physically and mentally active. According to [8] AAL has achieved the first rank among various IoT applications in health care and has had the potential to be a reliable opportunity in the near future.

In contrast with these works, our aim is to provide a real-time AAL system and improve AD patients' ability to carry out everyday task on their own, at home by designing a system, based on smart glasses, without compromising of patients' privacy. The main goal of this study is introducing preliminary results of possibility for this implementation. To the best of our knowledge, no one has studied any method on integrating of AR and IoT technologies to develop an effective AAL system that helps the AD patients and provides the monitoring option to the family members via Internet.

II. Internet of Things Implementation

A. MQTT Middleware

The Organization for the Advancement of Structured information (OASIS) approved Message Queuing Telemetry Transport (MQTT) Version 3.1.1 as an OASIS Standard in 2014, and it has been defined as the reference standard for IoT [9]. MQTT is a published-subscribed message transfer protocol that includes managing communication unit (broker) and clients. The MQTT broker is a message transfer platform that authorizes the message producer client to publish messages with a message identifier topic. Fig. 1 shows MQTT protocol operation in our study. Each client subscribes to one or more topics. A client that sends messages called publisher, and the one that receives messages is called subscriber. Clients must notice hostname/IP and port of the broker in order to publish-subscribe to messages. In this study, we used this standard because the message header requires only 2 bytes, which is extremely lightweight published/subscribed messaging protocol for small and constrained devices. We created both of our applications for patient and his family based on Android operating system. We have also designed another user interface, windows application, for patient's family to show the notifications related to the events detected by the sensors and to control other actuators' states in the home environment.

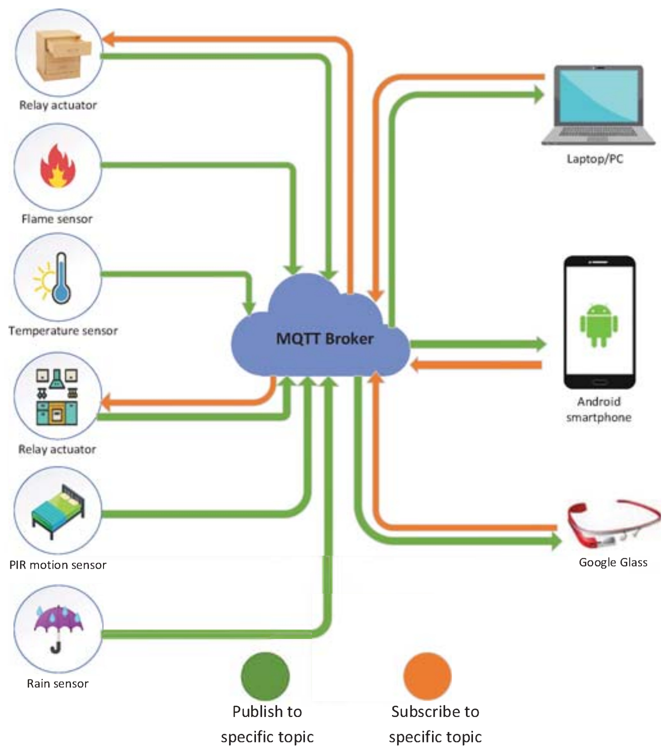

Fig. 1. MQTT protocol operation in AAL system.

B. Sensors and actuators

For monitoring patients and making interaction with them, five types of sensors and actuators were placed in four different locations including bedroom, kitchen, TV room and the main entrance. We also used QR codes for reminding regular events according to sensors' and actuators' data values. The general architecture of the designed AAL system is shown in Fig. 2.

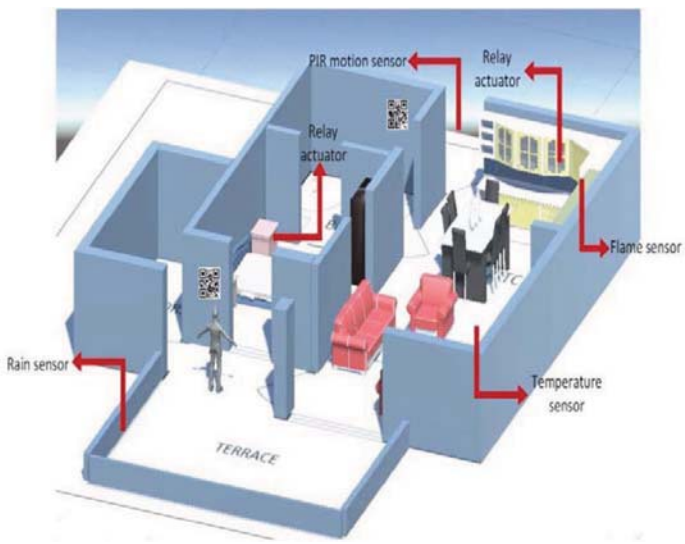

Fig. 2. General architecture of AAL system.

We used rain sensor in the terrace for rain detection, enabling the system to notify the user based the event in the form of AR messages. For fire detection, we considered flam sensor in the kitchen. Moreover, for reminding the weather condition changing, we utilized temperature sensor in the TV room as shown in Fig. 2. We used relay actuators to open or close the drawers or cabinet doors based on certain events, which we describe in Section IV. In addition, PIR motion sensor was used for recognizing user presence in the kitchen.

We attached QR codes on the specific places, where user probably staring at them, for giving some extra information to the user. For example, on the bedroom door, the user could view his family picture and get relevant clues about them in the form of an audio message. These messages could be helpful for memory difficulties.

C. Platform

The ESP8266-12 [10] boards provide communication abilities to the sensors, through a built-in Wi-Fi interface. Thus, by means of a Wi-Fi home Access Point (AP), sensors are allowed to connect directly to the broker and publish messages whenever an event is detected via MQTT protocol. Once a sensor activation is detected, the node that generally remains in a low power consumption mode starts the Wi-Fi connection phase. When the connection is recognized, the node is able to access the remote MQTT broker. As a result, the MQTT connection begins, supposing to the role of MQTT client. Once connected, it publishes a message on the established topic [11]. In our case, sensors were connected to ESP8266 in order to publish messages on temperature, gas, flame etc. data values, and family from a smartphone or a computer could read these values by subscribing to this topic. When the smartphone was offline, all the notifications could be stored by the server and then sent again when the smartphone connected to the Internet. Family could also publish a value such as LED's or relay's states and the ESP8266 needed to subscribe to this value in order to read it. The published-subscribed messaging pattern requires a message broker. The broker manages and handles all these messages between all the subscribed clients. We used several WEMOS D1 mini with a DHT shield to send the data values on temperature, humidity, motions, etc. to a MQTT topic and applied HiveMQ as a MQTT messages broker.

III. Augmented Reality Application

For designing our AR application, we have used Android ARCore platform, which is Google's open source AR Software Development Kit (SDK) and it is capable of creating three-dimensional contents. In this paper, we developed our application based on Android based smartphone, and then we investigated the possibility of transferring this app on the Google Glass as the ultimate tool. In this section, we first explain why we have chosen Google Glass as a user interface for AD patient, then we consider the difference between AR and QR tags in AR applications. Finally, we perform our current application on a smartphone and present preliminary results for system implementation.

A. Google Glass

Google Glass has clear utility in the clinical setting, i.e. surgery [12], assistive device for people with Parkinson's [13], remote chest X-ray interpretation [14], surgical education [15], vital signs monitoring [16], patient monitoring [17], etc. It also has applications in robotics, i.e. remote control of a mobile robot [18]. We have chosen Google Glass for AR implementation because of its minimal heads-up display and lightweight, so it could be used by each mild to moderate AD patient simply after short-term training that does not require any special skills. In comparing to other AR glasses, it gives patients access to information in the simplest possible way that does not distract their daily life and it makes enough essential virtual information while patient is interacting with physical world. Moreover, if patient is a glass-wearer, real glasses can have Google Glass screwed onto them. For example, Microsoft HoloLens is too bulky and distracting for patient, so it is not appropriate for this purpose. We are aware that our application could run on Google Glass, because the glass has the same operating system as Android smartphone.

Table 1 classifies the specification of the Google Glass which includes common components found in smart devices, i.e. central processing unit (CPU), camera, global positioning system (GPS), speaker, microphone, display, etc.

B. QR Codes

In this paper, we have used six different QR codes, because they can be simply processed using free open source software. In addition, QR codes printed on paper are cost effective. However, they can only be recognized one at a time, which was not a limiting issue in this study because we required simultaneous recognition of single symbols. On the other hand, if we want to recognize multiple symbols in any future study, we must use AR tags. Similar to QR codes, the AR tags can be printed on paper using open source software [5]. Therefore, it is cost effective too.

TABLE I. Google Glass Specifications

Specifications	
Processor	Dual-core 1.2-GHz Texas Instruments OMAP 4430 SoC with Power VR SGX540 GPU
Connectivity	Bluetooth 4.0 and Wi-Fi 802.11 b/g
Display	640*360 resolution
Storage	16 GB memory with Google cloud storage
Camera	5.0-megapixel camera, capable of 720p video recording with 30 frames per second rate
Battery	570mAh lithium-polymer batt
Charger	Micro USB and charger (outlet or PC charging)
Weigh	50 gr
Compatibility	Motion Process Library (MPL) Accelerometer, MPL Gyroscope, MPL Magnetic Field, MPL Orientation, MPL Rotation Vector, MPL Linear Acceleration, MPL Gravity
Sensors	LTR-506ALS Light Sensor Rotation Vector Sensor Gravity Sensor Linear Acceleration Sensor Orientation Sensor Corrected Gyroscope Sensor

In some scenarios, three second timeout occurred in QR code detection algorithm when we wanted to recognize that the user was staring at the QR code.

C. Software implementation on the smartphone

For simulation and evaluation of AAL system, we have used Samsung Galaxy S7 smartphone, which has quad-core Snapdragon 820 processor, 4GB RAM and 12MP rear camera. Fig. 3 shows some pictures based on scenarios we have defined of our distributed mechatronics system. For example, in Fig. 3(a) rain warning was detected by the rain sensor and at the same time user was staring at the main entrance. So, after this event they could see an umbrella and hear an audio reminder message related to the event. In Fig. 3(b), flame sensor near the oven in the kitchen detected the presence of a flame, and so the relay actuator was activated that helped the user receive an image notification. Th user could also observe the current and previous image states by scrolling through the received images. In Fig. 3(c) this state is shown on the LCD screen. The dishes picture for reminding the place of them in the kitchen, shows the current state, which is based on the user's field of view, and the right image is the pervious picture that was sent to the user by family to remind them of the medication time.

IV. Scenarios of Use

We are considering for the possibility of using this system in daily life of an AD patient. Here, we have explained some distributed mechatronics scenarios, evaluation of which are presented in the next section. The following sample scenarios describe how the AAL system would be used as a memory aid:

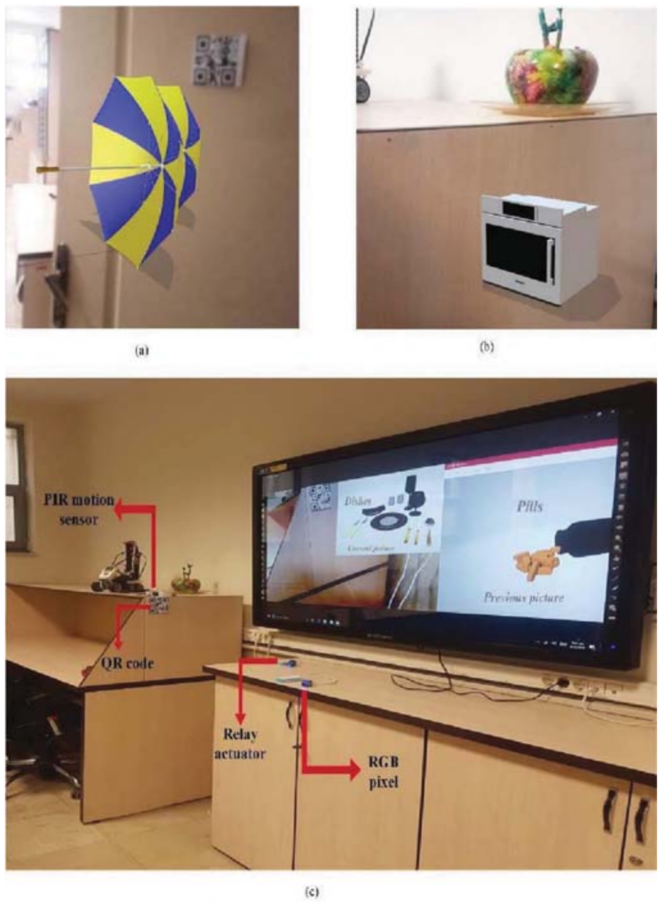

Fig. 3. (a) The rain warning was detected by the rain sensor and a picture of an umbrella is generated as a reminder, (b) the flame sensor in the kitchen near the oven detected the presence of a flame, so relay actuator was activated and user received an image notification, (c) an illustration of the user's field of view shown on the LCD screen.

1) When a relay actuator is activated by the smartphone application, the drawer lock is opened and the user can see an image of pills on the screen. In addition, the user receives an audio message as a reminder for his medication time.

2) When the QR code attached on the bedroom door is detected by the camera, the user can see their family picture and get some personal information about them as an audio message.

3) If the user enters the kitchen and the PIR detects this event, then they can see the picture of the dishes. Moreover, an audio alert is played about the dishes locations.

4) If the temperature sensor detects that the indoor weather is cold, then a text message is shown to the user on the screen. If this message is confirmed by the user, then the heater can be turned on.

5) If the flame sensor detects a flame or fire, then the relay actuator is activated and oven can be turned off.

V. RESULTS AND ANALYTICS

In this section, we present our AAL system reliability and performance according to the effective parameters and preliminary experimental results. First, we consider minimum QR code size that is large enough to be scanned by a camera, and then we describe system response-time in different conditions.

A. QR code minimum size

The minimum printed size of the QR code is dependent on some factors:

1) *Camera parameters*
2) *Number of modules*
3) *The distance between the code and the scanner*
4) *Scanning environment quality*

In this study, we have used version one of the QR code which has 21*21 modules. Two minimum QR sizes are defined based on first, the environmental parameters and the second one, the camera parameters. The final QR code size is determined according to these calculated parameters.

The first minimum QR length is calculated as

$$Minimum\ QR\ Code\ Size\ 1: L_{min1} = \left(\frac{D_{scan}}{K_{dis}}\right) * K_{den} \quad (1)$$

Where $K_{den} = \frac{21}{25} = 0.84$ is the data density factor (the maximum module number divided by 25 to normalize it to the equivalent of a Version 2 QR); $K_{dis} = 10$ the distance factor start from a factor of 10 reduced by 1 for each of poor lighting in the scan environment, a mid-light colored QR code being used, or the scan not being done front on; and D_{scan} defined 300mm as maximum scanning distance.

The second minimum QR size is calculated as following:

$$Minimum\ QR\ Code\ Size\ 2: L_{min2} = \frac{PPQ * FOV}{CCD_W} \quad (2)$$

Where FOV is the camera's field measured by experiment, in this case 340 mm; PPQ is defined as pixels in each dimension needed per QR. Considering 10 pixels needed for each module we define:

$$Pixel\ per\ QR = PPQ = 10\ pixels * 21\ modules \quad (3)$$

And CCD_W is the width of the CCD array calculated by solving the following equations:

$$Camera\ Resolution: CCD\ Area = CCD_W * CCD_H \quad (4)$$

$$CCD\ Width\ and\ Height: CCD_W = \phi * CCD_H \quad (5)$$

Where ϕ is normally the golden ration defined as:

$$Golden\ Ratio = \phi = \frac{1+\sqrt{5}}{2} \cong 1.618 \quad (6)$$

Finally, we can find the minimum required QR size for printing according to the following logic:

$$Minimum\ QR\ Code\ Size: L_{min} = \max(L_{min1}, L_{min2}) \quad (7)$$

Based on our 12MP camera and computational result as shown in equations, we must prepare at least 21*21mm printed QR code.

B. Response-time

For estimating the system performance and complexity, we have determined the application's computational response-time and analyzed the battery consumption. For example, we first published a new data value for turning on the relay actuator via MQTT protocol, and then the response-time for playing an audio message was assessed. In another test, we scanned a QR code and measured the response-time for displaying an augmented image after publishing a new message for turning off the relay actuator via MQTT. Both experiments were then replicated under the same conditions fifty times to evaluate the system-accuracy as shown in Fig. 4 and Fig. 5. The system required an average 364ms to play an audio message and for displaying three-dimensional image based on QR code detection, the average response-time was 106ms. We found that playing an audio message instead of displaying the image, had better performance and less battery consumption. However, using QR code to display AR image could decrease the response time in compare to playing an audio message.

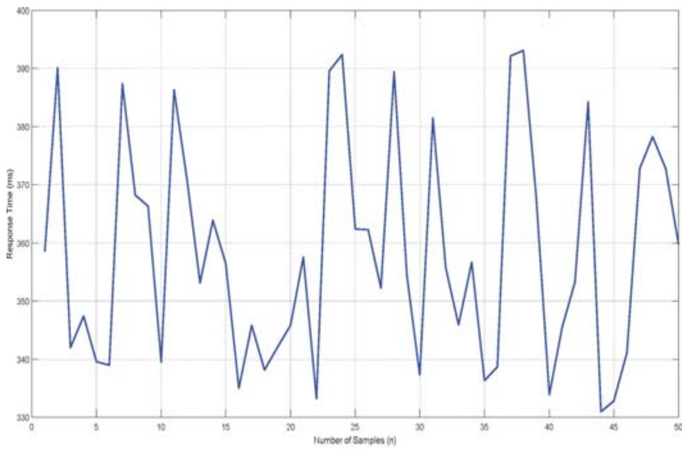

Fig. 4. Voice message response-time after publishing a value to the MQTT server.

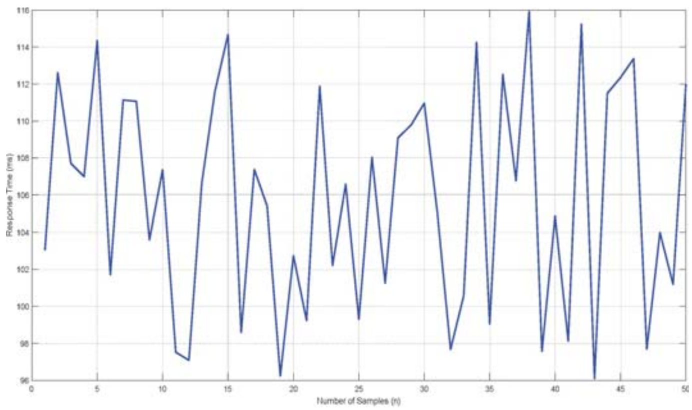

Fig. 5. Image message response-time after publishing a value to the MQTT server.

We are aware of the fact that the average published-subscribed latency in MQTT server is estimated to be 120ms and the data-transfer rate is limited, so our algorithm is executed in an accurate way according to the results. For real-time systems, similar to our work, this delay was adequate. Moreover, data loss did not occur after performing a series of data transfers.

VI. Conclusion and Future Works

In this paper, we have presented an AAL system, using ARCore library for Android operating system to assist people suffering from AD and make them live more independently through interaction. This system can be used by mild to moderate AD patients who perceive their disease as a memory impairment. We have also designed Android and windows application, which allow caregivers and family members to monitor the patient via IoT platform, so they can be notified with the aid of the environment sensor data values. In addition, the caregivers/family members are able to control the actuators' states, so that the patient can be reminded about different events such as medication time etc.

We conducted an evaluation of the AAL system to analyze its performance under several conditions. We found that playing audio message instead of displaying image message, had better performance and less battery consumption. However, using QR code to display AR image could decrease the response time while comparing to playing an audio message. The result showed that MQTT is adopted for a quick and reliable messaging transport among various devices.

In this study, we performed operational test and evaluation of the system. Our current plan is to implement our system on Google Glass for real-life scenarios of AD patient's daily-life who already uses paper tags placed in home by the family members.

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