Remote-Touch: Augmented reality based marker tracking for Smart Home control

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***Abstract*—People of physical limitations like old age people, physically disabled people, and autistic people face a lot of challenges to accomplish their daily tasks. It is hard for them to operate regular appliances (like fan, light, opening or closing the window) which may seem very casual for us who are physically blessed. Now a days touch based controlling has greater psychological impact on human mind. Touch uses the user's imagination power more. Driven by these key thinking, we have thought of a home appliance controlling system - touch based smart home which augments the users real life experience. In this paper we describe the development of a prototype that uses the augmented reality based on touch controlling system to control the daily home appliances in a smart home. We have used a smart phone to design the user interface, QR code to track appliances, web service to communicate between the central controlling system and a client app (the smart phone), through X10 to control the appliances physically.**

***Keywords*—Remote-touch, smart home, augmented reality, marker tracking, elderly care, SOA**

I. Introduction

Physically disabled or autistic or elderly; these classes of people often find that it is very difficult to operate their daily [1][2] appliances which might be very casual to other people. In our system, users use their smart phone to focus their desired object which s/he wants to control. The smart phone sends the image of the object to server through a web service [3]. A previously settled marker, the QR code [4] is then extracted from the image; upon reading the QR code system identifies the object through their ID numbers. Then upon user feedback that s/he wants to do either turn on/off or regulate (see Figure 1); by the server takes the physical actions instantly through the X10 [2] devices and the synchronized status of the device are saved to XML file.

Providing security and safety for elderly and disabled people is not new, many researchers have developed prototypes [1][2][3][5] that helps a real world event to continue of an easy life of elderly and disabled people. Their focus was to use modern technology like RFID [3][6], Bluetooth [7][8], SOAP [14][3], virtual 3D world [9] to control home services.

Using an assistive technology, Marine Chan developed [1] a smart home automation system that monitors the elderly and the disabled people. In their system, information is gathered from the elderly and the disabled people for whom the proposed system is used an array of sensors stay in a room. They used magnetic contact sensors, active or passive (IR) detector works to detect motion, temperature probes that control the limit of the temperature. Context and device states are important factors for device monitoring. User context depends on different factors such as the users current mood, appearance, activity, and so on. Hossain et al. [5] presented an ant-inspired framework for controlling smart home services in a dynamic context.

Hossain et al. [9] designed and developed a prototype to control and monitor a physical home. In order to bridge the gap between virtual and real life, they introduced virtual annotation mechanism for second life [9] object for physical space monitoring.

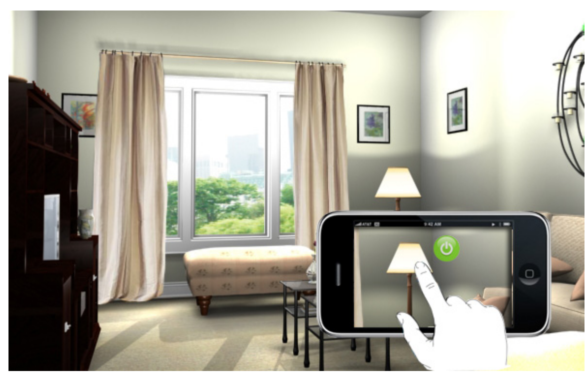

Fig. 1: A physical light control through remote touch using an iphone [10].

Interaction design is an important part for smart home automation. Different existing approaches like motion path based gesture interaction [11], voice based interaction QR [12] or barcode [13] based interaction and vision based interaction [11] are popular now. In the gesture based interaction an IR camera capture the hand gesture and later on match the drawing symbol with the predefined set of actions. In the QR code based interaction using a vision based camera the QR are detected and extracted the ID number for controlling the devices.

Augmented Reality (AR) has the potential way in which information is delivered to a user. Simon et al [14] proposed an approach focusing on the problem of developing mobile

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augmented reality systems in large, complicated environment.

Our contribution in this paper is three-fold. First, we presented an approach for controlling home appliances through remote touch. Second, we introduce the architectural design of the proposed system. Third, we evaluate our system in different metric and presented our developed prototype's results.

The remainder of the paper is organized in the following way: Section II describes our proposed system architecture for controlling home appliances through a usable user interface. We developed a prototype based on our proposed approach. Section III describes the implementation detail of this prototype. We performed different experiment using this prototype and the evaluation results are in Section IV and finally we conclude with our future goal in Section V.

II. Proposed System Architecture

Our system is organized in total four modules. Before proceeding further, we need to know about two key terms. QR code and X10. QR code; it was developed by Denso Wave. QR code is known as a kind of 2D barcode. It has some features like large capacity, small printout size and high speed scanning etc. It is comprised of following patterns like: finder pattern, timing pattern, format information, alignment pattern, and data cell .The QR-code images are specified by the specification: GB/T 18284-2000 (based on ISO/IEC 18004:2000). Now X10; it was first developed by Pico Electronics of Scotland in 1975. It is first general purposed domestic network technology and is widely used now. It is an international open industry standard for communicating among electronic devices. X10 is a protocol which works over our regular electrical wiring and need not to modify the regular wiring infrastructure.

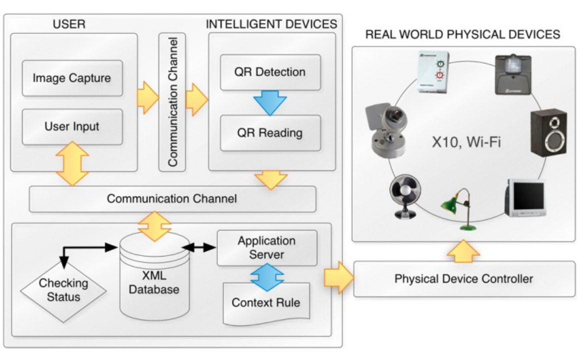

Fig. 2: Architecture of our proposed system.

In the installation process, we will tag a unique identifier to each device. Then a QR code will be generated for that identifier, the printed QR code will be sticked beside the device for later identification. After sticking QR, we need to install the X10. Figure 2 depicts our proposed system architecture.

1) Client module: Client module, is basically a smartphone enabled with flash light. Flash light is required to entertain the service under low light environment. User will focus his phone's camera towards the device s/he is intended to manipulate. Then we will have two approaches depending upon Internet bandwidth of the user. High bandwidth causes to select the server or low bandwidth causes to select the phone for QR detection. This is because analyzing an image to detect an object is a heavy task in the sense of computation and memory also.

2) Web service: Upon interpretation of the QR code the device will send the ID of the device or object to the web service. Or the web service itself will retrieve the ID from the image of the QR code.

3) Synchronization: The server will interact with the web service and the X10 device. It will store the current status of each and every device in an XML file (Figure 3). After detection of the object, it will provide feedback to the client module about the current status of the device and controls available for the specified device. For example a fan will have different regulation status while a light will have only turn on/off state. In our system, it has the option to select three states to control the devices.

4) X10 modules: Finally the X10 modules. This module works at the physical device controller layer of our framework. It will be connected to the server physically. The X10 will communicate with the client module via the webservice.

III. Implementation

We have implemented our proposed system in four phases. In our application a user first capture an image of intended appliance which s/he want to control and then from the server (normally) the QR code is detected and decoded; now from the XML database current status of a device is checked and a feedback is provided to the user. User chooses any one of the available options and the server then takes up the necessary physical action through X10. We used eclipse to develop the client side application as it was developed for android OS enabled smart phone. For the QR detection part, we used the ZXING API from Google [15]. We incorporated Visual Studio 2010 to integrate the API with our system. For the web service, we used Visual Studio 2010 as our web-service was in the .NET platform. The implementation details are described in following prototypes:

A. Android application

There is a client side application. It is an android application. The application was developed in eclipse using java. It grabs the images continuously and stop immediately upon finding a marker in the image. If it can successfully retrieve the object or device ID from the QR code in the image it shows the user corresponding available options.

B. QR Detection

QR detector detects QR either within the device itself or from the server. The QR detection was done using some built in algorithm from Google's Zebra Crossing API ZXING. In server, we have implemented it with the .NET web service and also for the android device as well. But it is to mention

Algorithm 1: Algorithm to detect and extract QR code from an image

```
Input: An image A: jpg or jpeg format
Output: Decoded QR code, S
begin
    ζ ← getLuminanceSource(convertToBMP(A)) ;
    bBitmap ← getBinaryBitmap(getHybridBinarizer(ζ)) ;
    if there are 3 rectangles containing 3 inner rectangle each in bBitmap
    then
        distanceList ← getRectangleDistances(bBitmap) ;
        if isQRCodeStandardDistance(distanceList, bBitmap) then
            α ← Decide the image as QR code and crop the surrounding
            area as a QR code;
            S ← getDecodedQRStringFromImg(α) ;
            return S;
        else
            step back and search for another three rectangles;
    else
        no QR is in the image prompt for another image;
    return null;
```

that the server always provides better performance than the client module. Algorithm 1 describes the QR detection of our system in an image. It takes an image as input. Then process the image and searches for QR in the image. If a QR is available, it decodes it and retrieves the ID of the object or the device; otherwise it prompts for another image.

```xml
<?xml version="1.0" encoding="utf-8"?>
<DeviceStatus>
   <object id="03421">
      <objectName>Light 1</objectName>
      <status>
         <turnedOn>false</turnedOn>
      </status>
   </object>
   <object id="03422">
      <objectName>Celing Fan 1</objectName>
      <status>
         <turnedOn>true</turnedOn>
         <regulationStatus>3</regulationStatus>
      </status>
   </object>
   <object id="03423">
      <objectName>Window 1</objectName>
      <status>
         <open>true</open>
         <sliding>false</sliding>
      </status>
   </object>
...
```

Fig. 3: Code snippets for XML file storing current status of the devices.

C. Web service

The web service was developed in .NET in visual studio 2010. It receives image from the client and detect QR and retrieve the ID of the object and provides necessary feedback to the user as string. It gets the details about the device or object that which device it is, its controlling options, current status etc. from an XML file shown in figure 3. Then again upon user feedback it get its job done by the X10.

D. X10 installation

Its installation is easy. A receiver was connected to the appliances and a transmitter was connected to the server PC. The server PC is provided the necessary command. We have designed our ID as seven digits. First two for floor, then three for room and last two digits is the address of the device. Say, 0403421 means 4^{th} floors 34^{th} room's 21^{th} device.

E. Device state synchronization

At this point we have an important issue about the device state synchronization. When the system receives a QR code successfully and retrieve that certain object is to be controlled, the system synchronizes all the devices those are pointing to the current object. Algorithm 2 illustrating the process of device state synchronization. The algorithm shows that it takes the decoded message from the QR code and send a confirmation or failure message to each device. It first enumerate all the devices which are pointing to a specific appliance at a certain time, then provides the updated status of that appliance to each pointing device. It then enque all the requests of the devices in a queue. If the system can successfully execute the command then it returns a confirmation message otherwise a failure message.

Algorithm 2: Algorithm to synchronize devices in real-time

```
Input: Decoded message from the QR code, S
Output: Confirmation or failure message, C
begin
    pointingList ← List all the devices pointing to S;
    retValue ← activatePhysicalDevice (S);
    if retValue is successful then
        α ← getUpdatedStateOfPhysicalDevice (S);
        Send α to the every pointingList;
        Send acknowledgement to the system;
        Cmd ← add the device manipulation command from each and
        every pointing device ;
        while cmd is not empty do
            Exe ← execute Cmd;
            return confirmation of successful execution;
    else
        return Message that - device initiation was failed;
    return null;
```

IV. Results

In this section first we have discussed about total systems time dependency, then every individual components time consumption and at last usability analysis upon the user feedback.

A. Response time

The response time of the system largely depends on the bandwidth, detection rate of the QR code, background of the image and X10 devices propagation delay.

$$R(t) = \alpha(t) + \beta(t) + x \tag{1}$$

Equation 1 is the response time of the system after triggering of the user command. Here $R(t)$ is the response time of the system, $\alpha(t)$ is the QR detection time, $\beta(t)$ is the communication time duration between client module and webservice and x is the X10 devices propagation delay.

Now, The QR code detection time; is proportionate to the noise in the image.

So, $\alpha(t) \propto \mu$, where μ is the amout of noise in the image. From equation 1 we found:

$$R(t) = \mu + \beta(t) + x \quad (2)$$

If $a(t)$ is the time that client module take and $b(t)$ is the time that web service take to communicate each other then.

$$\beta(t) = a(t) - b(t) \quad (3)$$

So from equation 2 and 3 we can say that:

$$R(t) = \mu + a(t) - b(t) + x \quad (4)$$

From the experiment we found out that the average QR detection time is $644ms$, average communication time duration between client module and web service is $249ms$ and average X10 propagation delay is $170ms$. So the response time of the system after triggering of the user command, $R(t) = (644 + 249 + 170)ms = 1063ms \cong 1.1s$

B. Processing time of different modules

In order to provide the user a real-time device control feelings, we measured the processing time of different modules. We measured QR detection time in image, communication channel delay and physical device controller delay. We measured total 10 times and the result is shown in Figure 4. From the figure we can see that the systems performance is largely dependent on the QR detection rate. So if we can improve the QR detection rate and high bandwidth is available then the performance will increase a lot. The X10 device's propagation delay is negligible.

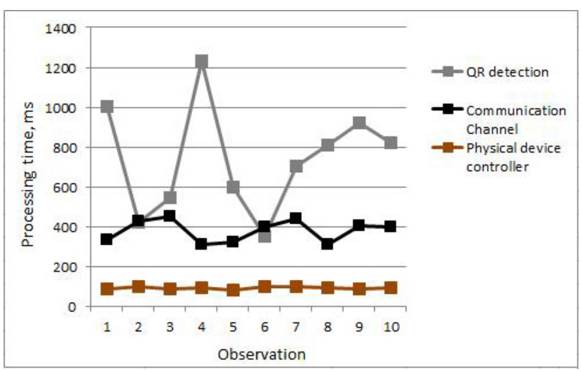

Fig. 4: Processing time of different modules.

C. Usability Analysis

We have done the usability evaluation [16] of our system. We provided the users with a smart phone, enabled with our system and asked them control a light or a fan using the smart phone. Our used smart phone was Samsung Galaxy Y S5360 and it has 2 mega pixel camera, operating system is Android OS, v2.3.5 (Gingerbread). After the users experimental use we asked them some questionnaires. The questionnaires are given in Table I.

TABLE I: USABILITY TEST QUESTION FOR THE USER

#	**Questions**
Q_1	The system is easily adaptable
Q_2	Response rate is satisfactory
Q_3	Beneficial for disabled and paralyzed
Q_4	Consider using the system in your daily life

Finally based on their feedback we prepared a graph which based on Likert Scale (see figure 5). From the figure we can see that a large number of people 40% is agreeing that people can adapt easily with our system. They also agree highly that our system is beneficial for the physically disabled and paralyzed people, also number of people consider to use our system in their daily life.

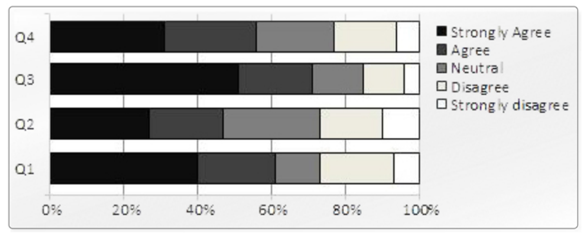

Fig. 5: Usability study based on the questioner listed in Table I.

V. Conclusion

In this paper we presented an approach to control regular home appliances. We presented that a user could control his/her home appliances using a smart phone associated with our prototype system. The system is very much viable for the physically disabled or sick or the elderly people. Our system was developed maintaining the SOA (Service Oriented Architecture) approach; so it is loosely coupled. Users always have the option to customize any individual module as per demand. Based on the user feedback which we took through our experiment; in future we want to increase the range to detect the QR, improve the QR detection time so that user can have more real time controlling feels and also the detection accuracy of QR as well.

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