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# Virtual Assistant Centric Home Automation System

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**ABSTRACT:** Home automation is the process of building automation for a home. A home automation system incorporates the functionalities of finding and registering smart devices on a home network, and providing the capacity to communicate with and control said devices using a set of human interface devices such as mobile phones, smart speakers, computers, etc. The system proposed here-in implements an XML based communication protocol to identify smart devices and share meta data of the smart device for automated device discovery and integration to enable simplicity in setting up the home automation network. The system also provides a virtual assistant centric human interface system to enhance the user experience using graphics, TTS software, voice detection and computer vision.

**KEYWORDS:** Home automation, Smart home, Computer Vision, Human Machine Interface.

## I. INTRODUCTION

Building automation for a home is referred to . It enables the automatic control of electronic devices in one's home. These devices are connected over the LAN or the internet to human interface devices that act as control interfaces for an end user to communicate with and control connected smart devices. With home automation devices can trigger one another thus eliminating the need for a user to manually provide input. Home automation often also implements voice control to allow for ease of access. The modern requirement of home automation stems from the wide spread usage of smart electronics and is backed by the rise in AI based technologies such as voice recognition, voice synthesis and computer vision. The increase in computational power has empower home automation systems to play a larger role in day-to-day activities at home.

The benefit of the system described here-in is the automated device discovery and capability registration at the central server through XML based LAN communication. This streamlines and automates the setup process and expansion of the home automation network with new devices being registered automatically. The implementation of XML messages also enables the devices to describe their capabilities to the central server allowing for seamless integration to the voice-based control system through the implement of NLP based command parsing. This system is integrated with the front-end consisting of a graphical rendition of a home assistant persona for improved user experience.

Paper is organized as follows. Section II describes home automation technologies as well as the systems currently implemented in homes. The block diagram describes the high-level design of the system. The general methodology used in the proposed system is given in Section III. Section IV presents experimental results of the implementation of the proposed system. Finally, Section V presents conclusion.

## II. RELATED WORK

The Smart home known as House automation, with the use of new technology, to make the domestic activities more convenient, comfortable, secure and economical [1]. The main components in home automation systems are:

- User Interface
- Mode of transmission
- Central Controller
- Electronic Devices

Currently a variety of open source home automation systems exist such as [2]:

- OpenHAB
- Home Assistant
- Domoticz
- Calaos

Some of the early challenges faced by home automation systems include high manufacturing costs, high development costs, lack of home automation standards, consumer unfamiliarity with technology, etc. [3]

Smart home automation exemplifies a smart environment constructed from various cyber-physical systems that produce vast quantities of heterogeneous, complex, and dispersed data from numerous sensors and applications. As a result, home automation is a demonstration of an Internet of Things (IoT) setting, where a communication network expands the current internet by integrating everyday items and sensors, In this case, it includes the possibility to optimize energy usage[4].

One of the greatest advantages of a home automation system is that it can be controlled and managed easily from an array of devices such as smartphones, tablets, desktop, and laptops.[5]

Over time, billions of devices are expected to leverage Internet of Things technologies by implementing internet-enabled features. As such, device discovery plays a more relevant role in the field as it's the task of finding relevant devices to perform a specific job. [6]

There's a balance between power consumption and the quantity of devices which can be operated on an IoT system. A greater quantity of redundant devices discovered implies a more stable environment [7]

### III. METHODOLOGY

The proposed implementation of the system described in this paper is as illustrated.

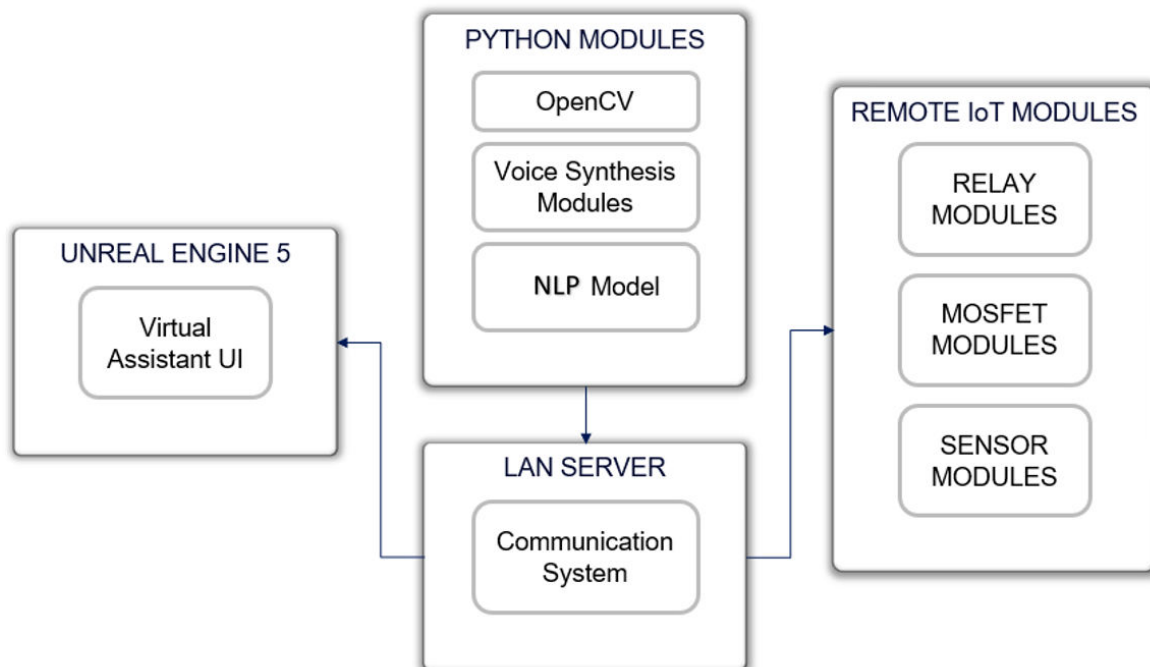


Fig. 1. HIGH LEVEL DESIGN

The system consists of 4 high level modules:

- **UE5 Application:**  
This module handles the visual elements of the human interface. Implementing a 3D graphics engine, it displays a persona of a virtual assistant.
- **LAN Server:**

A local central server which servers as a control and coordination system which receives input from all Human Interface Devices and sends control messages to the smart devices being controlled.

**Remote IoT Modules:**

A sequence of independent smart devices which can be controlled wirelessly by the central server.

**Python Modules:**

Consisting of the python module handling the AI/ML backed components of the system i.e the voice communication and recognition, Language model and computer vision elements.

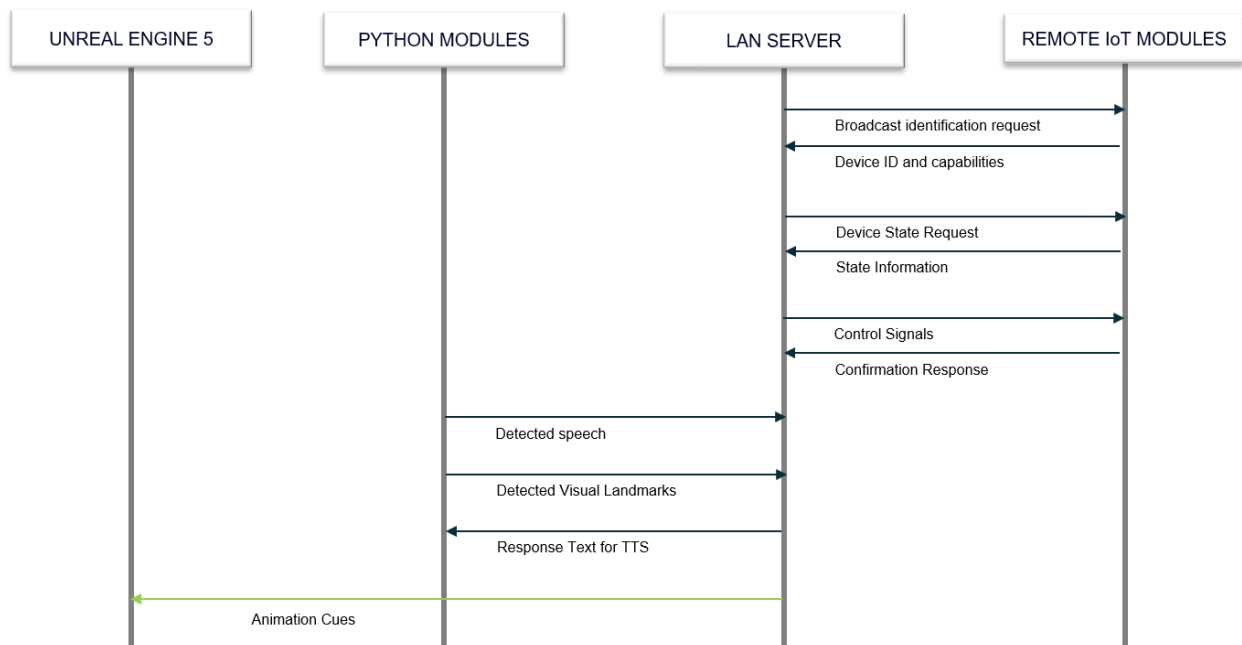


Fig. 2. NETWORK COMMUNICATIONS

The course of device discovery and identification involves the broadcasting of a message over the LAN connection to which all compatible devices respond with a message containing its MAC ID as well as device capability information stored on the smart device itself. This information includes device’s common name (such as: switch, relay, button, etc) as well as the actions supported and common state names (such as: Turn, Switch, Lower, On, Off, etc).

The data gathered from the devices is stored at the central server which then accepts the voice commands as detected from the python modules. The commands are parsed and the appropriate command is sent to the required devices. The system is also capable of generating appropriate responses to user cues through the implementation of an open-source language model.

Throughout the process, the server also communicates with the Human Interface device with relevant animation cues required to render an interactive virtual assistant for a User Interface.

**XML Descriptor:**

Each Remote IoT Module implements an XML based descriptor of it’s own functionality as well as identifiers, descriptions as well as actions that can be performed by the device for automatic integration into the NLP based command parser. An example of an XML descriptor is as follows:



```

1 - <DEVICE>
2   <TYPE>LIGHT</TYPE>
3   <ACTIONS>
4     <ACTION>
5       <WORD>TURN</WORD>
6       <VALUES>
7         <KEY>ON</KEY>
8         <KEY>OFF</KEY>
9       </VALUES>
10    </ACTION>
11    <ACTION>
12      <WORD>SWITCH</WORD>
13      <VALUES>
14        <KEY>ON</KEY>
15        <KEY>OFF</KEY>
16      </VALUES>
17    </ACTION>
18  </ACTIONS>
19  <ADJECTIVES>
20    <ADJECTIVE>LED</ADJECTIVE>
21    <ADJECTIVE>BLUE</ADJECTIVE>
22    <ADJECTIVE>NEON</ADJECTIVE>
23  </ADJECTIVES>
24  <NOUNS>
25    <NOUN>LIGHT</NOUN>
26    <NOUN>STRIP</NOUN>
27    <NOUN>LED</NOUN>
28  </NOUNS>
29 </DEVICE>
    
```

Fig. 3. XML DESCRIPTOR

NLP Based Command Parsing:

The implemented system uses Semantic Role Labelling (SLR) to segment a command based on what role each word plays with respect to its relation to a predicate and the related properties. These relations are based on a list of pre-determined semantic roles of the given predicate.[8] Segmentation of this kind can be used to relate a command to a specific device registered on the network as well as to determine the control signal to be transmitted to the device by cross referencing the XML descriptor of the device’s capabilities shared during the discovery phase of the device.

An example of Semantic Role Labelling has been demonstrated below with the parse tree constructed for the sentence: “She should decrease the prednisone by 1-mg weekly” [9]

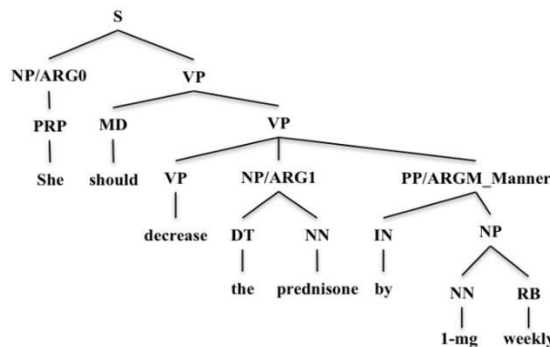


Fig. 4. SEMANTIC ROLE LABELLING

Semantic Role Labelling has been implemented using the Natural Language Toolkit for python which is a leading platform for working with human language data using python scripting. [10] Once the command has been parsed, if the parsing has yielded a relevant device as well as a recognised action relevant to said device, the command is then sent via LAN UDP communication to the device and is executed on the devices end.

IV. EXPERIMENTAL RESULTS

```
Broadcasting Discovery Message...
Received Device Information From : 192.168.1.188
Descriptor:
{
  "DEVICE": {
    "ACTIONS": {
      "ACTION": [
        {
          "VALUES": {
            "KEY": [
              "ON",
              "OFF"
            ]
          },
          "WORD": "TURN"
        },
        {
          "VALUES": {
            "KEY": [
              "ON",
              "OFF"
            ]
          },
          "WORD": "SWITCH"
        }
      ],
      "ADJECTIVES": {
        "ADJECTIVE": [
          "LED",
          "BLUE",
          "NEON"
        ]
      },
      "NOUNS": {
        "NOUN": [
          "LIGHT"
        ]
      }
    }
  }
}
```

(a)

```
Command : switch the blue light off.
Semantical Roles : [('switch', 'VB'), ('the', 'DT'), ('blue', 'JJ'), ('light', 'NN'), ('off', 'RP'), ('.', '.')]

Target Device : ['blue', 'light']
Action Required : ['switch']
Value : ['off']

Device identified at : 192.168.1.188
Sending Command : { ACTION : SWITCH , VALUE : OFF }
```

(b)

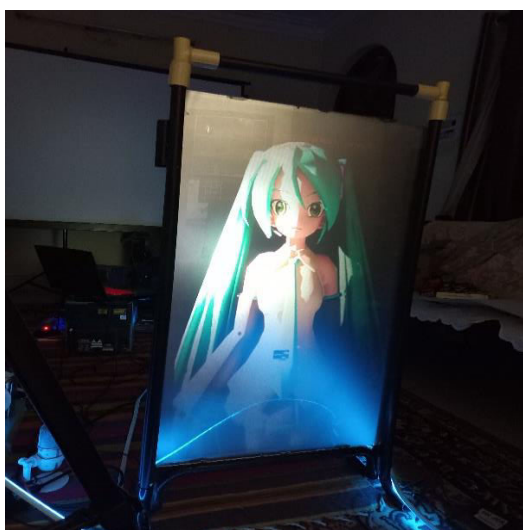
```
Command : Turn off the blue light.
Semantical Roles : [('turn', 'VB'), ('off', 'RP'), ('the', 'DT'), ('blue', 'NN'), ('light', 'NN'), ('.', '.')]

Target Device : ['blue', 'light']
Action Required : ['turn']
Value : ['off']

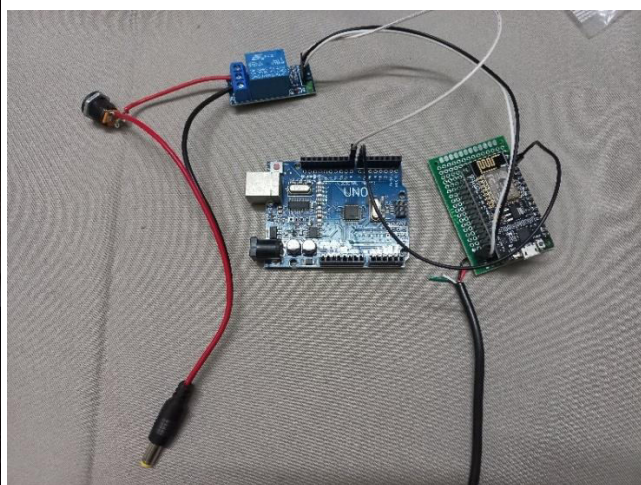
Device identified at : 192.168.1.188
Sending Command : { ACTION : TURN , VALUE : OFF }
```

(c)

Fig. 5. (a) Broadcast discovery message and device identification, (b) & (c) Semantic Role Labelling of Natural Language Command



(a)



(b)

Fig. 6. (a) 3D Rendered Virtual Assistant projected using Pepper’s ghost method, (b) IoT Relay Module consisting of a NodeMCU for WiFi communication, Arduino Uno for 3.3v to 5v Level shifting and Solenoid Relay for circuit switching.



## V. CONCLUSION

We have implemented a virtual assistant centric home automation system which implements XML based device discovery and identification. The system provides a simple approach to setting up a home automation network by autonomously identifying smart devices connected on the Local Network. We've also integrated it with a 3D rendered user interface implementing CV and Speech recognition. The system has demonstrated the capability to identify and communicate with smart devices without manual setup with relevant commands provided verbally.

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