3D Virtual ‘Smart Home’ User Interface

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Abstract – In contrast to the rapid development of home automation equipment and ‘smart home’ capabilities, comparatively less attention has been paid to the development of comprehensive, comfortable and self-explaining user interfaces. This is acknowledged to be an important obstacle for the broad success of smart home ideas and products. In order to make home automation desirable and economically feasible, it is vital to improve the attractivity, intuitivity and adaptivity of the user-home interaction taking advantage from modern information technologies such as Virtual Reality technology and downloadable hypertext documents. The user interface is augmented by the use of a virtual environment in conjunction with the physical environment adding information from different systems and sensors in the home, based on virtual environment activities. In this paper we describe a powerful graphical interface created with standard 3D programming tools to control and supervise the household. A number of features implemented in a prototype and implementation aspects will be described.

Keywords – home automation, graphical user interface, 3D virtual environments

I. INTRODUCTION

Concepts and efforts in the field of home automation generally focus on (1) security issues, (2) environmental issues (energy savings, indoor air quality), (3) comfort and entertainment issues [1-4]. The hardware infrastructure of ‘smart’ homes consists of a large variety of different networked sensors, actuators and systems, which interplay in a defined manner. However, with growing complexity of the overall system, the existence of a comprehensive, easy-to-use interface to supervise and control the network and its appliances gains significant importance. The Man-Machine-Interface (MMI) is often acknowledged to be the most sensitive area for the acceptance of home automation systems. Desired features of a user-friendly MMI are:

• The user interface gives a clear and intuitive imagination about the home environment, e.g. by geometrical view,
• the system structure is easy to configure: new elements are easily added or removed without changing the overall structure,
• the system is adaptable to the user’s needs and desires,
• remote control of the home equipment should be possible.

Commonly, smart home graphical visualization tools are still based on familiar windows, icons, menus, and point-and-click (WIMP) interfaces. Flexible, adaptable and more universal interfaces are still an open issue. One of the promises of information visualization research has been to overcome human cognitive limitations via advancements in visualization techniques. Visualizations of complex relationships could enhance the user abilities to handle the increasing amounts of information available to them more quickly and user-friendly.

With the tremendous increase in affordable computation power, new approaches for a similar universal interface for 3D environments are pursued. For specific applications, individual interfaces can be developed taking into account user-specific settings and learning processes. Hence, Virtual Reality approaches combined with an user-centered design of ‘post-WIMP’ interfaces can provide increased access, convenience, and efficiency.

II. VIRTUAL 3D ‘SMART HOME’ USER INTERFACE

In our SmartHOME Lab on the University Campus site, Fig. 1, a networked smart home environment has been established comprising a multi-bus network topology for specific system (lights, blinds, heaters, ventilators etc.) and a fully redundant data acquisition system (data loggers, data base, control and backup computer) [5,6].

For the user, it is highly desired to have the current state of all system intuitively displayed on a graphical screen [7,8]. For this purpose, a sophisticated 3D virtual smart home environment has been designed. A Virtual Reality (VR) Java (with Java3D classes) based software application has been estab-

Fig 1: View of the SmartHOME Lab
lished and its usability in the smart home environment has been tested. The visual model of the house and its rooms with assigned sensors and actuators replaces the WIMP approach and enables the user to have the sought data from a structured information database properly visualized.

The evolution of virtual interfaces has led to an important human-computer interaction medium which has the potential to present the ‘ideal’ interface between the user and a computer mediated, multi-dimensional virtual environment [9,10,11]. A virtual reality system has a number of inherent properties that makes it an ideal interface for home automation control as well, namely:

- Real-time interaction
- Direct manipulation of virtual objects
- Multi-modal interface capability (gestures, speech, faces etc.), though not yet fully exploited today
- Delivery of a sense of presence or ‘being in the environment’
- Ability to change user’s scale in time and Cartesian space
- Improved situational and spatial awareness
- Reconfigurable environment

With a VR approach, the user fully benefits from the advantages of the 3D view design: instead of abstract objects labeled ‘room 1’, ‘light left’ or ‘heater 2’ and a hierarchy of windows, icons and data files, a realistic view of the house with its structural components like rooms, stairs, windows will be given to the user, Fig. 2. All the house equipment and functions to be controlled (lights, heaters, ventilators, blinds, indoor climate control sensors and settings etc.) will be displayed with realistic spatial localization and context and with direct access without a multi-level hierarchy.

**Object Oriented Structure**

Since the interface will be connected to a physical model of a house consisting of a combination of rooms with its specific parameters, an Object Oriented Structure (OOS) is used presenting the structure in a clear way on code level, enabling easy modifications and extensions. A node can simply be added and the rest of the interface will not be affected. The implementation makes use of the leaf class which forms the parent for all domestic appliances implemented. The basic object type ‘room’ comprises a realistic 3D view of the room and includes several module objects corresponding to certain parameters, functions or equipment of the room. The room class can be extended by all the different instances of rooms and in those classes, the domestic appliances for that room will be instantiated. The module (M) class is the link between the central data base and the associated tool or functionality. All modules have the same structure, but with different contents depending on the application. A module can have different representations:

- 3D view (e.g. of a room, an equipment),
- Text sheet (explanations, instructions),
- List (several systems in a room, combined in a group),
- Dialog menu (manual settings),
- Speech dialog - not yet implemented.

The contents and the dependencies between different systems in each room is defined by the user through a special editor.

Finally the OOS makes use of the house class. This class combines all rooms and all domestic appliances. It gathers all information of the connected rooms and thus creates statistics for the entire house. If additions of domestic appliances occur, only a new class file for this appliance needs to be created. The appliance then has to be put in the room to which it is connected. No further modifications have to be made. The same is valid for the addition of rooms; only in the house class, instances need to be added. Fig.3 displays exemplarily the used structure including some selected 3D views of rooms and domestic appliances.

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Fig. 2: Virtual 3D presentation compared with common solutions
III. INTERACTION WITH HOME APPLIANCES

One of the most important features of the interface is the interaction with the domestic appliances in the household. The user can view consumption values and manipulate appliances, like turning lights on or off or moving blinds up and down. The user can perform actions in three ways:

- **Push buttons**: On one of the control panels, the user can find push buttons to view and/or manipulate domestic appliances.

- **Text**: Making use of a simple shell tool, the user can type commands. Also in this shell tool, messages from the server are shown. These messages may tell the user whether something is wrong in the household.

- **3D Virtual Reality**: The interface optionally displays the rooms in the house in a three-dimensional way, using a Virtual Reality interface. Appliances are represented as simple objects, via which the real appliances can be selected.

The most interesting feature of the VR smart home representation is the spatial localization of the home automation systems and other equipment like in reality in the house. From a general 3D view of the house, the user can choose the interesting object among all different functions simply be clicking it with a finger or pointer on the touch screen of the visualization surface. From the clicking point the system projects a beam into the house structure and highlights all objects lying on its way together with their labels displayed in a separate menu. Because all rooms appear transparent on the display, even objects hidden inside the building can be easily picked up this way, Fig. 4.

![Fig. 4: Choosing an object in the 3D world](image)

**Intuitive Interface**

The graphical interface should be user-friendly and intuitive. There are several methods to make software intuitive. The layout of the screen is of great importance. The screen should not be a puzzle. Instead, everything should be located in an organized way. Simultaneously visible functions have to be kept to a minimum by making use of various sub-functions. The interface uses images to make even more clear what is meant by all features. For instance, if the user asks for the consumption values of the heater, a graphical display of the values is shown next to the picture of a heater.

After loading the visualization software, a graphical interface like the display menu in Fig. 5 is created. The display center is reserved for the 3D views of the house or rooms. A pop-up menu (area 1) shows the hierarchy structure of all rooms for better orientation and easier room selection. All graphical objects can be rotated in different axes manually with a pointer on the touch screen. In area 2, the tilt angle and transparency level can be set. For complex context menus (e.g. stored cameras pictures, last telephone calls etc.) an icons can be activated (area 3). Current settings of sensor data (e.g. outdoor or room temperature, humidity, CO2 concentration, number of persons in the room etc.) will be displayed in a separate area (area 4). Using a control menu (area 5), devices like lights or jalousies can be controlled. On a large text field (area 6) additional context information (e.g. recommendations considering heater settings or warnings) will be displayed.
IV. IMPLEMENTATION

With tools based on de facto Internet standards an application-invariant architecture is built. The combination of Java2 with Java3D software libraries [12,13] enables the 3D visualization independently of the platform directly on a Web page.

In Fig. 7, the structure of the data acquisition system is shown. The visualization software consists of the Server part running on a Web server, and a Client part. Minimal hardware requirements are:

- 500MHz Intel® Celeron™
- 128MB SDRAM
- 500MB HDD
- 3D accelerator with 4MB VRAM
- Internet Browser with Java 1.3.1 Plug-in & Java 3D libraries

For mobile applications, a wireless network (e.g. Siemens I-Gate 11Mbit) and a Pen Tablet PC have been used.

Fig. 5: Example for a graphical interface of a room

Objects belonging to the same class can be highlighted with a simple click, e.g. all light on a floor and their settings (on/off in different colors), see Fig. 6.

Fig. 6: Highlighted objects
V. CONCLUSIONS

In this paper we described the SmartHOME User Interface, a working prototype for an interface to an automated household. We described a number of implemented features together with some implementation details. As a conclusion we believe this kind of interface to have a very high potential in the near future. Main reasons for this are that it is based on standard tools and thus can utilize advances in other information technology areas and that client software is very powerful and intuitive.

REFERENCES