The CUSTODIAN Tool

Simple Design of Home Automation Systems for People with Special Needs

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1 Introduction

Higher autonomy at home for people with special needs plays an important role in the growing public demand for home automation systems. This is particularly important in the context of a continent where life expectancy is very high and better medical care helps to extend the life of people with severe disabilities. The opportunity to improve the quality of life for this sector of the European population constitutes a challenge for the home automation market, in particular because the target users (including care providers) are willing to assess the usefulness of this technology, but the current generation of development tools were designed only for the technically-skilled professionals.

Home automation products for the consumer electronics market are able to successfully replace proprietary environmental control systems for people with special needs, bringing the advantages of automation within reach of a much wider group of users. However, the development and validation of home automation systems is still confined to the technical community, due to the lack of tools that are effectively able to hide the complexity associated with the underlying technology.

In this paper we describe a tool that is being developed with the objective of facilitating the design and validation of home automation systems, particularly for people with special needs. The CUSTODIAN tool enables design and validation activities to be done at a higher functional level and technology-dependent software modules are employed to generate a technical specification compliant with the target home automation technology. A more detailed presentation of the motivation leading to this project is presented in section 2, followed by a description of the project consortium and technical setup, presented in section 3. The core features of CUSTODIAN, and its technology-dependent features for the EIB technology, are presented respectively in sections 4 and 5. Section 6 presents an application example to illustrate the operation of the tool, and a concluding section summarises the work done so far and the future developments that are envisaged.

2 Motivation

A great potential in the daily lives of disabled and elderly people and for those providing services to them has been envisaged for the integration of a whole range of assistive technology and general systems on home networks. The key purchasers of such systems will be the Local Authorities, Community Care Providers, Housing Associations and other specialist service providers. These organisations will not have, nor desire to have, the necessary technical expertise that can specify a system that meets the needs of their clients (disabled or elderly people) and then source and integrate the products to construct it. This brings about the need for a software tool that allows the design of home networks without requiring the users to have a specialised technical background. Thus, it will be possible for the design to be carried out directly by those specialists who are best prepared to deal with clients with special needs, such as occupational therapists, project co-ordinators of housing associations, etc.

The detection of design errors while still in the design stage is necessary to ensure that

the purchased and installed equipment in fact meets the client's needs. The involvement of the client in the design process is also essential to decrease the chances of partial rejection of the final installed system. This results in the need for the inclusion of visual simulation capabilities in the envisaged software tool.

An accurate translation of the system design to an EIB Tool Software project is necessary to ensure that the installed EIB-based system will exhibit the exact functionality initially devised by the non-technical specialist in co-operation with the client. This brings about the need for a software module that aids the user in performing this conversion.

3 The CUSTODIAN project

The CUSTODIAN software tool is being developed within the scope of the CUSTODIAN project (Conceptualisation for User involvement in Specification and Tools Offering the Delivery of system Integration Around home Networks), which is an E.U. funded project to be carried out in the framework of the Telematics Applications Programme between 1 January 1999 and 31 December 2000 [1].

The CUSTODIAN project is primarily concerned with the introduction of Smart Homes technology to non-technical users. In addition, it acts as a design aid and support for the specification and evaluation of Smart Home networks. The CUSTODIAN tool is a visual, easy-to-use, intuitive yet efficient and flexible tool that simulates Smart Home networks prior to their physical installation.

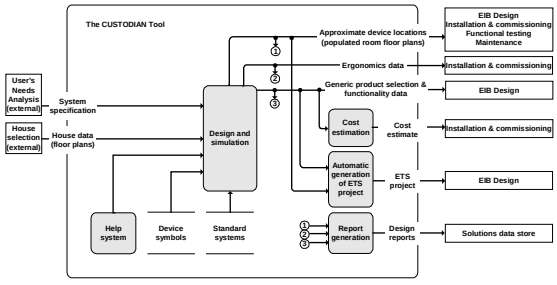

Figure 1 – Main modules of the CUSTODIAN tool

Figure 1 is a level-0 "Data Flow Diagram" that depicts the main modules of the tool and the flow of information between them.

3.1 The consortium

The Robert Gordon University (UK) co-ordinates the consortium and participates in the technical development work. The University of Reading (UK) is responsible for the development of computer based models and takes the lead in the software development tasks. FEUP, the Faculty of Engineering of the University of Porto (Portugal), takes charge of the translation of identified users' needs into the system's definition and undertakes system-wide specification and user interface design. EIBA, the European Installation Bus Association (Belgium), is responsible for ensuring the successful integration with their existing tools and takes part in the dissemination and exploitation work, in order to engage a wide range of industry interest into the project. The Edinvar Housing Association (UK) co-ordinates the initial collation of users' needs and system's definition and, together with the Tayside Consortium (UK), carries out a detailed consultation process with regard to the provision of home network solutions for the elderly and disabled people.

3.2 Technical set up

Microsoft Visio 2000® is a business diagramming application that aids the creation, editing, storage and sharing of diagrams. Its built-in support for Microsoft Visual Basic for Applications (VBA) 6.0 lets developers enjoy easier coding and better inter-application development support simplifying the integration of any custom solution written in Visual Basic, Visual C++ or any other programming language that supports automation [2]. Through automation, an extensive collection of objects, methods, properties and events are exposed. Thus, programmers can access not only all of Visio's built-in functionality but also enhance it with new custom functionality as needed, by inte-

grating add-ons and external applications. The Visio 2000® environment also enables two key features: the tool complies to the standard Windows interface that most PC users are already accustomed to; and developers primarily focus on the tool's core functionality implementation.

The CUSTODIAN tool is distributed in a Visio "stencil" file. This stencil file contains both the application code and a collection of EIB-compatible technical representations of "smart devices" (such as actuators and sensors) that can be programmed to interact and used to create or modify a Smart Home network. Additional stencil files that contain user-friendlier visual representations of smart devices are also shipped. Users are free to create their own representations of smart devices or even create custom libraries of their own. Due to its ability to match the user's personal preferences, the CUSTODIAN tool can be used as an effective demonstration application of Smart Home networks.

4 CUSTODIAN – The core features

The technology-independent features of the CUSTODIAN tool are presented in this section. Design and simulation support, libraries provided (standard systems, device symbols), report generation and help facilities are described by this sequence.

4.1 Design and simulation module

The user designs a Smart Home network by simply selecting smart devices from stencils and dropping them on the drawing area, as depicted in Figure 2. All the common edit commands (Cut, Copy, Paste, Duplicate, etc) can be safely performed on single smart devices or entire selected groups.

Visio pages can also be inserted to represent different rooms of a house and architectural floor plans can be imported onto the pages to serve as guidance.

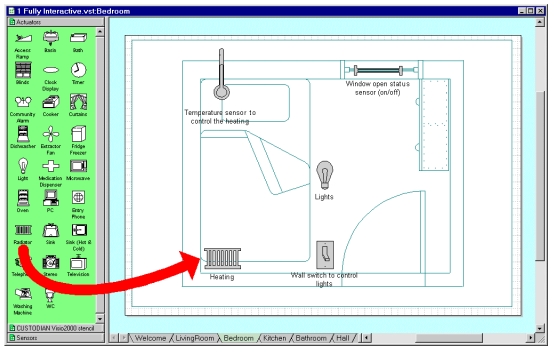

Figure 2 – Drag-and-drop of smart devices from a stencil to the Smart Home project

Once the design and layout of the network is completed, the properties of each smart device are instantiated. The user enters general details, physical installation details, binding details and device functionality. General details consist of a short description of the device (to help distinguish among similar devices in the network) and any useful comments the user may wish to include. Physical installation details contain ergonomics information about physical positioning in the home. As an example, Figure 3 shows the section on physical installation details, in the dialog that bears the properties of a selected device. Binding information is used to bind devices together so that if the user removes a device from the network the tool can automatically detect which other devices should also be removed.

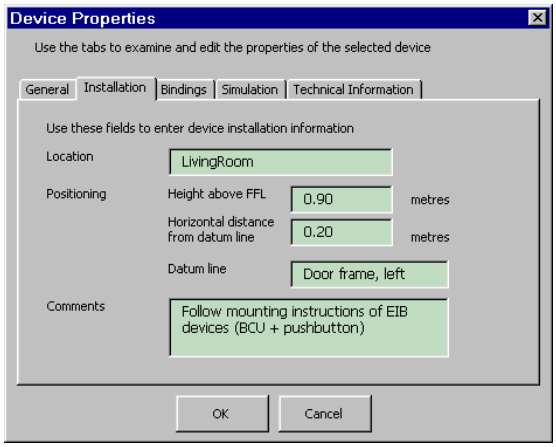

Figure 3 – Installation details section in the Device Properties dialog

The functionality of each smart device is specified by entering the logical condition that must be TRUE for the device to be ac-

tivated (otherwise the device is deactivated). This condition is called *Simulation Condition* and may be any binary expression that can be evaluated to either TRUE or FALSE. Binary operands can be smart devices, "states" or any comparison operation that includes Time functions. Figure 4 presents the dialog that allows editing the functionality of a selected device in the network.

States are binary flags that indicate whether a certain condition holds or not in the network, and therefore are different from a single device's status. For example, when a button is pressed the state TurnOnLights is set to TRUE, to indicate that the button has been pressed and therefore lights should come on. The introduction of "states" is an invaluable feature as it creates a level of abstraction and enables complex interactions of devices to be expressed more simply. Users do not need to calculate complex binary representations to indicate when a device should be ON and when it should be OFF. Rather, they specify a binary expression with triggering state(s) (any other valid binary operand can also be used in conjunction) and the network simulation module decides whether a device should be activated or not. During the programming of a device the user specifies how and which states are affected upon activation and deactivation of the device. This feature of the CUSTODIAN tool allows users to easily replace a device with another one or even directly import whole subsystems from one network to another. Moreover, states make it possible to model actual control sequences in the network, as opposed to merely combinational interactions.

The simulation module of the tool is responsible for the propagation of any changes that occur in the devices until the network settles down to a new condition. During this process, each smart device in the network modifies its status as appropriate. When a device changes its status, the simulation module is notified by means of a message. The process continues until all devices have settled down to their final status. In case the network cannot stabilise due to a user-programmed "livelock", the user is notified and the simulation process is terminated so that the network can be debugged.

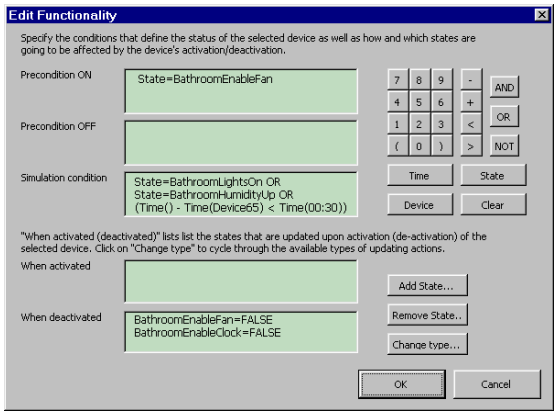

Figure 4 – Edit Functionality dialog

The Time functions offer the user the ability to configure the network to behave differently depending on the time of the day. The Time() expression returns the simulated time of the day. Time is being simulated by means of an ActiveX control that can be embedded into any network, presented in Figure 5. The Time(Device) expression returns the time of a device's last activation. This feature makes it possible to program built-in delays or to program actions to be carried out at specific times.

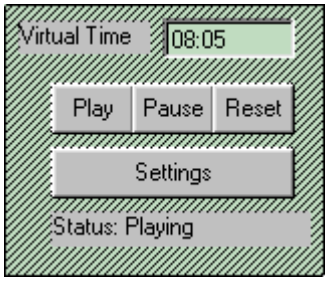

Figure 5 –ActiveX control that simulates time

Another useful feature that the CUSTODIAN tool introduces is the ability to define safety operation rules, by entering two additional conditions that define the functionality of a device. Only when the first condition (named *PreconditionON*) evaluates to TRUE is the device capable of being activated. Similarly, only when the second

condition (named *PreconditionOFF*) evaluates to TRUE is the device capable of being deactivated. In case both of these conditions evaluate to FALSE the tool overrides the *PreconditionOFF* condition and the device is deactivated.

4.2 Library of standard systems and library of device symbols

The specification of Smart Home systems from scratch every time, in addition to replicating 90% to 95% of the design effort, also repeats the risk of omitting vital components and generating a specification that requires a great deal of further integration work [2]. For that reason, a range of four standard home networks for people with disabilities has been devised and is briefly described in the following paragraphs:

- Fully Interactive: the occupant exercises full control over the operation of the house and services and the automation features are minimal. This type of Smart Home network is suitable for people with physical disabilities and for elderly people with low care needs.
- Automated: a safe and secure environment is provided for people with mental impairment (learning difficulties, brain injuries) and who are mentally stable (excludes schizophrenics, potential suicides, and very severe dementia).
- Moderately Interactive: the occupant is provided with some control over the operation of the house and services. This type of Smart Home network is suitable for elderly people with moderate to high care needs or for people with moderate dementia.
- High Visual Impairment: this standard home network solution is derived from a Fully Interactive system and represents the essential core of a Smart Home System. [3]

Project templates have been implemented for these standard Smart Homes. Figure 6 shows a detail (the Bathroom page) of the template for the Fully Interactive standard system. For each individual case, a standard project template will be chosen and then shaped to the client's needs through some *manipulation* (of the selection of devices, approximate location of devices and the system's functionality).

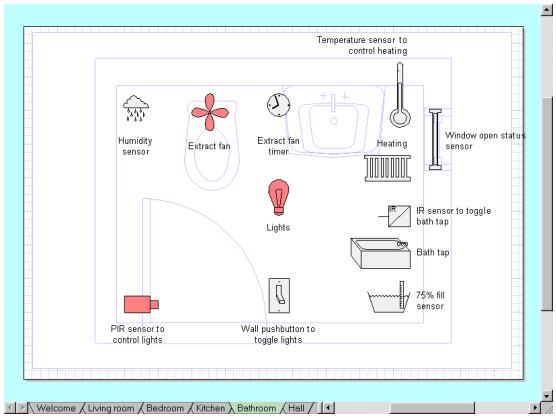

Figure 6 – Detail of the template for the Fully Interactive standard system

The tool also provides the user with a library of smart devices, arranged in a number of stencils. New devices can be dragged-and-dropped from the stencils onto the project under design. The friendly symbols used to represent smart devices are still being improved, in order to optimise recognition by all potential users and clients. Device palettes for Sensors and Actuators are shown in Figure 7.

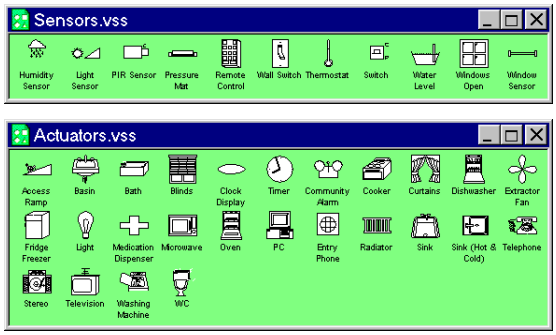

Figure 7 – Device palettes for Sensors and Actuators

4.3 Report generation feature

The text report generated by the CUSTODIAN tool is divided according to the functional areas of the house (bedrooms, kitchen, bathroom, etc), containing information about all the devices installed in

each area. For each device, the information provided is divided into four sections, namely ‘General information’, ‘Bindings’, ‘System's functionality’ and ‘Installation’. Figure 8 shows the initial sections of a sample text report.

Figure 8 – Detail of text report generated by the CUSTODIAN tool

In the future, the report generation module will be enhanced to provide a report "wizard". This "wizard" will let the user decide which information should be included in the report and how to structure it, so that different kinds of reports may be created for different purposes, such as the EIB design, the procurement of equipment, the installation process, etc.

4.4 Help system

The tool features a help system, which provides the user with online information on how to get started with the tool and how to design and simulate Smart Home systems. Example tutorials are included as well.

The help system is accessible to the user through an HTML Help Viewer. Microsoft® HTML Help is the standard help system for the Windows platform. The Help Viewer uses the underlying components of Microsoft Internet Explorer to display help content [4].

5 CUSTODIAN – Technology-dependent features

All the features described in the previous section are technology-independent. However, and once the required system functionality is achieved and validated by the user, it should be translated into a given smart home technology. Technology-dependent modules are therefore also present in the CUSTODIAN tool, in an architectural set up that was envisaged to support commercially available or emerging smart home technologies. As a specific example, the first version of the tool will support the EIB technology, by including the automatic generation of an ETS project and the corresponding cost estimation [5].

5.1 The automatic generation of an ETS project

At the time of writing this feature is still under development. In this paper an overview of the technical specification guiding this work is given. The Automatic Generation of an ETS Project will create an ETS-compatible output file, describing the standard ETS views.

The information required to support the automatic generation of an ETS project will be partially derived from the information entered by the user using the CUSTODIAN technology-independent modules (the core features referred previously), but further technology-dependent information may be inserted as described in the following paragraphs.

The *Project Properties* dialog box opens when the user creates a new project (*Project Properties*), and includes the four tabs shown in Figure 9. Selecting the *Technical* tab, the user accesses the following fields:

- *Building Name* – Name attributed to the building. By default, it will be the client name.
- *Type of Medium* – This field is a “combo box” where the user must choose between "Twisted Pair" and "PowerLine".

- *Manufacturer* – To select the default manufacturer of devices. It is however possible to change the manufacturer of a specific device in the *Device Properties* dialog box. The *Tools* menu of the CUSTODIAN Project includes an option where the user can import the products database of several manufacturers.
- *Maingroup and Middlegroup* – These two frames are used to create the structure of the *Level Group Addresses*. Pressing the *Add Item* button in the *Maingroup* frame, the software creates a table with the contents of the *Name* and *Address* fields. When the *Add Item* button is pressed in the *Middlegroup* frame, the software executes the same procedure at this level and relates the current middle group item to the main group selected.

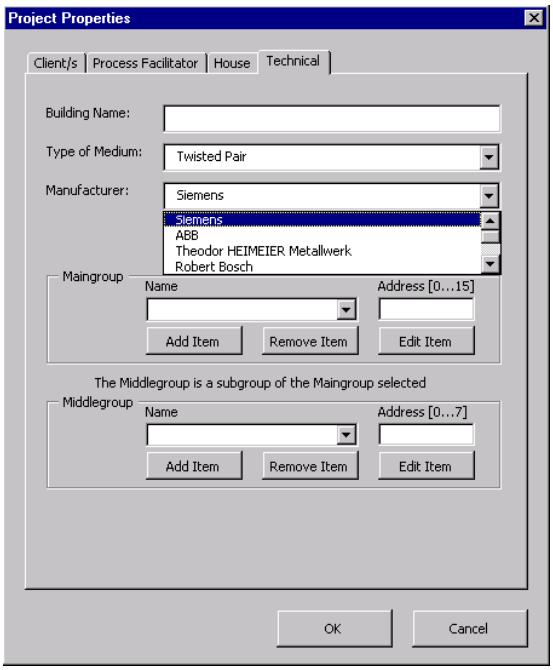

Figure 9 – *Project Properties* dialog box

The *Device Properties* dialog box is used to specify the inherent properties of each device. Choosing the item *Device Properties* of the selected device (through a right-click on the mouse), the dialog box shown in Figure 10 appears on the screen. The following fields are available to the user in the *Technical Information* section:

- *Line* – This information is updated automatically. When 64 components are present in one line, the line number is increased. The line number can also be modified in the *Automatic Generation of ETS Project* dialog box, as will be explained shortly.
- *Manufacturer* - The user can specify the manufacturer of each device. The manufacturer specified in the *Technical* tab of the *Project Properties* dialog box will be present by default in this field.
- *Description* – This field is meant to provide a short description of the functional role allocated to each device.

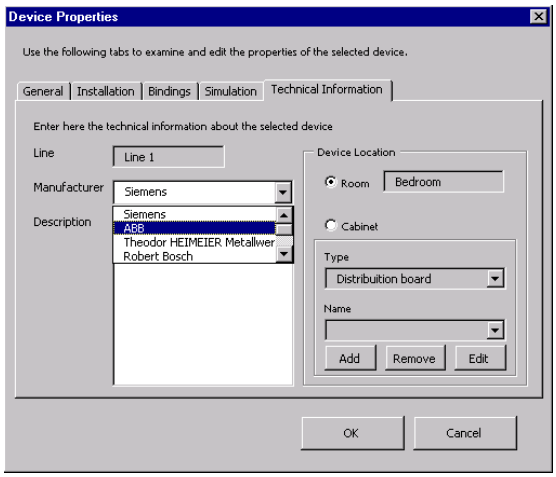

Figure 10 – *Device Properties* dialog box

Since the CUSTODIAN tool allocates one page to each room, the name of the page (*room*) will automatically be attached to the device. In the *Device Properties* dialog box, the radio buttons *Room* and *Cabinet* enable the user to specify the preferred device location (this procedure creates the *Building View* structure of the ETS project).

On the *Tools* menu of the CUSTODIAN Project, the option *Automatic Generation of the ETS Project* leads to the dialog box shown in Figure 11. The automatic generation of *Maingroup* and *Middlegroup* addresses will appear as default in this dialog box, creating the structure of *Level Group Addresses* up to the level two. The

last level of the *group address* will be created by the user with the ETS software.

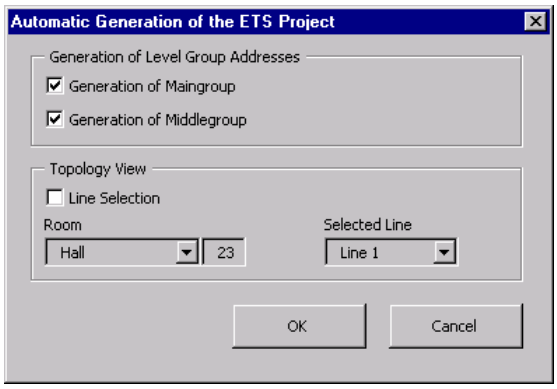

Figure 11 – *Automatic Generation of the ETS Project* dialog box

In the *Topology View* frame, the user can define the physical structure of the bus. By default, this option is disabled and the configuration created during the development of the CUSTODIAN project is adopted. However, by enabling the checkbox *Line Selection*, it is possible to structure the *Topology View* manually. The user will in this case make use of the list box *Room* and the list box *Select Line* (the user can select up to twelve lines). All the devices that belong to the selected room will be tied up to the selected line. The field beside the list box *Room* will indicate the number of devices that are linked with the selected room. The user can assign all the rooms to the same line, but more than 64 devices in one line will cause a warning message to pop up.

5.2 The cost estimation module

Each template system will have a global cost estimation associated with it, based on data coming from actual systems constructed with commonly used components. Such global estimates should consider the cost of equipment that corresponds to all the smart devices chosen in the design stage (for example a wall-mounted switch will match a Bus Coupling Unit plus an EIB pushbutton, while a door actuator will match an EIB binary output plus a non-EIB actuator). The global estimates should also consider the cost of all EIB system components that are needed to make the home network complete (Power Supply Units, bus connectors, etc). The set of system components may, however, vary with the topology of the actual house in which the system will be installed (for example, different topologies may correspond to different numbers of bus lines).

In addition to the global cost estimation, each smart device will have a partial cost estimation associated with it. Thus, after the user has shaped one of the template systems to meet the needs of a particular client, the global cost estimation may be corrected just by adding or subtracting the cost of a few smart devices. All cost estimations (either global or partial) include two components, one of them indicative of the equipment costs and the other one indicative of the installation and commissioning costs.

6 Application example

Gary is a 19-year old ex-boxer who suffered a cerebrovascular accident (CVA) on his right-hand side, which has left him with a number of problems both physical and cognitive in nature. He has slow mobility due to weakness on his left-hand side. The assessment of user needs is done during a consultation between the end user and the care provider, which results in the production of a "User Needs Report". This report is then used in conjunction with the CUSTODIAN tool to produce the necessary information required by all those who will be involved in the acquisition, installation and testing of the Smart Home system.

The room we will look at in this case is the client's bathroom, populated with seven smart devices, as shown in Figure 12. When Gary enters the room, the PIR sensor is activated and this turns on the lights and the extractor fan. The user of the CUSTODIAN tool can easily simulate this occurrence, as shown in Figure 13. The lights will remain on as long as the room is occupied (i.e. the PIR sensor is being activated); once the room is vacated the lights

will go out. However, the extractor fan will remain on if the humidity sensor has been activated, as shown in Figure 14. The extractor fan will only go off when the humidity level has dropped and the humidity sensor has therefore been deactivated.

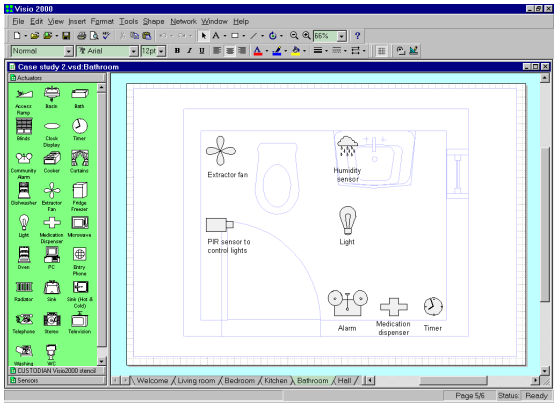

Figure 12 – Smart devices in bathroom

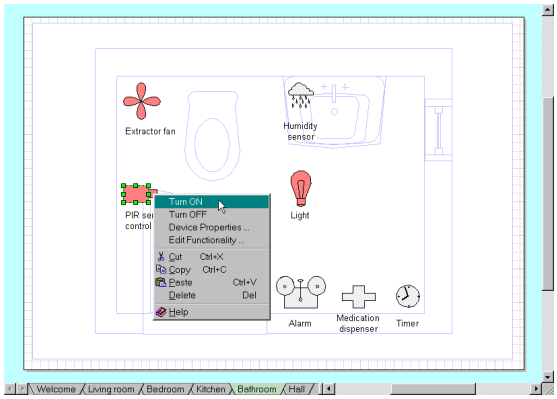

Figure 13 – Simulation of client entering the bathroom

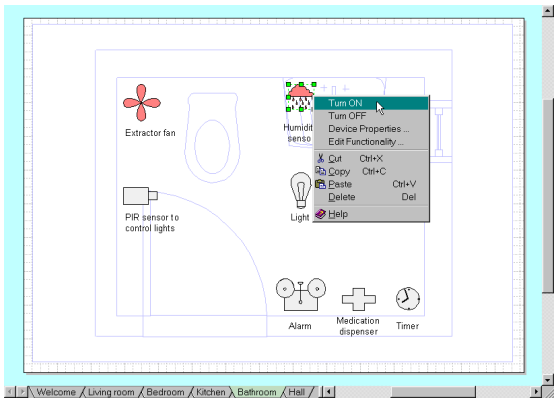

Figure 14 -- Humidity sensor keeping the extractor fan on

In case Gary has problems with time management and self-medication, this scenario can also be solved by the application of smart technology. The medication dispenser is attached to a timer and alarm. The timer is set to go off when his medication should be taken. When the timer goes off, the alarm alerts the user and the medication dispenser unlocks to allow him to take his medicine. This situation is illustrated in Figure 15.

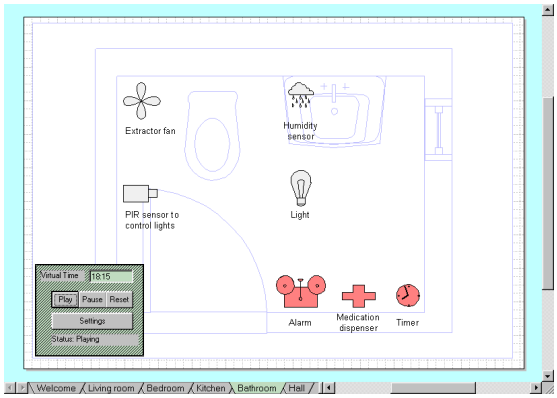

Figure 15 – Timer triggering the alarm and the opening of the medication dispenser

If the cupboard has not been shut within 5 minutes of the alert the alarm will be reactivated. This facility could be extended to include a paging device, which can be used when Gary is out of the house.

7. Conclusion

The technology-independent features of CUSTODIAN enable care providers and other target users to design and validate the functionality of a home automation system without prior commitment to a specific technology and without requiring the participation of skilled home automation professionals. Furthermore, its technology-dependent features enable the automatic generation of a first design iteration for the target home automation technology, which should then be processed by specific development support packages. However, it is important to refer that CUSTODIAN is not meant to replace existing home automation design packages, which continue to be necessary for final design and commissioning tasks.

While the only technology-dependent module developed so far addresses the EIB technology, the CUSTODIAN consortium envisages the development of modules to

support other home automation technologies. Lower-end products in this technology spectrum, such as X-10, are also able to benefit from the CUSTODIAN concept. The first design iteration will in this case be closer to the final technical specification and require less further refinements, effectively shortening the gap between conceptualisation and benefits to the users.

The validation phase of CUSTODIAN is currently under way, under the responsibility of the Tayside consortium, comprising the key healthcare, social service and social sector housing providers within the Tayside Region of Scotland, and of Edinvar's community care services, which are provided to people living in Edinburgh and the Lothian's area, predominantly inner city and the surrounding urban areas.

8. References

[1] *Conceptualisation for User involvement in Specification and Tools Offering the Delivery of system Integration Around home Networks (CUSTODIAN)*, April 1997 TIDE Call for Proposals.

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