

Implementation of a remote and virtual laboratory in the field of home appliance systems

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Abstract. One of the most dynamic branches of educational systems is linked with e-learning. In engineering, experiments play an important role in the learning process and, in general, impose student's presence in laboratory in order to allow them to interact directly with instruments and objects under test. The paper presents some practical examples on how is possible to replace the traditional laboratory with a remote and virtual laboratory in the field of home appliance systems. The remote laboratory is based on two dedicated systems (named DomoControl128 and TinyDomots). Structure, main features and operational principles of current implementations are briefly presented.

1 Introduction

The VIRTUAL-ELECTRO-LAB - "Using information and communication technologies in development of virtual and remote laboratories for initial and continuous education oriented on efficient professional (re)insertion in electrical domain" project received the support of the Leonardo da Vinci Program from the European Community. In the project's title, main goals are referred. E-learning plays a central role.

Advantages and disadvantages of e-learning systems in general are well known. In particular, for the field of electrical and computer engineering, it is very important to develop the practical skills; in this sense, usage of e-learning environments complemented with remote laboratories can have a significant impact in the student's learning rate.

Considering the VIRTUAL-ELECTRO-LAB project, one of the areas where it was foreseen to apply the developed methodologies and tools around the virtual and remote laboratory concept was in the area of home appliance systems ("*domotics*").

A specific Learning Management System was developed within the VIRTUAL-ELECTRO-LAB project, considering the resources of virtual and remote laboratories.

Our laboratory represents a specific support for the *domotics* course, where some of the main functionalities of a home appliance system can be exercised.

Considering our laboratory as a home appliance system that can be monitored remotely, the main improvement (from the point of view of the learning process) consists in the capability to enable remote reconfiguration and parameterization of parts of the system. In this sense, the structure of the system includes a set of embedded processors, which can individually be remotely reconfigured and enables the dynamic changes in system's functionalities.

2 Starting with the Intelligent Building concept

Remote access to home appliances has been always referred in the literature as a main feature associated with the concepts of intelligent home and intelligent buildings.

Also, integration of systems commonly used within buildings being supported by "open protocols" has been always referred as a target. **Fig. 1**, derived from the views of the European Intelligent Building Group (EIBG), shows different levels of integration normally identified within the intelligent building concept (named as "Computer Integrated Building"). It as to be noted that the timeframes associated with each of the market development periods have been up-dated along the last decade (in the sense that the top-level is something to reach in the very near future).

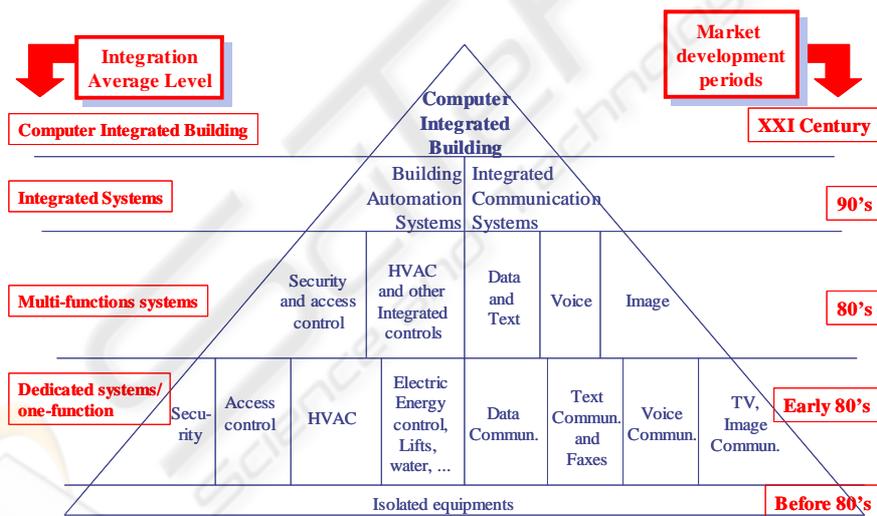


Fig. 1. Evolution of the "Computer Integrated Building" concept

Several efforts have been done by companies and academia (some are also under development). Although, the driving force of such developments has been the industry and market opportunities. This had a severe impact in the evolution of the intelligent building concept implementation, in the sense that most solutions are proprietary and the open systems and open source strategies have had a limited impact on those

home and building systems. Anyway, from the communication protocol infrastructure point of view, there are several standards available, some of them already approved inside standardization boards, others approved inside companies' ad-hoc coalitions as de-facto standard (where the market is the driving force). Anyway, interoperability of equipments and systems provided by different companies is limited and a push towards the adoption of open protocols in this area of intelligent homes and intelligent buildings is welcomed (from the point of view of the user).

From the point of view of the present paper (and of our remote laboratory), only the left part of **Fig. 1** is considered, which means the building automation systems.

3 About the VIRTUAL-ELECTRO-LAB system

The VIRTUAL-ELECTRO-LAB system is an e-learning platform that includes the access to a set of module courses in the field of electric and computer engineering, supporting each module through specific virtual and remote laboratories. The e-learning platform includes a web-site that could be accessed by registered users and supports experimentation at two levels (see **Fig. 2**):

- Physical experiment remotely controlled, and
- Remote access to specific simulators associated with specific experiments.

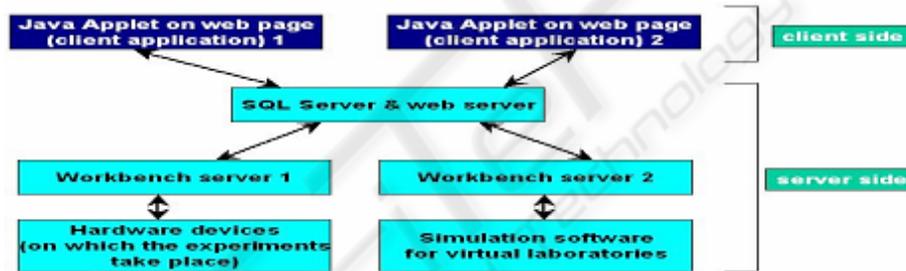


Fig. 2. Structure of the VIRTUAL-ELECTRO-LAB platform

The platform operation is based on the client-server paradigm. The client (user), after authentication, can access the Web server and associated SQL server capabilities and issue requests. Relying on the database structure correlated with the workshops, using the web services, the user could access the remote/virtual laboratory experiments. He can get access to the past experiment results that are archived on database and could add new experiments by his/her-own. The communication between workbench servers and SQL server uses a very flexible xml-based form, which could be easily adapted for different laboratory types.

3 Domotics laboratory

The laboratory is implemented around two different systems: DomoControl128 and TinyDomot. The two systems can be linked together via a RS-485 bus, although interoperability is limited, at the current stage of implementation. The link with the server SQL is implemented using a serial line RS-232C through a PC that plays the role of workbench server.

3.1 The DomoControl128 system

The structure of DomoControl128 system is shown in Fig. 3. It is based on two ATmega128 microcontrollers, interconnected through a SPI link.

One of the microcontrollers, the HMI-controller (on the upper part of the figure), runs programs that implement specific protocol to assure Virtual-Electro-Lab workbench server connectivity, and also the EIB protocol to enable connection for supervisor level purposes. The SPI interface assures data transfer between the two microcontrollers and with the EEPROM memory. The HMI-controller will be referred here by processor 1, and the interface-processor (at the bottom part of the figure) will be referred here by processor 2.

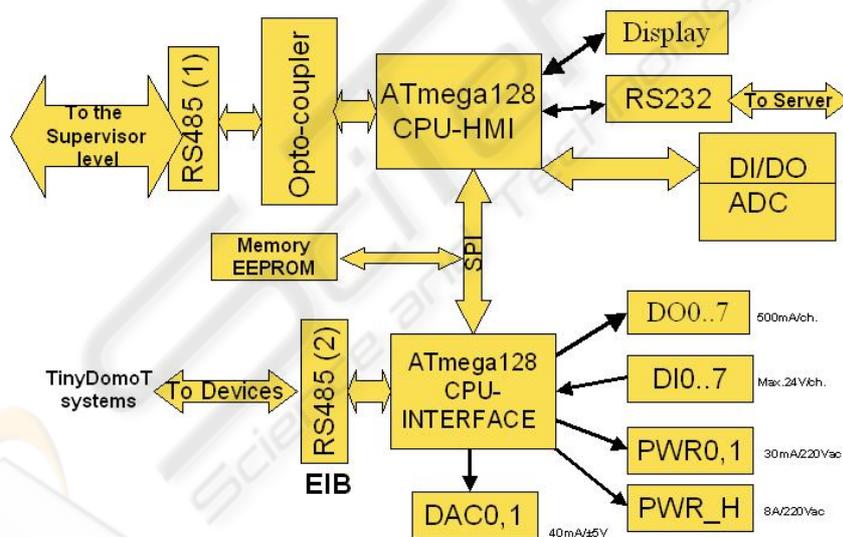


Fig. 3. Structure of DomoControl128 system

The functions implemented by DomoControl128 system are: acquisition of analogue signals up-to 12 channels with 10-bit resolution, maximum sampling rate 15kS/s; dual channel analogue outputs 12-bit resolution, sampling rate 50KS/s; sixteen digital input/output channels; four serial interfaces, and more 8 timer/counters.

The remote user (a student, for instance) can define the strategy to be used in order to control the *domotics* system in the following ways:

1. Writing directly into the flash memory of controller 1 (directly supported by the use of the microcontroller's LPM instruction) in order to change specific parameters to configure the system [2];
2. Using reprogrammability capability of the processor 2 (that is responsible for the low-level control of system) [3]. **Fig. 4** shows the reprogramming flow for processor 1 with a new control algorithm or strategy.

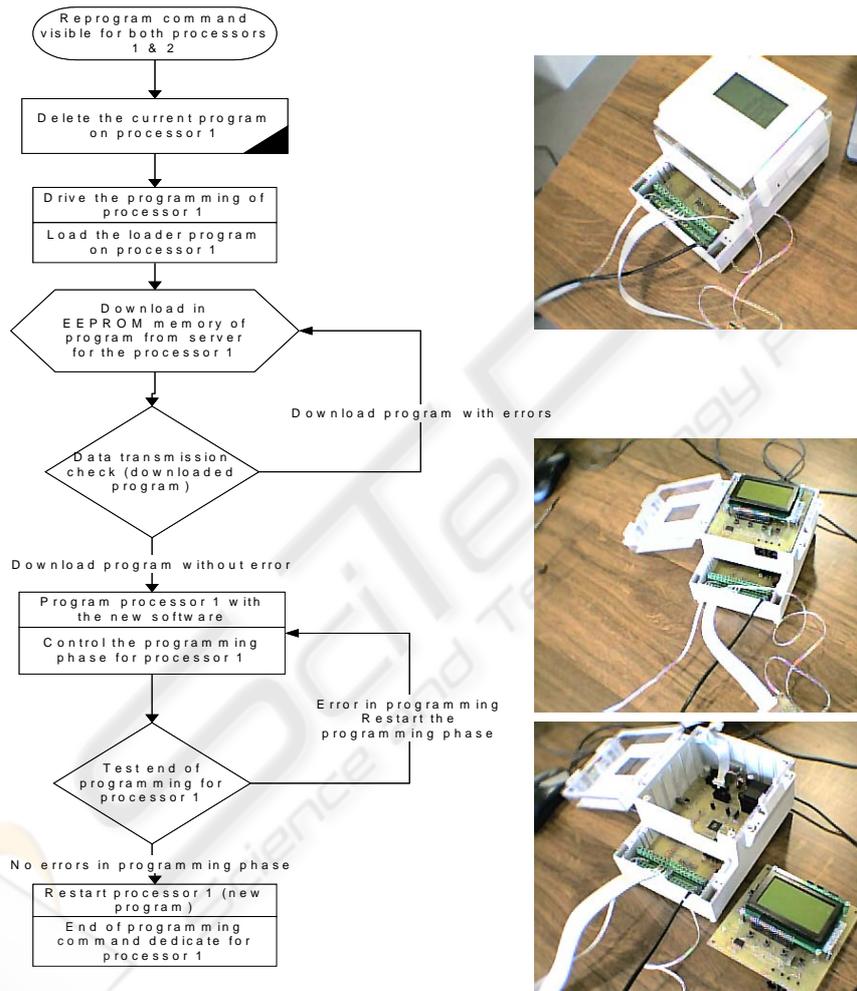


Fig. 4. Flowchart diagram for reprogramming flash memory of processor and some photos of the DomoControl128 prototype.

3. Using the resources of a specific operating system installed at the microcontroller (like microC-OS II, which allows up to 63 simultaneous

tasks on the system, and was successfully installed in the ATmega128 microcontroller system and is currently under configuration). In this case the management of tasks are more simplified, but with important limitation of speed.

In current implementation, second option was selected, assuring maximum speed of program's execution, but with the penalty of using flash memory more often [4].

From the point of view of the implementation of the control strategies in the processor 2, we introduced the "image process", through the mapping of the actual status of the input/outputs into the system SRAM memory (see Fig. 5). Moreover, the Plug-and-Play strategy assure the automatic updating of "image process" when a new module is connected to the RS-485 bus, supporting the EIB protocol. When the new device is registered, it comes into the system with its own data structure too.

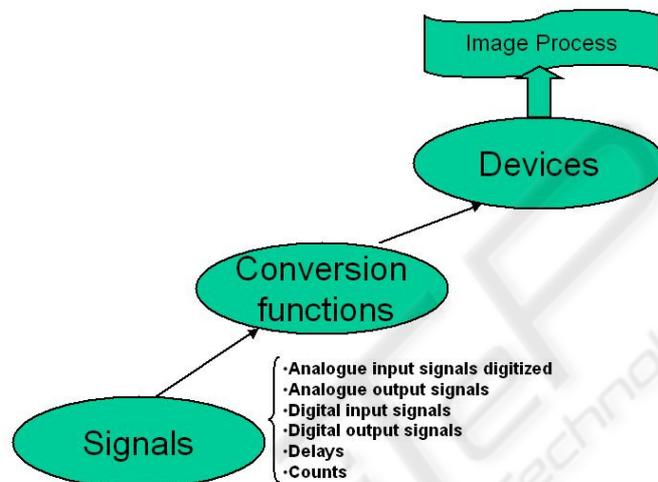


Fig. 5. The way from signals to the image process in the DomoControl 128 System

3.2 The TinyDomot system

The structure of a network of TinyDomots is shown in Fig. 6 [5]. Each TinyDomot is developed around a PIC microcontroller (although the port to a different platform based on the ATmega128 is under way).

Each TinyDomot can have a simplified user interface (keyboard and display), which can also be reproduced remotely, several inputs from sensors (temperature and light sensors, presence detectors, and so), and outputs to actuators (lamps, fan, several equipments), and can be equipped with one network interface. Several communication supports are possible, from high-speed LAN (Ethernet), to dedicated low-speed LAN (RS-485), wireless and through the power-line. Specific adaptors making the bridge between the different sub-networks are available (bridging wireless and power-line, and so on). All controllers and adaptors were developed using low-cost micro-controllers, with free-of-charge or low-cost development environments, in order to allow their usage and replication by a wide number of users.

Among the main features of the TinyDomot controller, we can refer to a set of functionalities targeted to home control and monitoring. As an example, we can refer to the capability to associate one specific input of one TinyDomot to a set of outputs in the network; in this sense, we can actuate an input of the TinyDomot located in one room and switch off the lamps in several locations (if they are switched on), like garage, haptic, and so, in order to prevent energy's waste due to forgetfulness. Another example is the capability of programming periodic events associated with specific outputs (like lighting on and off a set of lamps during holiday period to simulate owner's presence).

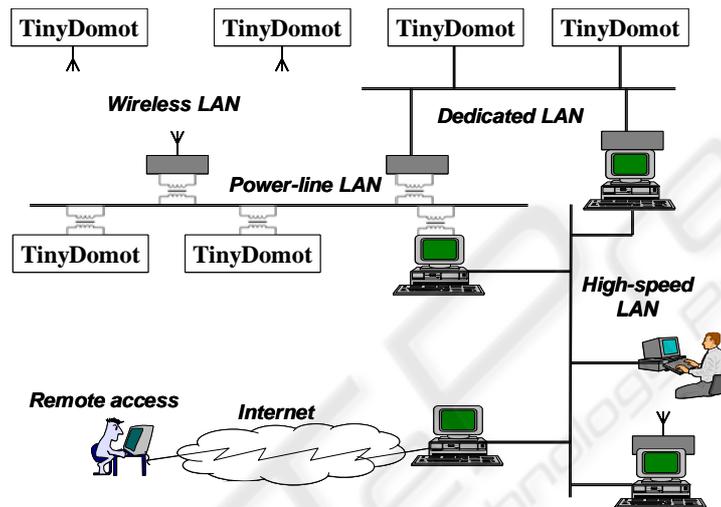


Fig. 6 Topology of the network for home appliances control.



Fig. 7 Some photos of TinyDomot prototypes.

Fig. 7 shows several photos of TinyDomot prototypes, namely the modem power adapter used in conjunction with a TinyDomot with LCD and in-and out-puts, and a network of several TinyDomots.

4 Didactic aspects

With the set of experiments, we intend to reach different levels of exploitation:

- First level is based on the remote control and monitoring of already available systems.
- Second level foresees (limited) remote configuration, reconfiguration or/and reprogramming of specific sub-systems.

Clearly, first level is associated with “regular” users, supporting remote operation and “play for fun”, while second level supports intermediary and advanced topics where the users can change configuration (at some extend).

As a first example, we can consider the heating and air-conditioning control system:

- At the introductory level, the user can only monitor house variables for every room (temperature and humidity, for instance);
- At the intermediate level, the user can change the set points and operative modes (week-days, week-ends, holidays, and so);
- At the advanced level, the user can change everything, even the control algorithm (from a PID controller to a fuzzy controller, for instance), through the reprogramming of the associated controller.

Afterwards, the user can access to the variable evolution registered in the database and conclude about the effectiveness of their control strategies. These functionalities are accomplished through the capabilities offered by the remote and virtual laboratory.

As a second example, we consider the access control subsystem. At the first level (introductory level), the user can remotely monitor the activity of the different access control controllers (registered entrances and exits). Although, at the second level, one can change configuration of specific access control sub-systems in several ways, for instance:

- We can change the users’ database characteristics, namely users and associated privileges (intermediate level),
- We can change parts or the whole controlling program, as far as the system supports dynamic reconfigurability (advanced level). This feature will allow the user to download specific control strategies to the controller. As a specific example, one can think about a different algorithm to be used for biometrics identification, for instance, through hand-geometry or fingerprint recognition (just to mention a few).

As a matter of fact, the already referred introductory, intermediate and advanced levels are concepts already applied to the theoretical part of all the module courses developed within the VIRTUAL-ELECTRO-LAB, namely to the associated hypertext, to allow some guidance to the users according to their expertise, motivations and goals.

5 Conclusions

The paper presents a remote laboratory targeted for remote monitoring and control of home appliances.

Two dedicated systems were developed (named as DomoControl128 and TinyDomots). Main features of current implementations are briefly presented. Interconnection between the two systems supporting partial interoperability is foreseen for the near future.

Exploitation of remote monitoring and remote reprogramming capabilities of the system can allow users (namely students) to test different control strategies applied to specific sub-systems within the house or the building.

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