INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
10 & 11 SEPTEMBER 2009, UNIVERSITY OF BRIGHTON, UK

MAKING SMART PRODUCTS FOR A BETTER WORLD

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ABSTRACT
Product design education has a special relationship with respect to the design of electronic products. Should students be able to design complete electronic schemes and develop PCB's? Is a working demonstration model sufficient or should the student be able to design the scheme virtually using special software packages? This paper shows the approach taken at the “Instituut voor Productontwikkeling” (IPO) in Antwerp, Belgium. It shows that relatively small smart products can be completely and relatively easy designed by following a specific approach. These systems can be used e.g. to monitor food quality, to measure air quality, and hence can improve the life quality of many people.
The courses in electronics at the IPO follow a specific path derived from what is called the “Product Data Flow Diagram” (PDFD). The bachelor course "introduction to electronics" is nearly completely focused on the use and choice of sensors for intelligent systems. In the master course "embedded and smart systems" a widely used microcontroller is studied in detail. This controller is programmed in the C-language using a software suite that enables the virtual design of a complete embedded system. In the master course "design of electronic products" the complete approach is taught: from initial and vague idea to a working prototype. Being able to make working prototypes is very important in the final master project. Students use the taught approach to proof that their system design works and that their products can make a better future for many people.

Keywords: Electronics education, smart systems, microcontrollers, virtual design

1 INTRODUCTION

There is a huge difference between the skills of an electronic engineer with respect to product development and the “electronic” skills of a product designer. At many universities the courses concerning electronics taught at product design students, are very similar to the courses given at electronic engineers. First, a course in analogue electronics is taught: resistors, capacitors, inductors, RCL-networks, theory of semi-conductors, transistors, OP-AMPs, thyristors, JFETs... This course is followed by a course in digital electronics: Boolean algebra, Karnaugh diagram, the four basic gates NOT – OR – AND - XOR, flip-flops and latches, counters ... At some universities both courses are followed by a course in microcontrollers. Very often the 8051 Intel microcontroller is taken as “the” example of a modern controller. Students have to study content with nearly no added value with respect to product development. In this paper another approach will be discussed: courses in electronics can help the students in designing smart products. These products can be developed and designed in a virtual environment by using specific software.

2 PRODUCT DATA FLOW DIAGRAM

The first step in designing smart products is the “product data flow diagram”. The product data flow diagram (PDFD) is the key issue diagram of any smart product. It allows for a complete overview of what the product will do in terms of data exchange between the user(s) and the product. This diagram has several levels. On the product level of the diagram (see figure 1) the following items will be shown:

- the product as a black box
- the users (using the product for different purposes)
- the external world (other products or systems - e.g. a computer system)
- the interaction between the users/the external world and the product visualized by data flow arrows.

The smart product shown on figure 1 is a tourist guide for a city. As one can see on the figure the users are: the tourists and the administrator responsible for the correct settings of the product.

An external entity can be a computer at the tourist information desk or a computer system in a library or any other information source (e.g. the info desk). The interaction between the user(s)/external entities and the product is very important. The question to be answered is: what kind of data is transferred between the users/external world and the product? In other words: what kind of data information is needed by the product in order to fulfil its basic tasks.

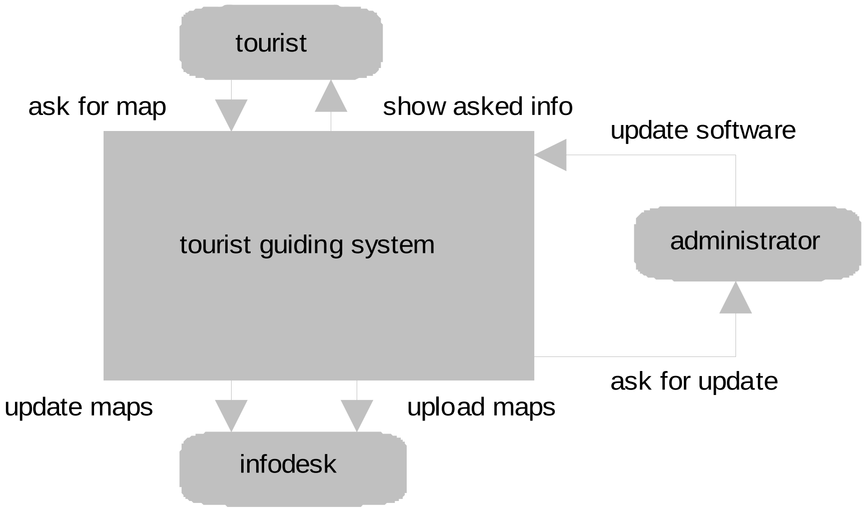

Figure 1. Product level of a smart product

How this information is sent to the product is of no importance at this moment. The information offered by the user(s)/external world will be processed by the product through a software program loaded in a microcontroller. In the case of the tourist guide the product will need detailed maps of the city. These maps will be updated from time to time by the administrator. It is clear that the city maps can be transferred into the product in different ways (wireless, USB-cable, USB-stick, FireWire …). On the product level of the PDFD no physical input or output systems are shown. These will be specified in the interaction diagram level. In order to draw this level, the following questions have to be answered:

- how is the data fed into the product,
- how will the users and the external entities interact with the product,
- what will the users "see" on the product (user interface - GUI),
- what kind of feedback will the product give to the users.

The next step will be to draw the software and the GUI level. The software level is a scheme that represents what happens with the received data at the inside of the product. In many cases the product will use internal databases where relevant data are stored. The GUI level will show the graphical elements on the input/output screen. User friendly GUI’s do not always have to be reinvented. Some operating systems do have their own GUI’s that are very suitable to use in the product. The software and the GUI levels are very closely related to each other.

Knowing what kind of data is sent by the user(s) and the external world to the product, and what kind of data is sent back by the product, the designer will now decide how the data will be physically transferred. This results in making important decisions for the choice of input as well as output devices.

One major problem in the choice of the input/output devices is that the world of smart products has a very short design phase and the availability of different input and output devices changes very fast. Therefore an up-to-date input/output devices database should be available to the designer. Part of the design project is that one will have to complete and update the available database of input/output devices. A web based software application is therefore designed so that the existing data can be updated or new devices can be inserted [1].

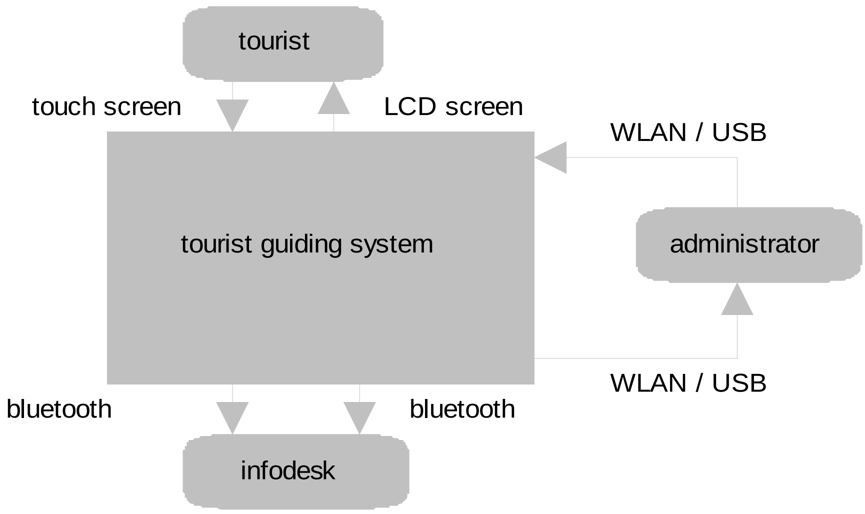

Figure 2. Interaction level of a mart product

The interaction diagram thus results in a scheme where all the PDFD data arrows are replaced by input and output devices based on a state-of-the-art database. On the scheme it is shown that the user will interact with the product through a touch screen. On the web site the designer will find extensive information on touch screens. The touch screen will also be used to present the available data. It is also shown that the administrator can enter new information into the product by means of a USB cable. New information can also be entered by using the wireless standard Bluetooth.
The tourist guiding system is an example of a smart system that designers should be able to design. Not only the (mechanical) design of the housing is important but also the electronic design. In order to be able to design the electronics a very accurate and consistent course path should be followed. This is in fact the crucial issue of this paper. How did we reorganize the curriculum so that students will be able to design such a smart product?

3 THE COURSE PATH

The electronic course path is based on three major courses and on applied research:

- electronic aspects of products,
- electronics of embedded systems,
- design of electronic products,
- applied research during the master thesis.

3.1 Electronic aspects of products

The first course is on a bachelor's level and is a first introduction into the world of electronics. The major part of the course is focussed on sensors and their applications. How the sensors work is illustrated by the use of physical laws. The main objectives of this course are illustrated by the following two items.

- a product designer should be an expert in the use and the choice of sensors. On a system design level of a new product sensors play a dominant role: the functioning of the product is completely determined by the stability of the sensors. Therefore special attention is given to stable sensors (e.g. less sensitive to temperature and zero drift).
- another important skill of product designers is the ability to design products based on different system designs. The system design of a smart product is a combination of input devices (sensors e.g.) and output devices (a flat screen e.g.) linked together by a microcontroller. The final goal is to produce a product with a stable functioning. Many system designs are possible but a trade off should result in a choice for a stable product.

3.2 Electronics of embedded systems

In this course - on a master's level - microcontrollers are introduced. We have chosen to study into full detail only one series of microcontrollers (the Atmel's range of 8-32-bit microcontrollers). These very fast, modern and versatile controllers all have the features needed to deal with every aspect of a microcontroller. Moreover these controllers are also used in e.g. the Arduino tool set. The controllers are programmed in the C-language and so a basic course in C is included in the course. Writing software for a microcontrollers in the C-language is much easier than writing C-software for e.g. a business application. Students are taught how to program the following devices:

- drivers for DC and stepper motors,
- LCD displays,
- SPI networks and
- input and output devices connected to the ports of the processor.

The programming of microcontrollers can only be successful if there is also a possibility to make simulations and breadboards.

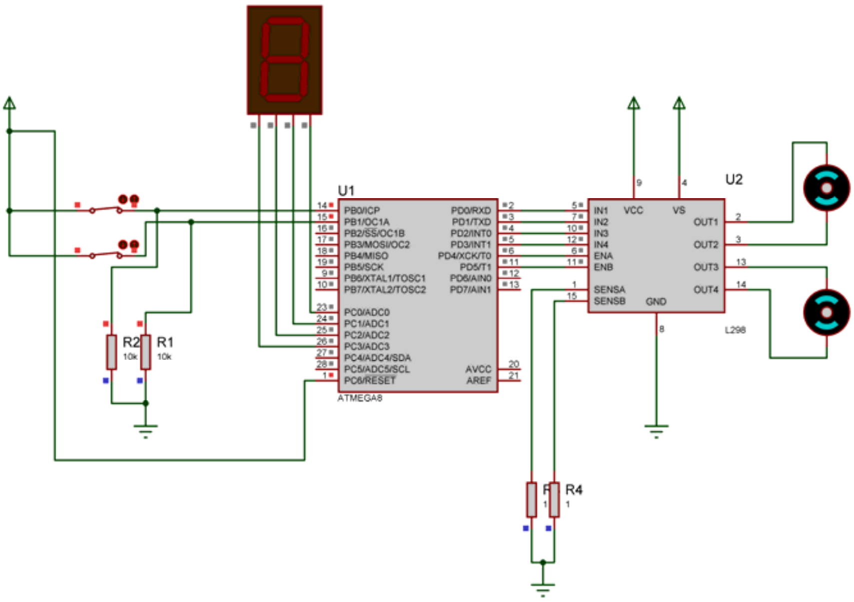

Figure 3. Simulation software

Both, simulations and breadboards, are used during the course:

- a software suite is used to program the microcontroller and to simulate the electronic scheme. The Proteus suite is an excellent software package to use. Microcontrollers can be programmed in the C-language and the electronic scheme can be fully simulated. Moreover the PCB can be designed based on the packages of the components and a three-dimensional view of the PCB can be made. Very illustrative for the students is the possibility to debug the C-code in real time mode. This means that the instructions in the C-program can be executed line by line and the result I seen on the scheme.
- starting from the PCB Gerber file a milling machine can produce the PCB. Students can then add and solder the components and can test, within a time span of four hours, a complete working model. The major advantage of this way of making models is that the end result really is a professional made PCB. Once the controller on the PCB is started the product, as a whole, acts exactly as in the virtual development world.

3.3 Design of electronic products

In this course additional aspects of electronic design are discussed (also see [2]). The following topics are just an extract of the content of the course:

- what are the rules to make a professional PCB,
- how can the reliability of the product be increased,

- how to choose power supplies in electronic products,
- environmental testing of products,
- poka-yoke methods to make products safer,
- programming the user interface using Visual Basic...

For the design of the graphic user interfaces the Visual Basic environment is used. Students do not have to be an experienced programmer in order to use this software. By using the included objects of the Visual Basic language, very complex user interfaces can be designed. These user interfaces can also be tested by using the many possibilities of the language (e.g. click events on the buttons).

3.4 Applied research during the master thesis

A good product design relies completely on a proven and stable system design. This means that any critical aspect of the design should have been tested or in some cases analytically verified. Students are stimulated to make prototypes of their system design. They should not be dependent any more on other people to make their breadboards. By using the specific approach described in this paper we see a continuous improvement in the quality of electronic product designs in the master year. Using the PDFD as a starting point for the complete design an efficient way of designing electronic products has been established during the last five years. It is however clear that improvements still have to be made and that the design method always needs some additional steering.

4 CONCLUSION

Electronic courses can be organised in such a way that a complete new world is opened to the product designer students. By focussing on what is really important and by introducing the product data flow diagram, smart products can be designed from bottom to top. By changing the content of the electronic courses towards mainly sensors and microcontrollers (included the programming in C) these courses become an essential design tool.

After five years of continuous adjusting of what have been described in this paper we could say that the final goal is in sight: electronics for product designers as a valuable tool.

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