DESIGNING EXPERIENCEABLE SYSTEMS BY USING MICROCONTROLLER BASED PLATFORMS

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ABSTRACT
Industrial and product designers have increased access to various microcontroller based electronic platforms to test system design and interaction design ideas. A well known example of such a platform is the Arduino environment, which offers both hardware and software tools to create prototypes. The main reason why the Arduino platform has gained popularity is the fact that the software is open source and free of cost. Additionally, the hardware is not expensive and the used electronic components are widely available. Besides the tools, there is a large community using and extending the platform. This results in the creation of a large amount of peripheral equipment that can be connected directly to the boards and specific code libraries. Both hardware equipment and software codes are accessible for people who lack specific programming knowledge.
This paper describes a study that took place during the course "designing electronic products" in the department of Product Development at the Faculty of Design Sciences in Antwerp. Students were given the assignment to develop a sort of immaterial information transfer between two persons by using the Arduino board as a prototyping platform. The eventual goal was to make a functional prototype, enabling students to test the interaction of a digital product, and refine it.
The 1st year master students had no prior course in programming in the Arduino (Wiring) language, a derivative of the widely used C language. The only background on electronics was given in the course "components of electronic products" in the 3rd year bachelor. The objective of the research was to see how fast an application can be written and tested without any prior knowledge of hardware or software. The students worked in groups of three to finish their assignment during a series of five two-hour classes. After the presentation of their design a questionnaire had to be filled in. This questionnaire included questions concerning their prior knowledge of any programming language, their knowledge of the used platform and their knowledge of sensors, displays ... They were also asked whether they would use the platform for future projects in their studies and if, by using this platform, the design of electronic products is better understood. The final goal of this questionnaire was to know if introducing the Arduino platform in the bachelor years is a possibility for replacing theoretical courses by practical competences.

Keywords: System design, interaction design, electronics, microcontroller, platform

1 COMPUTATIONAL TECHNOLOGY AS A DESIGN MATERIAL

Digital products are fundamentally different from mechanical products. To design digital products, the designer must have an understanding of what this difference entails. The operation of a mechanical construction is, although not immediately obvious for anyone, accessible to our sensory apparatus, and in that sense readable. We are, after all, familiar with the mechanical actions and principles of our own body: hinges, actuators (muscles), leverages, degrees of freedom, ... (Overbeeke, Djajadiningrat, Hummels, & Wensveen, 2002).
The operation of digital products is also physical in nature: the continuous distribution and redistribution of electrical charges on electronic components is not a virtual, but a physical phenomenon. Every digital product is a physical structure that manipulates physical entities (Vallgårda & Sokoler, 2010). The difference with the operation of mechanical products lies in the fact that digital processes are beyond human perception. In that way, they are not illustrative and comprehensible, nor directly manipulable. If we want to use digital technology, we need to convert digital processes into a

form that is available for our senses. Digital processes must be "translated" before we are able to interact with them.

The way in which this translation is shaped, is product-dependent and must be determined by designers. Up to now, this is commonly realized through a display, a keypad and a mouse. This phenomenon is described as the "Desktop Computing Paradigm" (Klemmer, Hartman, & Takayama, 2006). In 2007, Apple questioned this paradigm by launching the iPhone and resolutely opting for a different type of interface. However, we believe there are still more possibilities to explore. For example, Tangible Interaction (Ishii, 2008) is a knowledge area that searches for physical forms of interaction with digital information and digital processes.
Hallnäs et al. have their own ideas on digital technology and mediation (Hallnäs, Melin & Redström, 2002; Vallgårda & Sokoler, 2010). They claim that designers must consider computational technology as a raw material, in the same way that bauxite is a raw material in the metallurgical technology. Bauxite in itself is unusable for us (Doordan, 1993). It becomes useful when it is treated with other materials to form aluminium. Vallgårda et al. claim that digital technology is only useful in a "composite shape" with another material. Therefore, we have to "alloy" digital technology (PCBs, electronic components) with this other material. This material then accounts for the above mentioned translation process. Vallgårda speaks of "Computational Composites" (Vallgårda & Sokoler, 2010). We find this theory interesting because it infers that designers must respect and exploit the intrinsic material properties of digital technology in the same way that we use the properties of wood and steel. The aesthetic qualities of a seat in wood will radically differ from those of a seat in steel.
What are the specific material properties of digital technology? The property that we chose to explore in this project was "temporality" (Hällnas, Melin & Redström, 2002). Digital technology is programmed, and works with software. When software runs, temporary structures are created. For example, on a computer display entities (windows, icons, ...) constantly appear and disappear. Everything is changeable and continuously in movement, and thus "temporarily". In that way, temporality is a material characteristic of digital technology. In our physical environment things are usually persistent and permanent (Gibson, 1979). How should we consider this material property in the design of digital products? A possible answer to this question is by the use of changes in physical shape. This would mean that a digital product can adopt different physical shapes by transforming from one physical shape to the other.
The idea of shape changes in digital products (Djajadiningrat, Wensveen, Frens, & Overbeeke, 2004) has been defined at Eindhoven University of Technology as one of the characteristics of Rich Interaction. The shape that a digital product adopts at a particular moment, tells us something about the state of its processor. The design of shape changes and the movement from one shape to the other, is defined as 4D design (Djajadiningrat, Matthews, & Stienstra, 2007). Frens has translated this phenomenon into simple concepts that are directly useful for industrial designers (Frens, 2006):
1. MURPS (Mode of use reflected in the physical state). The state of the processor is translated in a physical shape, and thus offers feedforward and affordances.
2. MR APs (Mode-relevant action-possibilities). These are action-possibilities that are offered through changes in physical shape. They are only offered when they are relevant for the mode-of-use.
These principles have been extensively explored by our 3rd year bachelor students Industrial Design at the department of Product Development in last year's interaction design project (Van Campenhout, Frens, Hummels, Standaert, & Peremans, 2012).

2 INTERACTION DESIGN PROJECT

Last year's interaction design project started by designing a payment interaction between two persons: the customer and the vendor. Only in a second phase, the students designed a set of products that served as a means to perform this interaction. In last year's project, mainly the physical aspects of the payment interaction were explored, by building cardboard models with the ability to move. The goal was to make digital money more tangible (Van Campenhout, Frens, Overbeeke, Standaert, & Peremans, 2013). The same subject matter was chosen for this year's project but this time, the digital world was included. In a well-designed digital product physical and digital processes are fully integrated. They are intimately connected and constitute each other. They need to be approached as such during the design.

In our interaction design project a set of two payment devices had to be designed whereby their physical movements were to be coupled to the movement of light. The objective was to promote the flow of matter (money) from one device (the personal payment device) to the other (the payment terminal) in order to achieve a meaningful interaction sequence. We based our project on three designs that were created last year.
The intention was that, in each of the three concepts, the interaction would be further elaborated. The new element was the introduction of the digital world. The end result was to be a set of two prototype models with integrated electronics. The emphasis of the assignment was not on the handling and use of electronic devices and circuits, but rather on the exploration of an interaction sequence. Formgiving of the models played a role in the interaction that was to be performed. Therefore, it had to be considered thoroughly.

Concept 1 (Gertjan Brienen and Collin van Hest)
The personal payment device is activated by a meaningful movement or change in physical shape (step 1). The blue light indicates that there is money on the account. Then this device is inserted in the payment terminal (step 2), which is somewhere on the desktop counter or any other horizontal surface. The payment terminal is activated: the money "flows" from one device into the other (step 3), apparently under the influence of gravity.

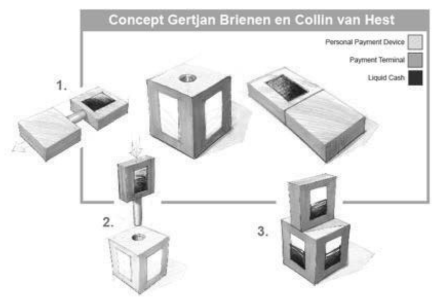

Figure 1. Design of G. Brienen and C. Van Hest

Concept 2 (Fabian Breës and Els Cassauwers)
This concept differs from concept 1 because there is no need for a desktop counter: the payment is a plain action between two people. The personal payment device is activated by pulling a lever "backwards" (step 1). Subsequently, the device is inserted in the payment terminal (step 2). When the connection is made, the customer slides the lever "forward", pushing light from one device to the other (step 3).

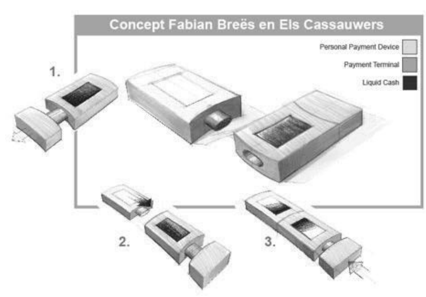

Figure 2. Design of F. Breës and E. Cassauwers

Concept 3 (Philip Mahy and An Vanaken)
Concept 3 refers to the traditional handshake. Customer and vendor each hold a device in their right hand. The vendor positions the payment terminal on the personal payment device of the buyer (step 1). Then, both of them make a rotary movement, in such a way that the payment terminal moves under the personal payment device (step 2), and the light can flow from one device to the other, apparently under the influence of gravity (step 3).

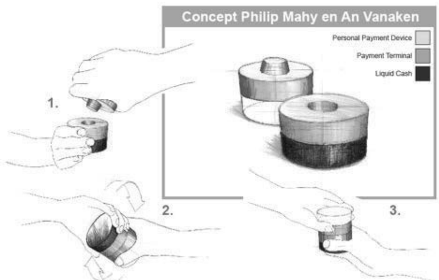

Figure 3. Design of P. Mahy and A. Vanaken

3 USED METHOD AND ADDITIONAL QUESTIONNAIRE

Every group of students created a set of two models: a personal payment device and a payment terminal. First, the concept was given further consideration through the creation of physical models and an electronic arrangement was built. Subsequently, both worlds were combined: the electronic arrangement was built into the set of physical models. The purpose of the mission was twofold: exploration of interaction through prototyping, and the introduction of Arduino.

Exploration of interaction through prototyping
The aim of the project was to explore a digital 'experience' and integrating this experience into a working prototype. It is important that the prototype is not seen as an end step, but as a tool to achieve a meaningful “rich” interaction. To achieve this, a number of iterations of prototypes should be run, whereby both the hardware appearance as well as the software code adjustments will need to create the desired effect.

Introduction of Arduino
Arduino was chosen as a prototyping platform. On the basis of a number of introductory examples some basic concepts of programming were explained. These concepts were indispensable in the further development of the proposed prototype. It is important to notice that the students had no programming experience nor any knowledge of the C programming language. As a side purpose of this project, additional questions were asked at the end of the project.
The figure below outlines the final prototype. The Arduino was to be used as a central unit providing the communication between two devices. One of these devices was the personal payment device, the other the payment terminal. The LEDs illustrate the money flow from one device into the other.

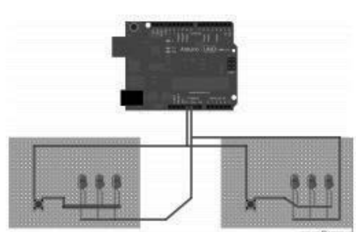

Figure 4. Arduino based solution. Payment device and terminal are connected to one board.

The focus of this project was on the interactive prototyping of an interaction, rather than on formal design or aesthetics. Because of this reason, students were asked to make the final prototype as simple as possible and only use basic forms. They were allowed to work with kappa cardboard (foam core), foam or plastic sheet. Parts and components of the prototype could also be milled or printed.

During the process, the participating students were asked to keep a photo diary, where they kept track of various models and how changes were made. The eventual deliverables of the exercise consisted of a video demonstrating the working prototype, a visual report of the process and annotated Arduino code. After handing in the final models, the students were asked to reflect upon five open questions in order to qualitatively evaluate their learning process.

4 RESULTS

The exemplar results shown in figure 5 and 6 give an idea of the results of the exercise. During the course itself, it became apparent that the main obstacle the students had to overcome is coding the Arduino platform. Although the Arduino community provides excellent examples to start from, there was a clear lack of understanding of how a computational system works. Transforming a sketch in actual, functional, code is a step that requires at least a basic understanding of coding structure and syntax. Neither of these elements are currently present in the standard curriculum the students go through. On a positive note, the students were very capable of defining their 'ideal' interaction they wanted to created. Most groups used sketches and schemes to 'design' their prototype before actually making it. Because of this approach, the Arduino system was used more as a verification tool instead of an actual design tool.

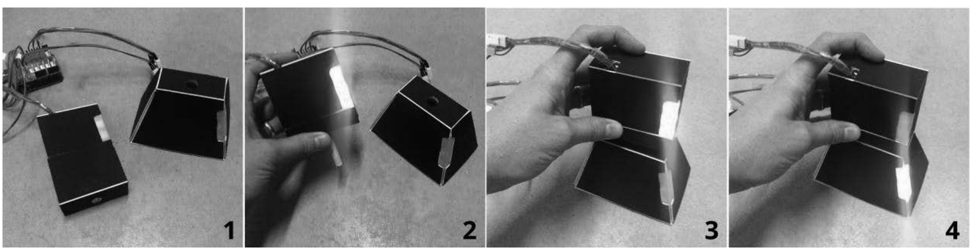

Figure 5. Example result, based on the design by Brienen and van Hest

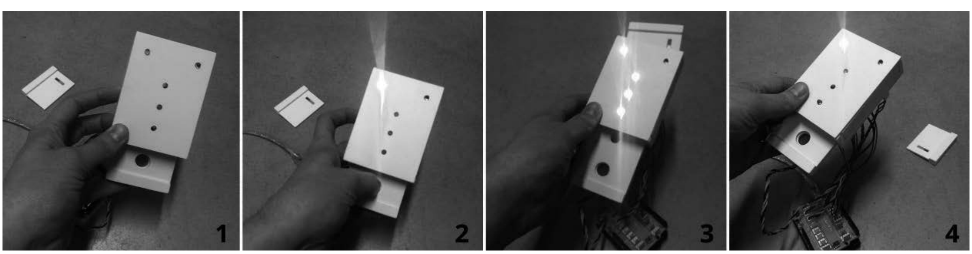

Figure 6. Example result, based on the design by Breës and Cassauwers

The qualitative evaluation provided the following data. Since we were unable to perform an extensive analysis based on the received data, we will only highlight the most prominent observations from the data gathered.

What was your knowledge of the C language prior to the exercise?

90% of the students said they had no prior knowledge of any programming language. The remaining 10% had already written small programs in Basic or in Java.

Dig your understanding of microcontrollers increase after the exercise?

Most students had a better understanding of the operation of microprocessors but were more interested in the applications. They were happier about the fact that their knowledge of sensors had grown.

Should we pay more attention to the structure of coding?

50% of the students felt that they were no real ICT specialists.

Do you see the knowledge of the Arduino board as an advantage for testing a system design?

The large majority was positive.

Should there be more such exercises, at the cost of theory?
It appears that the students prefer to practice first and then become interested in the underlying theory. More projects at an earlier stage in the course / curriculum are therefore welcome.

All student teams used pre-made electronics (Arduino Tinkerkit) to create their prototypes. This means that they did not have to make their own electric circuits, but could plug in sensors and actuators using ready made connectors. The implication of this was that the final models were often overdimensioned because of the size of the electronic components. Although this might seem as a shortcoming at first, it did allow the teams to focus on creating the prototype and software and saved a substantial amount of time by not having to design custom circuits.

5 CONCLUSION

In a world where digital and non-digital interactions are increasingly blending with each other, industrial designers cannot neglect the integration of computational systems in their design. We presented an overview of how the Arduino platform was used to engage students in digital creation in a five week long design exercise. The students started from a previously created design, which they were asked to re-interpret and make interactive. A qualitative evaluation of this process indicated that, amongst industrial design students, there is a lack of understanding of how computational logic works. From a prototyping point of view, most students found excellent methods to integrate the given sensors in their prototypes. Although this allowed them to make functional prototypes, very few students were comfortable enough with the coding language used to actually design the functional interaction. This implies that, using the current tools, a more profound understanding of computational logic is required.

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