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WHERE DESIGN AND ELECTRONICS MEET: INTEGRATE ELECTRONICS IN PRODUCT DESIGN

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ABSTRACT
In the last decade inexpensive digital electronic components have become accessible for the field of product design, making it possible to integrate electronics in all kinds of products. By using integrated electronics a product can differentiate from its competitors with a large variety of new functions and/or product behaviours. However at the same time the complexity of the product increases. Therefore a selection process is required that explores the added value and at the same time evaluates the feasibility of electronic technologies early in the design process. With a combination of user centred design and technical knowledge especially industrial designers seem to be well equipped for this selection process. Unfortunately evaluating the technical feasibility of integrated electronics is currently receiving too little attention in design education.
This paper presents the conclusions of a qualitative study in the working methods of professional design practice to gain insights in this early selection process. It shows industrial designers themselves possess limited technical knowledge of the electronic domain, but compensate this by communicating with external electronics experts early in the design process. Their communication is facilitated by the visualization skills of designers making it possible to talk about integrated electronics in a “designerly” way with little technical terminology. However this way of working also has its downsides, because it limits the exploration of different electronic systems and the ability of designers to design the product behaviour. By comparing the findings of this study with research on inter-disciplinary cooperation this paper proposes a starting point for design educations to empower designers to work with integrated electronics early in the design process

Keywords: Product design, Integrated electronics, Design education, Inter-disciplinary cooperation

1 INTRODUCTION

In the past few years the field of product design got a new set of materials to work with. ICT components that were first restricted to electronic devices such as computers are being integrated in an increasing variety of products. A development that is described in various paradigms such as ubiquitous computing [1] and the Internet of Things [2]. The integration of these electronic technologies enables products to collect, manipulate and share digital information resulting in many new possible functionalities. Furthermore integrated electronics has a large impact on the product behaviour making it possible to take into account or anticipate users emotional state, environmental factors [3], [4] or enhance the interaction with these products [5]. However transforming this large amount of new possibilities into feasible products with added value creates challenges at the start of the design process.

1.1 Differentiating with the use of integrated electronics

Besides the opportunities for totally new products this paper focuses on the impact of integrated electronics on existing products that (seemed to) have a fixed set of functions. Take for example the smart thermostat, figure 1 shows two thermostats that both fulfil the basic functionality of regulating heating, but use different integrated electronics to provide added value over “traditional” thermostats. Where the left thermostat ‘Toon’ focuses on data collection and visualization [6], the ‘Nest’ on the right offers automated adaptation of the product behaviour [7]. Especially when looking for opportunities to differentiate from competitors it is not clear at the start of the design process if, which and how electronics should be integrated. Deciding which values to offer for end users and the selection of feasible electronic technologies is an iterative process where the outcome is not clear from the start, as is illustrated by the development of a third smart thermostat by Bosch [8]. This combination of exploring the added value and evaluating feasibility has a large impact on the direction of the design process and success of the final product. Industrial designers seem to be well equipped for a central role in this process with a combination of user centred design methods and technical knowledge.

Figure 1. Two smart thermostats, the Toon (left) showing real time energy use and the Nest (right) analyzing user behaviour to automate the heating schedule.

1.2 Challenge for design education

At the Technical University of Delft the faculty of Industrial Design Engineering (IDE) stresses the importance of combining user centred design and technical knowledge [9], [10]. However the technical knowledge is mainly focused on the mechanical domain [11]. Currently the attention for the domain of electronics and mechatronics is increasing in the curriculum, but the education on the feasibility of electronic technologies is still marginal.

The absence of technical feasibility can also be seen in design literature, which often focuses on a relevant but abstract level [12], [13] or on a more specific level emphasizes the importance of the product behaviour, but leaves out technical details [5]. Technical literature often starts from a very theoretical level [14], or focuses on people with a background in mechanical, electrical or software engineering [15], [16]. It is unrealistic to include the in-depth background knowledge of one or all of these fields in design education, but as a result it is difficult for industrial designers to find practical information sources in for design projects.

Without practical sources, judging the feasibility of electronics is already difficult, but early in the design process this is extra challenging, because technical criteria are vague or even unknown. Especially unknown unknowns, criteria that are overlooked and later in the design process turn out to be important, create pitfalls in the design process [17]. Therefore understanding what impacts feasibility and evaluating the feasibility are both important to achieve the added value of integrated electronics in the final product. By missing this crucial part in design educations it becomes difficult for industrial designers to get a grip on integrated electronics early in the design process.

When trying to improve this aspect of design education it is important to take into account the diverse nature of industrial design and consequently the limited time to cover background knowledge of all relevant fields. Therefore the research in this paper focused firstly on professional practice to get an overview of current working methods and identify what methods, tools and knowledge is relevant.

2 RESEARCH IN PROFESSIONAL PRACTICE

To gain insights in the process of exploring and evaluating integrated electronics a qualitative study has been conducted in professional practice. Preliminary interviews with several design professionals emphasized the importance of cooperating with electronics experts to judge the technical feasibility. Based on these interviews a framework is formulated that shows the steps industrial designers are expected to take when considering the integration of electronics (figure 2). Because the early design phase is vague designers are expected to detail integrated electronics to a certain extend before communication about technical criteria and feasibility is possible.

Based on the framework in (figure 2) three workshop sessions are held in design agencies, each with two participating design professionals. Using the design of a smart thermostat as example case the participating designers were asked to explain their way of working, methods and/or tools. During the workshops participants were specifically asked about their information sources to gain insights in their technical knowledge, and cooperation with electronics experts.

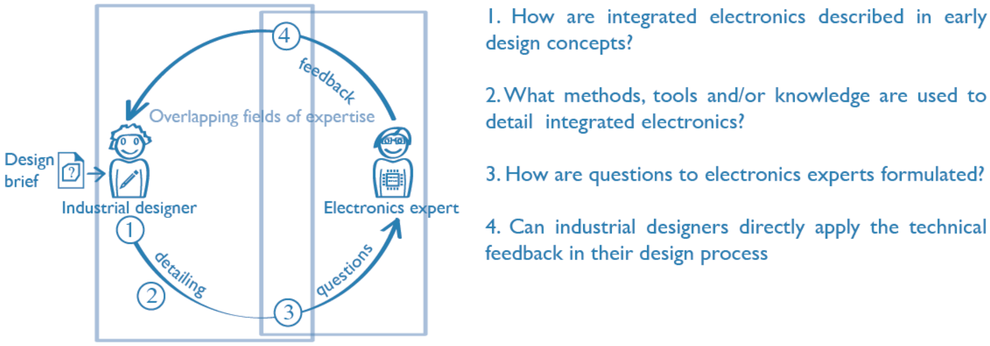

Figure 2. Framework for working with integrated electronics, based on preliminary interviews with design professionals

3 CURRENT WORKING METHODS AT DESIGN AGENCIES

The workshops in different design agencies showed clear similarities in the design process when considering the integration of electronics. However there is no standard approach and designers emphasized that the exact way of working depends heavily on the project brief. Besides several common actions, such as benchmarking with competitors, two aspects have a clear central role in all participating design agencies: use scenarios and knowledge from experience (figure 3). Visualizing use scenarios is done to specify functionalities, product behaviour, required components and known criteria. Making these use scenarios is an iterative process to explore different options and include as much details as possible of the (known) aspects that are involved.

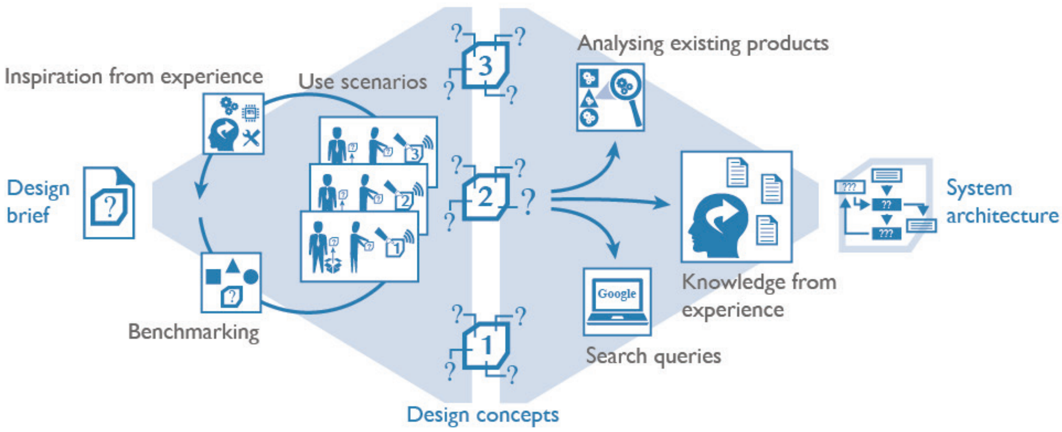

Figure 3. The exploration and detailing phase of integrated electronics, showing the main role of use scenarios and knowledge from experience

During the exploration process aspects that are uncertain and known to be important for the success of the product are specified. This results in one or more early design concepts with several uncertainties that have to be clarified in order to judge the technical feasibility. At this point the importance of knowledge from experience becomes evident. Again exact working methods differ between design agencies, but all industrial designers rely heavily on their own experience to identify and investigate uncertainties.

During the workshops several methods and tools were mentioned to gather more (technical) information about electronics needed to judge the feasibility. Internet queries using standard search engines, analyzing products with similar functions and small tests are all used to gather information. However when discussing these actions in detail it became clear the industrial designers need to have previous experience with a very similar situation to be able to apply the found information in a new design project. With the variety in design projects and electronic technologies encountering a very similar situation is rare, therefore the help of external electronics experts is often needed very early in the design process.

3.1 Communication with electronics experts

Ideally a schematic overview of the electronic technology is made when contacting external electronics experts. During the workshops each design agency showed their own kinds of visualizations, but they are essentially system architectures, showing the known electronic components as black boxes with their input and output. System architectures are mentioned as very useful because the in- and output can be based on use scenarios and can also be used by experts to further detail electronic technologies. In other words it is a visualization where the input from industrial designers and electronics experts comes together. But again industrial designers mentioned they have to be familiar with the electronic technology before they are able to visualize a system architecture. However this is not a threshold for industrial designers to contact external experts.

When discussing the cooperation with external electronics experts during the workshops it turned out most communication starts without any technical specifications or terminology. Electronics experts are contacted with small questions or vague ideas and much earlier then expected, which is shown in Figure 4. In these cases industrial designers use their use scenarios and other visualizations that show the functionalities, user interaction and context of use. Using this input electronics experts can identify requires components and technical criteria themselves and provide some general feedback. At first this is not enough to judge the technical feasibility, but electronics experts also help with further detailing of the electronic technology by thinking along with the designers about the criteria and alternatives. This makes it possible for industrial designers to evaluate the technical feasibility in close cooperation with electronics experts without possessing the required technical knowledge themselves. However this working method also has its downsides.

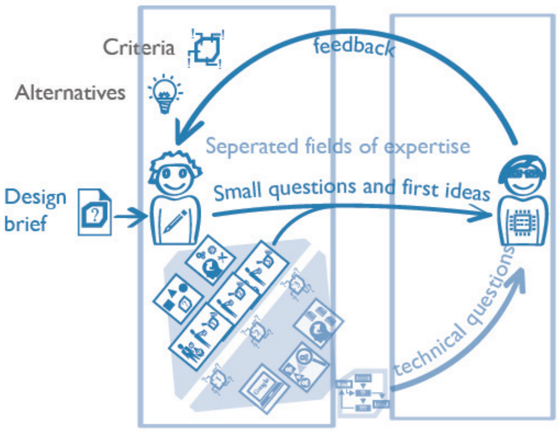

Figure 4. The current working method of industrial designers showing that electronics experts are also contacted when no detailing is done by designers

3.2 Limitations of the current working methods

In the current design practice industrial designers rely heavily on external experts to identify important uncertainties and criteria based on visualizations and communication in general terminology. As a result the required technical knowledge is not shared between designer and expert, but only the implications for a specific design project. This results in a slow and fragmented learning process for industrial designers where they only learn to apply a certain electronic technology in a specific design.

But the current way of working not only influences the learning process, but also the design process itself. All design agencies emphasized the time pressure in professional projects; making it important to reduce uncertainties as quickly as possible. In this situation the large dependence on knowledge from experience creates a strong incentive to only consider electronic technologies that have been used before. Then the change of missing important uncertainties and create unknown unknowns is smaller and the cooperation with external experts smoother, because (a start of) a system architecture can be made. This incentive to only apply what is applied before results a limitation of their solution scope. At the same time relying on external experts to specify technical criteria makes it difficult for designers to influence the product behaviour in detail. Especially aspects related to the user experience are difficult to translate from interaction qualities and metaphors to technical criteria and difficult to communicate to electronics experts that have no experience with this “fuzzy side of electronics”, as one participating designer called it. Therefore with their current working method industrial designers are not only limited in their ability to judge technical feasibility, but also in the exploration and detailing of integrated electronics and their added value.

4 DISCUSSION

The current working method in professional practice shows a very practical approach that enables designer to work with technologies that were not covered in their education. However the current limitations prevent designers to really explore and design integrated electronics. The field of mechatronics emphasizes its multidisciplinary character to be able to integrate electronics successfully [18], but as mentioned in chapter 1.2 the role of industrial designers is underexposed, especially when cooperating with external experts. In a recent research Guido Stompff specifically focused on the role designers have in successful cooperation within multidisciplinary teams [19], which provides some interesting starting points for improvements.

Guido Stompff identified a facilitating role of designers in multidisciplinary cooperation by letting different experts reflect on their impact on the intended final product with the use of boundary objects and physical meetings. Boundary objects are visualizations wherein multiple experts can provide their input, identify criteria and see the relations between their separated fields of expertise [19]. In the communication with external experts a system architecture can fulfil this function, but this requires the designer to be aware of the involved components, at least on a general level.

By using these boundary objects in meetings a dialogue between experts can be created where uncertainties and criteria’s are identified that experts would not consider on their own [19]. The current cooperation with external experts on the other hand is largely based on the initiative of the designer to ask questions and response of electronic expert based on interpreting visualizations and general terminology. To decrease the change that electronic experts miss technical criteria because they are not asked or specified, industrial designers should be aware about uncertainties that could be important for different kinds of electronics. Again this is knowledge on a general level that can be useful without the required background knowledge to solve these uncertainties.

Compared with designers that work within multidisciplinary teams, the cooperation with external experts requires designers to step more outside their own field of expertise. This requires an increase in knowledge about electronics, not necessarily to do the work of electronics experts, but to facilitate the cooperation. By taking this idea as a starting point we think design education can provide a relevant basis of knowledge on a general level while taking into account the limited time for each field in a diverse study as industrial design engineering.

5 CONCLUSIONS

In design projects where the integration of electronics is considered, the working methods of industrial designers from different design agencies have large similarities. Industrial designers start from the perspective of the user to explore the possible added value of electronic technologies. However to judge the feasibility of integrated electronics the technical knowledge of industrial designers is not sufficient. Instead industrial designers rely on communication with external electronics experts early in the design process.

To be able to discuss integrated electronics when technical criteria are not yet clear the visualizations skills and previous experiences of industrial designers are very important. With visualizations that show the user interaction and context of use it is possible for electronics experts to derive technical criteria and think along with designers. However this working method results in a large dependency on external experts and creates a fragmented and slow learning process for industrial designers making it difficult to check if important aspects being overlooked that can result in unknown unknowns. Furthermore the large dependency on previous experience in combination with the time pressure in professional practice creates a strong incentive to only consider technologies that are applied before, limiting the solution scope of industrial designers. Therefore the current working method not only limits the ability of industrial designers to evaluate technical feasibility, but also limits the exploration of possible integrated electronics and their added values for users.

A practical way for design educations to improve the current working situation is to focus on a knowledge base about electronics that improves the communication with external experts. Especially the components, criteria and uncertainties of different kinds of electronic systems that are relevant for the technical feasibility. In detail this differs for each design project, but being aware of these aspects on a general level forms the starting point for an improved cooperation with electronics experts about feasibility and product behaviour.

6 RECOMMENDATIONS FOR FURTHER RESEARCH

This paper provides the basis for a practical approach in education that helps industrial designers to get a grip on the feasibility of integrated electronics. The educated general knowledge could work as a framework wherein designers can place newly learned knowledge and thereby decrease the current fragmented learning process. To develop this framework it would be very interesting to get insights on this topic from the opposite viewpoint; how do electronics experts see the cooperation with industrial designers? By combining the input from different experts the framework can be substantiated.

Looking further ahead this framework should form a combination with design methods and tools that facilitate communication with experts that goes further then feasibility. By combining this basic level of knowledge with methods such as experiential prototyping, the goal should be to empower industrial designers to change from integrating electronics to: designing integrated electronics, its product behaviour and influence on user experience.

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