# Designing multisensory user experience with everyday products

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*CHI'13*, April 27 – May 2, 2013, Paris, France.
ACM 978-1-XXXX-XXXX-X/XX/XX.

## Abstract

User experience (UX) is defined as the way a person feels when using a product. This term is commonly used referring to interactive computer-based systems. Anyway a good user experience when interacting with everyday products, not necessarily computer-based, is becoming a key factor for their success on the market. Indeed, it is one of the major drivers to the perceived quality about a product. Consequently, marketing experts who strongly influence company strategic decisions, are urging design teams on prioritizing the design of the user experience respect to technical and functional features. Besides user experience is subjective in nature since it involves personal multisensory feelings during product interaction and use. Hence, the necessity to properly consider UX issues when designing common products, is also demanding a change in currently applied design methods and tools. Virtual Prototyping based on multisensory Virtual Reality environments seems to be appropriate for this purpose. A justification to that statement is provided in this paper, where we describe a methodology developed for the design of user experience with everyday products through the use of interactive virtual prototypes.

## Author Keywords

Interactive Virtual Prototyping; Multisensory User Experience; Product Design.

## ACM Classification Keywords

J.1. [Computer Applications]: Administrative Data Processing: Marketing.

## General Terms

Human Factors; Design; Measurement.

## Introduction

What makes a product be successful on the market is a complex issue. Anyhow it is widely recognized that the way a person feels about using a product, named User Experience (UX), is strategic for determining a product success [12]. In the process of perceiving a product all the human sensory channels are involved, even those users are not aware of [11]. Recently the senses of touch and smell are acquiring a higher importance compared to the past. They are considered together with the senses of vision and hearing, important to be positively stimulated for achieving a good user experience when interacting with a product [9, 16].

The term User Experience (UX) is generally associated with interactive computer-based products [1, 13]. As a matter of fact, we interact and use several common products in our everyday life which are not necessarily computer-based. Therefore, the importance of designing a good user experience becomes a key factor for winning products in a broad sense.

People from the marketing divisions of companies, who are responsible for taking strategic decisions about new products, are urging design teams to first focus on the design of the user experience and then on functional and technical features (when designing new products). This new task (i.e. addressing the design of multisensory user experience) requires changes in the traditional product design process and in the enabling tools used. In fact, once a new product is conceived, its features and the way of using them have to be specified and tested with target users, to make sure that the designed experience is of good quality and well accepted by existing, former (why not) and potential customers.

An effective way to get information about the quality of the user experience and to capture target users' feedbacks about a new product is to put it in front of them since from the early stages of the development. In fact, various research works [5] have pointed out our limited abilities during these stages to reason about product qualities, including usage issues, unless we put the product in the hands of the user. Consequently, a prototype would enable target users to effectively perceive the new product properties or features directly interacting with it (or better with its replica). And this would be more convenient if performed already at the beginning of the design process [5]. Indeed, the results of these studies can be used as valuable input for detailed design.

The use of physical prototypes, which has been the traditional way of doing these studies so far, has limitations and issues. First, building a physical prototype is expensive and takes time. Second, representing variants of a proposed product requires the development of several physical prototypes, for the difficulties to perform real-time changes on physical items. Physical prototypes can be effective if built when the design is almost fully developed, but any design change at this point might significantly affect development times and costs.

Conversely, the use of Virtual Prototypes [4] would enable design teams and marketing experts to perform analysis about user experience in a more flexible and effective way: early in the product development process and avoiding prohibitive prototyping and re-design costs. However, for being effective, Virtual Prototypes have to be based on a multisensory interaction environment and faithfully reproduce the multisensory experience that happens in reality when using a product. Besides, Virtual Prototypes should be easily and quickly modifiable on users' requests so that several variants can be quickly defined and tested. Information about user experience and preferences can be gathered and transformed into technical specifications to use in the subsequent detailed design.

Taking into account all these aspects, this paper discuss the preliminary results of an on going research activity aiming at designing the multisensory user experience with everyday products through the use of interactive Virtual Prototypes.

## Related Works

The design of multisensory aspects of traditional consumer products is becoming a common practice in different product areas [16], such as food, cars, domestic appliances, soap, etc. The test of the perceptual feedback of such products is commonly based on the use of physical prototypes and artifacts. In particular the use of physical prototypes is necessary when tests require the physical interaction with the product through the senses of touch and smell. Regarding the visual appearance and the sound emitted by products, technological advances in virtual reality make it possible to simulate them faithfully through virtual prototypes.

Besides the use of Virtual Prototypes is gaining interest in industry because of its flexibility, growing fidelity, cost and time factors [4]. Traditionally, most of the tests performed on Virtual Prototypes have been purely visual, so aiming at evaluating the aesthetic aspects of a new product.

More recently a number of haptic devices have been developed to simulate the haptic feedback with products and their components. For example custom haptic device have been developed to simulate the physical interaction with refrigerator [15] and car [17] doors. The aim of these haptic-based virtual prototypes is testing design solutions concerning the haptic bahaviour, and eventually review the design of the product. In other works [3] it has been demonstrated the effective use of a multisensory environment based on touch, hearing and vision to capture users' preferences, already in the concept design phase. These initial studies have demonstrated the potentiality of Virtual Prototyping, and have highlighted the necessity to change the way new products are designed [8].

## Interactive Virtual Prototypes

*Limits of Physical Prototypes*

Physical prototypes are usually simplified versions of the product which are specifically built to perform experimental campaigns and revision activities. The more the design process is at the beginning, the more the prototypes are far from being similar and behaving exactly as the final product will. Early physical prototypes, as those produced during the concept phase, are usually made with materials, and manufacturing processes that are different from those used for the final product [19]. They are handcrafted or made with rapid prototype techniques with materials having different textures, density, smell and producing different sounds compared to the final product. As a consequence running a user experience evaluation on this kind of prototypes would probably return useless results. Furthermore these prototypes are not easily modifiable to verify product variants. Usually a set of significantly different prototypes has to be built when performing comparative tests. That strategy determines a waste of resources (i.e. time and materials) and it is not compatible with the need of companies of reducing development costs.

*Prototyping Interaction Though Virtual Prototypes*
The use of virtual prototypes is a common trend in companies operating in various industrial sectors, due to low cost and flexibility that virtual prototypes offer. However, one of the major issues concerns the kind of results deriving from testing. In fact they are not always reliable because of Virtual Reality technology limitations. In case of visualization technologies a high degree of maturity has been reached, so that the evaluation of aesthetic features of a product can be performed on visual/virtual prototypes. In recent years there has also been a growing interest in the study of simulation technologies addressing the other human senses. Specifically, good rendering quality can now be obtained for the sense of hearing while less for the sense of touch. Very few example of olfactory display are available, and they have strong limitations [10]. Hence, further research efforts are needed since, in order to be applied for correctly assessing users' experience, a Virtual Prototype has to resemble the real product and recreate the same interaction modalities that people would perform when using it. Therefore, the interaction must be multisensory, at least including the sense of sight, touch, hearing and smell (when available). Since the term Virtual Prototypes is nowadays used to identify any kind of digital model, we propose the use of the term *interactive Virtual Prototypes* to intend *interactive multisensory simulations of products experienced by users through advanced Virtual Reality technologies*.

*Sensory parameterization*
Interactive virtual prototyping is based on a complex combination of geometrical, multi-physics models, accessed by means of Virtual Reality (VR) technologies. Geometry represents the shape of the product, including rendering features as colors, materials and textures. Multi-physics models are used to define the physical and realistic behavior of the product in action and when used by a user. For example, it is possible to realistically simulate a door opening, by visualizing the door turned round the hinge, by exerting the reaction forces generated by friction, and by playing the related sound.

The digital nature of virtual prototypes brings the main advantage of allowing a full parameterization of information. This is very easily done for what concerns the geometry of the prototype. In fact, digital shapes of objects can be quickly modified by changing the values of parameters defining their dimensions. Parameterization can be also applied to other features of objects, which can be perceived through other senses than vision. In fact, we can change the haptic or the acoustic behavior of an object, modifying the corresponding parameters. For example, let us suppose we want to render a general force profile through a force feedback device. That force can be mathematically represented by means of a parametric equation, describing a spring/damper effect. Then, we can ask a user to try and experience this force profile by interacting with the haptic device, and tell us if she is satisfied with the reaction, or if she wants to change the reaction, by increasing or reducing the force feedback effect. The modification of the behavior can be obtained easily by changing the parameters describing the force profile. This allows us to make parametric, and therefore easily configurable, the product from a perceptual viewpoint.

*Separation of senses*
In order to evaluate a multisensory experience with a prototype it might be useful to have the possibility to combine the senses, and to vary one sensory feedback independently from the others. For example, when evaluating the experience of opening and closing a door, it might be useful varying the force feedback and the sounds separately. This because a door might be perceived as robust not only on the basis of the haptic feedback but also on the basis of the sound emitted [2, 14]. It is difficult to perform this kind of evaluation by using physical prototypes, since sounds are associated with materials and shapes, as well as are the forces. Therefore, for doing so it is necessary to build several prototypes, made of different materials and shapes.

Conversely, it is more convenient designing, varying and validating the multisensory experience and simulating in parallel and independently the input for each sense. That is only possible due to the use of iVPs and appropriate modeling strategies chosen to represent the phenomena. Then, we apply a reverse process on the basis of the quantitative definition of each physical phenomena that generates the global output in terms of forces, acceleration, damping, frequencies and intensity [18]. This is easily performed on interactive Virtual Prototypes where sounds, forces and the visual aspect are only digital pieces of information that can be handled separately.

## A Framework for interactive Virtual Prototyping

*General Framework*
In this paper we propose a framework for interactive virtual prototyping to use for designing and testing multisensory user experience with products. The framework is shown in Figure 1.

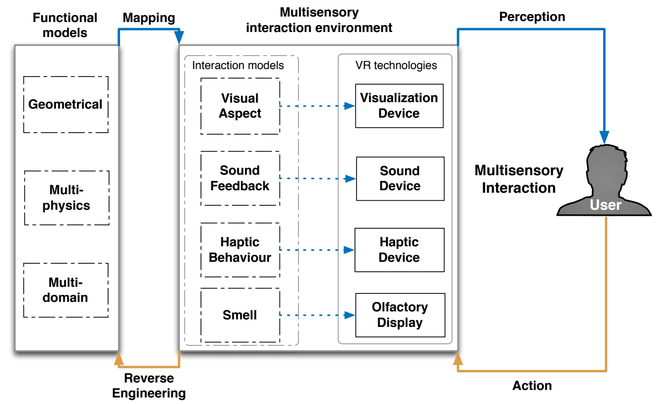



**Figure 1:** Framework for interactive Virtual Prototyping.

The Functional model includes geometrical, multi-physics and multi-domain models that describe the product and its behavior. These models may be complex and computationally demanding, thus preventing their use in an interactive application, which requires real-time response to users' actions. Therefore, they are mapped into multisensory interaction models that separately define the sensory information to send to each human sensory channel. The format of these items of information is also dependent on the kind of Virtual Reality technology used to render the information to the human. That VR technologies could be: a stereo projection display or stereo glasses for realistic visualization, 3 or 6 degrees of freedom force feedback devices for haptic rendering, stereo audio systems or single speakers for sound rendering and any kind of olfactory displays for smell [6]. The multisensory interaction models are parametric, so that each behaviour can be set and modified independently from the others.

*Framework for three senses*
In the following we will focus only on three sensory modalities, i.e. vision, touch and hearing, despite smell plays a fundamental role in the multi sensory user experience appreciation of a product.

A multisensory user experience based on three senses for a specific product is defined as follows. First we develop the geometric model of the body and of all visible parts, and then the functional models for the behavior of those product components/sub-systems we are interested to study. Then, we use the results of the functional simulations to create simplified models for the haptic and auditory effects, to render using selected VR technologies.

Now, a user can experience the interactive virtual prototype: she looks at it for evaluating the aesthetic aspects of the proposed product, she operates its components for evaluating their haptic response, and she can also listen to the emitted sounds and evaluate their pleasantness. If she doesn't like any of these aspects, we can modify the parameters related to this effect, and the user can test the prototype again and again. When she is fully satisfied of the multisensory experience, we store the multisensory interaction model that includes the parameters describing the optimal design solution for that user in terms of usage experience. These results can be used for building a customized product for that specific user, or can be considered together with the results of all users' tests performed for that product, in order to average the design solution.

Finally, the multisensory interaction model has to be mapped on the functional models, which includes the technical and engineering specification of the product and its components, through a reverse engineering process. At present, this activity is not fully automated and straightforward, and actually deserves more thorough studies to understand how to specify in quantitative physical values the preferences to be reached by the engineering design. Some tools exist today that may be used to perform this reverse engineering activity based on optimisation algorithms.

## Examples

This section describes two examples of interactive Virtual Prototypes that have been developed to design and test the user experience with two different kind of products: tactile tiles (Figure 2) and household appliances (Figure 3).

The first example has been proposed by a company operating in the industrial design sector producing the so-called tactile tiles, i.e. tiles that are not only visually pleasant but that are also such from the tactile point of view. In order to allow a group of users to experience some new designed tiles visually and haptically we have built a virtual prototype of each tile, which allows the definition of a combination of shape, texture and color, which can be perceived by a user through vision and the sense of touch. The user can setup her own favorite combination of these three properties, which can be changed independently of each other. In this way, also uncommon combinations can be created, as for example the friction exerted by a surface made of aluminum associated with the texture of a glass-made object. Even if this case is hard to imagine associated with traditional materials and manufacturing processes, the extensive research in both fields is leading to the development of new materials and processes that allow the creation of such multisensory experiences.

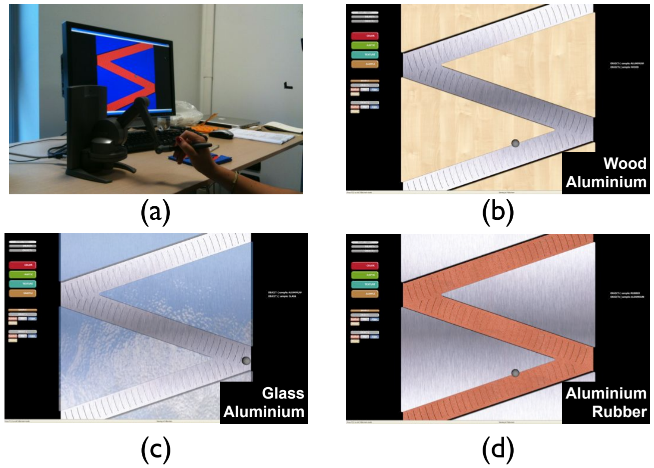
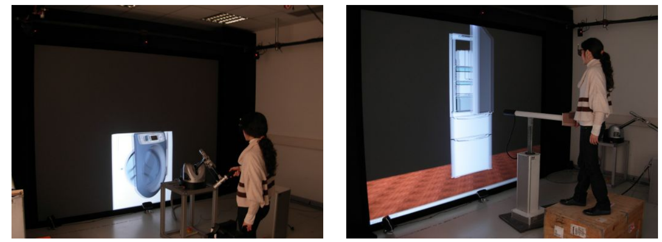



**Figure 2:** Examples of interactive Virtual Prototyping for multisensory user experience design of a tactile tile with different materials combinations: b) wood/aluminium, c) glass/aluminium, d) aluminium rubber.

The second example has been proposed by a company producing household appliances that is interested in experimenting new methods for letting users experience the interaction with new products, early in the development process and anyhow before building working full-scale prototypes. We have built a virtual prototype of a washing machine door/knob (Figure 3-a) and of refrigerator doors (Figure 3-b). They consist of the realistic visualization of the product, and of the haptic interaction with the doors/knob, which also utters sounds during the opening/closing actions. When a user opens and closes the doors and rotates the knob, visual, audio and haptic feedbacks are returned, in order to offer a much more complete multisensory experience. In this case study we have omitted the creation of the surrounding environment, anyway in order to improve the quality of the multi sensory experience simulation that aspect should be added.

In order to design the experience, a user is asked to test a pre-defined force feedback of the door/knob and is also invited to propose some changes to the haptic behavior until a desired condition is reached.



(a) (b)

**Figure 3:** Examples of interactive Virtual Prototyping for multisensory user experience design of: a) a washing machine door and knob, b) refrigerator doors.

In these examples sounds and haptic feedback can be modified independently from each other. In this way it can be easily evaluated the influence of the sound and that of the force feedback on the user experience.

The full implementation of the interactive Virtual Prototype of the refrigerator is described in [7].

## Conclusion

The paper has described a methodological approach proposed for the design of multisensory user experience (UX) with products through the use of interactive Virtual Prototypes (iVPs). Providing a good user experience is strategic, especially in case of consumer products, as a means to attract potential customers, influencing their purchasing decisions. Indeed it represents the differentiating element for choosing one product over another that is similar in terms of price, functionalities and technological content. However user experience is multisensory and for properly designing it new methodologies and tools have to be applied in the design process as proposed in this paper: iVPs could be seen as a new approach for experience design. Compared to physical prototypes, iVPs provide higher flexibility during design evaluation and re-design phases. They are built starting from functional models and simulations translated into parametric multisensory interaction models. Hence the simulated behaviour can be easily and swiftly changed and configured to meet users' preferences. Two examples demonstrate the potentiality of the method. Interesting to notice that the multisensory prototype maintains the control of the senses separately, so that the response for one sense can be changed independently of the others. This is something only possible by using virtual prototyping; it has the benefit that a design team can concentrate only on the effect and not on the physical principle that produces it. Future work concerns the study of the approach for using test results as input for the re-design of the product and the introduction of the sense of smell.

## Acknowledgments

Authors would like to thanks all the students that have contributed to the development of the examples, and the companies that have proposed the case studies.

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