Communication and Exchange Between Information Visualization and Industrial Design

Zhenyu Cheryl Qian
Purdue University

qianz@purdue.edu

Yingjie Victor Chen
Purdue University

victorchen@purdue.edu

ABSTRACT

Our daily activities now heavily rely on data, and sometimes are even controlled by them. Integrating InfoVis into people's daily lives can help them to access, explore, understand, and utilize the vast variance of data. This paper aims to explore and discuss the idea exchange between the traditional domain of industrial design and the novel field of InfoVis. There are three potential approaches. Extending InfoVis into a product design can fill up the small screen on the product and make the product more user friendly. Appling the 3D form of industrial design to InfoVis can bring it to the physical world and enhance the information qualify in our lives. We also argue that there could be a harmonious combination of industrial design and InfoVis that integrate the benefits from both. To understand this hybrid domain, we introduce some preliminary research explorations that covers both the industrial design and InfoVis, along with our education practices, including our assessment framework, research outcomes, education approaches, and student design projects.

Categories and Subject Descriptors

H.0 Information Systems: General

General Terms

Design, Human Factors

Keywords

Information visualization (InfoVis), industrial design, visualization excellence, ambient information display

INTRODUCTION

We are now in the big data era. Its "bigness" is about the volume, velocity, variety, and also the coverage. The data are created not only from business using information technology (e.g., e-mails and transaction logs, but also from people's daily lives almost everywhere at any time. In our lives, many natural phenomena have been converted into data. Consider, for example, the temperatures of a day are a series of numbers with fixed time intervals (e.g., by hour); weather information is categorical data (e.g., rain, overcast, clear) with possibilities; health information is a multidimensional data set containing several numerical indicators, such as height, weight, BMI (body mass index), blood pressure, blood-sugar level, and heartbeat rate. The drive from home to office can be recorded as pairs of longitude and latitude values with time stamps. Our daily activities now heavily rely on these data, and sometimes are even controlled by them.

With advanced technologies, we are collecting data more frequently with higher accuracy and from many sources. In academia research and business practice, information visualization (InfoVis) has been approved as an effective means to communicate large volumes of data by taking advantage of the broad information pathway of the human perception system (Thomas & Cook, 2005). We believe that by integrating InfoVis into people's daily lives, we can help people to access, explore, understand, and utilize the vast variance of data, leading them to better life quality and experience.

The domain of industrial design was defined in 1919. Working in a range of industries, industrial designers combine art, business, and engineering to make products and improve systems that people use every day. "Industrial designers play a significant role in today's innovation economy, and they bring a creative lens to approach complex problems or challenges," said NEA (National Endowment for the Arts) Senior Deputy Chairman Joan Shigekawa (Gifford, 2013). Nowadays, with the increasing popularity and variety of electronic products, industrial design starts to overlap into the fields of user-interface design, graphics design, information design, and interaction design.

This paper aims to investigate communication between the traditional domain of industrial design and the novel field of InfoVis. This communication has two directions. How can we extend InfoVis into a product design to make it more user friendly and enhance user experience and user awareness? How can we inform InfoVis using the 3D form of product design to make InfoVis enter the physical world? Is there a harmonious combination? I will introduce some preliminary research explorations that covers both the product design and InfoVis, along with our education practices, including our assessment framework, research outcomes, and student design projects.

VISUAL EXCELLENCE AND DESIGN PRINCIPLES

There have been different perspectives to guide, access, and discuss

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the qualities of design projects in different design domains. It is necessary to review these criteria of good designs in both InfoVis and industrial design domains.

Research in InfoVis covers both design and computing. In computer science and computer engineering, InfoVis has been established (e.g., Meirelles, 2013; Spence, 2015; Ware, 2012) for years that includes varieties of design, technique, and algorithm issues for visually presenting different types of data sets. From the design perspective, researchers are investing the relation among human perception, cognition, information, and graphic layout, as well as the interactive design. Evaluation of InfoVis is complex. We have to understand the visualization thoroughly, not only by assessing the visualizations themselves, but also the complex data and information that the visualization is meant to communicate. Catherine Plaisant (2009) outlined the challenges existing while evaluating InfoVis systems. Lam et al. (2012) described seven scenarios of possible empirical studies. To guide the visual design of info is, Edward Tufte published a series of books (Tufte, 1990, 2006; Tufte & Weise Moeller, 1997) that originated from the statistics, and they turned out to be the most significant contributions to the information graphics (infographics) design domain. Tufte (1990)mproposed the principles of "graphical excellence". Based on such principles, Al Globus proposed the concept of "visualization excellence." He slices it into four layers (Globus, 1994):

- Consist of complex ideas communicated with clarity, precision, and efficiency;
- Provide viewers with the greatest number of ideas in the shortest time with the least ink in the smallest space;
- Always be multivariate;
- Require telling the truth about the data.

Globus set the design goals of visualization as "content focus, comparison rather than mere description, integrity, high resolution, utilization of class designs and concepts proven by time" (Globus, 1994).

Researchers in InfoVis and HCI (Human Computer Interaction) tried to bring InfoVis into the daily lives of humans by developing an ambient information display. Wisneski et al. (1998) tried to turn an architectural space into an interface to let people access digital information. They tried to go beyond the small rectangular computer display. Information is presented through subtle changes in light, sound, and movement to achieve awareness in the background. Skog et al. (2003) converted the traditional scientific information visualization display into a more aesthetic appealing device, but keeping it effective in communicating useful information. Pousman and Stasko (2006) synthesized the design patterns toward four different types of ambient information systems, including symbolic sculptural display, multiple-information consolidators, information monitor display, and high throughput textural display. System developers can use these patterns to model their system designs. Focusing on infographics design, Connie Malamed started from human cognition and listed the six principles (Malamed, 2011), such as organizing information for perception, emphasizing on visual cues to direct the eyes, providing context to make the abstract concrete, remain with the structure to clarify complexity, and charging up the graphics with emotional elements and innovations.

In the domain of industrial design, Dieter Rams proposed 10 principles of "good design" in the 1970s, such as being innovative, useful, aesthetic, and understandable, to evaluate quality of product design (Wise & Newcomer, 2011). Donald Norman (2002) suggested design principles for understandability and usability: provide a good conceptual model, make things visible, ensure cognitive mapping, and provide immediate feedback. John Maeda (2006) offers ten laws for balancing simplicity and complexity in business, technology, and design -- guidelines for needing less and actually getting more.

Product design also emphasizes the understanding of materials and the manufacturing process. A good product design is not only successful in terms of its form and functionality, but also in a smooth integration of materials usage and easy manufacture. Furthermore, the concept of "affordance" was first introduced by Don Norman (1988) from psychology theories to the industrial design field. It is now widely adopted by different design societies, such as in architecture (Şahin, Çakmak, Doğar, Uğur, & Üçoluk, 2007), robot control design (Maier, Fadel, & Battisto, 2009), and user-experience design (Forlizzi & Battarbee, 2004). Affordance provides strong clues on how to use an object, and it can be instructive to guide the design.

No established literature for connecting industrial design with InfoVis is presently available. By adopting the above theorized principles, we create our own heuristic assessment framework to guide and evaluate this type of hybrid design.

1. **Understandable**: The appearance of design clearly expresses its functions or meanings. There should be little concern about its affordance. Especially when InfoVis becomes a physical object, little room is available for adding legend or explanation.
2. **Direct the eyes:** Emphasize human visual perception, and consider the position, movement, size, and other visual cues in the design.
3. **Visualization excellence**: Communicate multivariate information accurately and efficiently.
4. **Reduce realism**: Be simple; consider issues of visual noise, silhouettes, line art, and quantity.
5. **Aesthetic and elegant:** Concentrate on the essential aspects; only well-executed objects can be beautiful.
6. **True and honest**: Tell only the truth and limits.
7. **Innovative and exciting**: Charge up design with emotional salience, narratives, metaphors, novelty, and even humor.
8. **Concrete**: Provide overview, time line, and other supporting information, if possible.
9. **Harmonious integration**: Naturally combine the physical form and the digital information as a consistent unit.

OUR EDUCATION APPROACH

In the educative exploration of integrating InfoVis into traditional product design, we made four kinds of efforts:

(1) Understand human visual perception and models of visual information processing. "Vision is not a mechanical recording of elements, but rather the apprehension of significant structural

patterns" (Arnheim, 2004), We introduced perception issues in the graduate course of "Cognition in Design,". Through study eye's structure, students can understand basic perception phenomena, such as we see things differently in the daytime than at night. They learn from concepts of visual field, eye movements, color theories, gestalt laws, to different scenarios that can cause illusion. We also discuss the most recent technologies related to vision, such as eye-tracker equipment's such as Tobii Glasses (Tobii, 2013). Based on such scientific and technique knowledge, students start to make send of why Malamed's six cognition design principles (2011) is important and useful.

(2) Learn and identify different visualization techniques. We offer the "information visualization design" course to our industrial design students. Different from computer science departments, the InfoVis course we offered focuses on the design perspective of visualization. According to the structure and data and relations of data items, data can be categorized into different types, such as un-structured text, multi-dimensional data, tree and network relation data, temporal data, and geospatial data. In real word, the data may carry multiple characteristics. The design has to fit for the characteristics of the data. For each type of data, students have developed several visualization designs. After digesting existing visualization methods, the students have to integrate and enhance these visualization methods to make more creative and effective visualization projects. Not only limited on regular screen monitors, mobile visualization and large-screen visualization are also discussed in the course. Through discussion, students see the potentials and limitations of existing system examples.

Design students typically lack programming skills. It is challenging for them to program interactive visualization systems solely by themselves. We tried to use existing InfoVis tools, such as Tableau and ManyEyes, to make their exploration and creation possible. We also tried to set up teams to let our design students collaborate with computer science students so that our design students can see their design in action. Their final projects were presented to a public audience in an InfoVis exhibition installed in the gallery.

(3) Emphasize on creativity and build up confidence to express a designer's unique merit, comparing to professionals in other areas such as computer science. Since 2011, we have integrated interaction design evaluation in the product-design process (Qian & Visser, 2011). Students were equipped with six evaluation methods. Instead of observing, they started to review other design projects as rational critics. Before they can not only recognize that one design is good or bad using their instinct. Now they can describe and analyse why it is good or bad based on definite reasons, such as that its features solve a crucial design requirement in the heuristics evaluation, or that the innovation matches user experience according to the observation. More importantly, as a designer, they can provide feasible solutions to improve the original design without damage the core value of the design.

(4) Gain more InfoVis design experience by participating in the InfoVis design competitions and real projects in a collaborative team environment. We started leading some students to attend InfoVis and interaction competitions, such as IEEE VAST (Visual Analytics Science and Technology) design challenges since 2012. In 2013, we won the only two "creative design awards" in the 2013 VAST challenge on designing a large information display for a cyber-security control room (Chang et al., 2013; Promann et al., 2013). Such experience built up students' confidence and opened up their vision of InfoVis and industrial design.

InfoVis Display on Products

Many products are equipped with digital display screens. These screens are usually small due to the limitation of the overall size, shape, functions, and the cost of the products. Comparing with these screens, mobile phones are much more powerful on computational power and much bigger on the screen size. These screens provide basic functions that allow the user to read and interact with the dynamic information provided by the product. However, problems still exist. Current advances in technology are able to produce hardware powerful enough to store a large quantity of information within tiny and inexpensive chip sets. But the interaction design and InfoVis design are far from satisfactory to allow users to see, recognize, and use the large amount of information.

As an example, for a blood-glucose monitoring device, it will be beneficial for the user to see pre-recorded data, including the overall history and details of each period (e.g., after each meal), and make predictions for future trends. However, on the current market we can hardly see any household device to provide such a capability. Even if one does allows the user to retrieve pervious data, the interaction is so complex that almost nobody can navigate through the functions. A proper visualization and interaction design can help the user access, see, and use these data. Thus we can make the user aware of the situation, guide the user to operate product, and achieve optimal results.

Previously, our industrial design student works have many nicely done product renderings with beautify 3D forms, but with black screens (Fig. 1). They lack the understanding of functions, the operation flow, and the information structures. They are afraid or unable to design the interface, not even mentioning to visualize the information collected in the product. Most often, the gap was left for later engineering and been filled by engineers or computer programmers. Although the product function has been satisfied, the detailed user interaction and experience has not been considered, which often leads to poor user experience that greatly limits usage of the product.

How can we present complicated information on various and small screens? Iconic visualization provides us a feasible solution that can naturally fit into the small screen of a product. Also, approaches from mobile phone information visualization are inspiring.

Figure 1. Good product design renderings with black screens

Iconic visualization uses small glyphs and icons to represent information and data values. The icon is a readable symbolic representation that shows essential characteristics or features of a data domain (Post, Post, Van Walsum, & Silver, 1995). The main purpose of iconic visualization is to replace the data with a symbolic representation that is clear, compact, faithful, and meaningful. As a 2D graphic, icons encode information through three groups of features: spatial features such as position and orientation; geometric features such as shapes; and descriptive features such as color, texture, and transparency. Combine these together, an icon can be used to represent simple multidimensional data.

By grouping several small icons together, we find it possible to communicate complex information. Based on the nature of human perception that a human is most sensitive to human face, Chernoff (1973) designed a set of cartoon human faces to display up to 18 variables (dimensions) of data. Although a later study shows that Chernoff face feature perception is a serial process and is not pre-attentive. But it stills inspire our designers that we can encode complex information using human familiar graphical glyphs. Benard Kerr's Thread Arts (2003) visualized the relationship among e-mails using connected arcs within a tiny visual panel. Using a space like a tool bar in the menu area, the user can see the email reply/forward relations among threads. Adopt these compact yet efficient visualization methods, we can display sufficient information within the small screen on a product. Due to cost reason, many products use mono-LCDs as the display units. Shape-coded icons, due to their compact form, have been widely used in such displays. For example, clouds/raindrops/snowflakes are standard icons to display weather information on almost all digital weather stations. Ward synthesized a set of principles for designing multivariate data glyphs(Ward, 2008)

Smart phones open up new possibilities for user-interface design. Powerful graphic hardware make it possible to apply a 3-D user interface on a mobile device to run the complicated interactions of drop-down, catching, and peeling (Capin, Pulli, & Akenine-Moller, 2008). Luca Chittaro (2006) outlines six steps to guide mobile visualization design: mapping (encode data into graphics), selection (filter out unnecessary data), presentation (lay out design), interaction design, human-factor consideration, and outcome evaluation. Focusing on design, Apples' IOS and iPhone has become one of the current mobile interface leaders. IPhone allows users to look over material adjacent in space rather than the traditional approach of stacking materials in time, which provide an elegant solution for the design problem of small screens by greatly intensifying the information resolution of each displayed page. (Tufte, 2008).

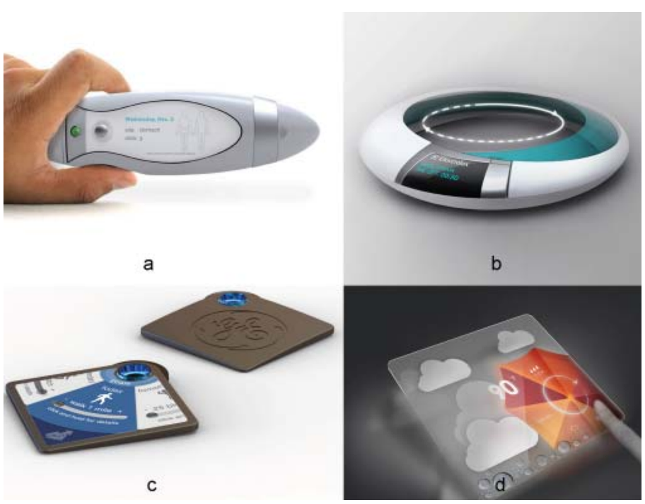

Figure 2. Information visualizations on small product screens

Here I present four student designs with InfoVis in the small displays collected from our design courses: a GE health-care medicinal injection device (Fig. 2a), an Electrolux futuristic intelligent cooker (Fig. 2b), a GE health-care exercise reminding device (Fig. 2c), and a futuristic weather forecaster sticker (Fig. 2d). These products all have integrated small display screens to communicate essential data to the user. These data are in different types.

a. GE health-care multiple sclerosis medicine injection device: It is crucial to remember when and where to take the medicinal injections accurately every day. But for a multiple sclerosis patient, it is challenging. It will be ideal if the injection device can be reminder of injection. The injection history of locations, times, and amounts should be clearly recorded and represented. To address this issue, the student integrates both the body map and calendar as visualizations in the small screen. According to our heuristics, understanding injection locations on the simplified body map is easy. The colored dots draw a user's attention to read the location carefully, and the overall interface is clean to read.

b. Electrolux futuristic cooker: The cooker-embedded cooking guide is visualized using graphic bars in the interface. Cooking mode, strength, cooking time, and other related data are displayed in the small screen. The curved display window and the blue graphic in the screen naturally integrate smoothly into the product.

c. GE health-care physical exercise reminder: The exercise reminder serves as a personal workout manager and communicator. The screen is the central intelligent component. Through displaying the tracked activity history, upcoming exercise events, and results through exercise, the device motivates the user exercise and using the product. It effectively used the small screen space to display multiple pages of information through a circular graph, which is good evidence of "visualization excellence." This design avoids the popular touch-screen interaction. Instead, it uses simple flip interaction on the blue ring to emphasize the circular affordance.

d. Weather forecaster sticker: Using a transparent, flexible touch screen, weather information is visualized and merged in the surrounding environment (Fig. 2d): Samsung officially launched its YOUM bendable display screen in January 2013 (OLED, 2012). Inspired by this futuristic material, one student created a transparent sticker to visualize calendar, incoming messages, and a future weather. The overall view is pretty simple, but all the weather information of the future seven days has been elegantly integrated in the right graph and background images. The user can stick it with any surface. The transparent material hides the product itself but blend the beautiful graphical information on the surface.

AUDIENCE–CENTERED DATA SCULPTURE

Data visualization doesn't necessarily need to be flat or screen-based. We have also explored other methods to communicate the message carried by the data. Physical visualization is a growing form of information visualization. With the rise of 3D fabrication such as 3D printing, the resurgence of maker culture, and the possibilities of shape-changing representations, physical visualization is becoming more possible, more popular, and more promising. Since 2010, a new trend of building data sculptures has appeared in the fine arts society (Dragicevic & Jansen, 2014; Fischer, 2011; Miebach, 2011).

We are interested in exploring the different physical visualizations offered in comparison to screen-based representations, alongside how industrial designers can present the data in different physical ways. Focused on the user-centered approach, industrial designers naturally read data from a 3D perspective. They are more familiar with the materials and fabrication process. Instead of presenting the data in an ambient approach as artists do, they tend to enrich the data sculptures according to visualization excellence of "communicating with clarity, precision, and efficiency." We integrate this design goal into our education through an information-design graduate course. This course is different from the typical InfoVis courses offered by computer science and computer engineering curricula that are focus on algorithms and techniques for different data. We focus more on the design and user experience side of visualization to communicate the message from varies types of data. Students were expected to be faithful to the data, communicate the message, and, more importantly, innovative and beautiful. Design students typically lack programming skills. To let students read and make sense of the data, we utilize existing InfoVis tools (e.g. Tableau (Tableau Software, n.d.)) to make their exploration and creation possible. After understanding the data, the students use their creativity and design skills try anything possible in their minds to create the data sculpture. The final outcomes were presented to the public audience in a public gallery exhibition at Purdue University.

a. Figure 3a is about the mysteriously high suicide rates in Japan. It is a sad topic, but the plain data just tell the facts from an objective perspective. The wood branch sculpture compares the suicide rates between Japan and United States during the past decade. The student-selected symbolic objects (cherry flowers and stars) are selected to represent the two countries. The left branches with cherry flowers present the national suicide rates in Japan, and the right side with stars presents U.S. rates. From the bottom to the top is the history from 2003 to 2012. Audiences can understand this piece of work immediately. They can also feel free to compare across the years or side by side.

b. The designer of Fig. 3b used a series of fur balls to visualize the fur industry in 2012. The ball colors imply the types of fur; the sizes show the market value; and the hanging sequence shows the hierarchy of the market structure. In each ball, the designer nested a smaller ball to show the size of the U.S. market compared with the global market. Audiences were first attracted by the abstract fox stand. With some explanations and touch interactions with the balls, they quickly started to understand more and to discuss the fur types.

c. The combination of infographic posters and data sculptures (Fig. 3c) focuses on the topic of World War II. The poster introduced major events, and the sculptures were trying to communicate different countries' human loss data from both the two military alliances (left side is the Allies, and the right is the Axis). Each country is represented as an independent pyramid. Their major leader's faces during the WW II were laser-caved on one side of the pyramid. The size of pyramid shows the overall population before the war, and the empty gap on the top marked the human loss from 1939 to 1945. All four sides of the pyramids have been enriched with different background information about the country's participation in WW II. But the audience was impressed most by the remaining dark gaps on the pyramids, especially in Russia and Germany.

d. The designer of Fig. 3d was a baseball fan and wanted to present the possibilities for an excellent player to enter the Baseball Hall of Fame in Cooperstown, New York. He used a bunch of baseball bats as the metaphor to demonstrate the numbers of players in different positions. For the audience, it is very obvious that the pitcher's position has the highest possibility to enter the Hall of Fame, and outfield positions have more opportunities than infielders do. The catcher has the lowest potential. The whole sculpture is clean and self-explainable.

Figure 3. Data sculptures in gallery exhibitions

All of these data sculptures aim to describe facts by visualizing the abstract data through physical objects. Information was demonstrated at different detail levels. Although they are not interactive, they were targeted to be communicative and interpretative in the gallery settings. We received very high compliments with the two physical visualization exhibitions in 2011 and 2014.

PRODUCTS AS INFOVIS, INFOVIS AS PRODUCTS

Integrating product design and InfoVis further, product itself could be a visualization of information, or the visualization could be a useful product. The size, form, color, and even the vibration and movement of the product, can all be utilized to communicate complex information (such as pressure, temperature, frequency, speed, and popularity) to the user. The information can be immersed in the product, which will lead to smoother user experience without visually interrupting the user while operating. This new perspective challenges designers to interpret InfoVis and product design more innovatively. Below we discuss two levels of such InfoVis-product: physical components and the whole product.

Low-tech: Physical Components as InfoVis

First, the InfoVis can leave the digital LED screen and become a physical component in the product. Here are two examples. In a washer-dryer project sponsored by Whirlpool, the designers surveyed thirty washing machine users, aggregated the data, and ranked the popularity of different washing functions. According to Fitts's Law, the time required to move a pointing device to a target is a function of the distance to the target and its size (Fitts, 1992). Basically, the closer and larger a target, the faster the user can reach and click on that target. The top image in Fig. 4 shows applying Fitts's law on visualization in the control panel design. The size of a button depends on how frequently it will be used. For example, the buttons on the right side are more frequently clicked than those on the left side. Although the circular time display screen is off-center of the menu circle, the affordance of these buttons is clear.

Figure 4b is a flower pot to grow vegetables outside of a window. Without opening the window, it is hard to tell if the soil is too dry or the outside temperature is too low. The designer ties this essential information with the growth of vegetables. The display of the soil's moisture level and temperature escapes from a digital screen, but appears as an indicator tag on the outside pot.

Figure 4. Examples of Visualizations as Physical Parts of Products

Both of these two examples show "low-tech" possibilities of how product components can visualize information. Without fancy technology, the design still meets the design criteria of being simple, accurate, concrete, and effective.

InfoVis Product

We can make information visualization a product. This more innovative approach is inspired and supported by the modern developments of ubiquitous computing and ambient information display. Ubiquitous computing thoroughly integrate information processing into everyday objects and activities of human (Lyytinen & Yoo, 2002). It is a post-desktop model of Human-Computer Interaction. Ambient information displays focus on displaying information in an environment that does not require the constant attention of the user (Jones, 2007). They seek to convey information in the background that the user may wish to be aware of and to attend to, but it does not require his or her consistent awareness.

Integrating ubiquitous computing with ambient information display provides a feasible way for us to design InfoVis product. Such product can transparently immerse technology and convey information in a smooth and natural way. In the 2012 product design graduate course, I assigned the students one project to

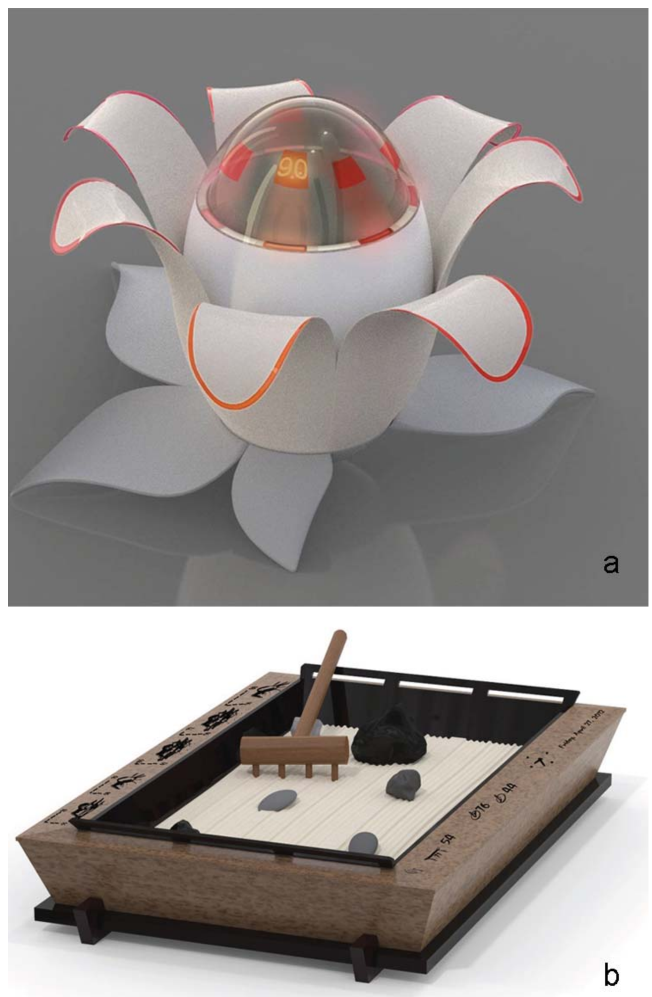

Figure 5. Examples of InfoVis Becomes Physical Products

create a “transparent design” (Wren & Reynolds, 2002) for weather forecasting. The product should be immersed in our living environment and effectively communicate all necessary weather information.

In the design shown in Fig. 5a, the openness, and ring colors of flakes forecast future seven days about each day’s humidity and temperature. With a glance, the user can quickly aware the condition of the next week, dry, wet, cold, or hot. The detailed data of today, including current and hourly temperature and weather, are projected to the canter egg-shaped glass as bar charts and noted with accurate numbers.

The tabletop Zen garden in Fig. 5b is another weather forecaster design. Weather data of temperatures and humidity are displayed using ancient artistic handwriting. Using the rake to move stones and sand in the garden is the interaction to query different kinds of weather information. The product itself mimic the zen garden to imitate the intimate essence of nature. Playing with rake and rock becomes an enjoyable moment to make the garden a soothing tool for the user to gain peacefulness from his or her busy life.

Both the flower and Zen garden are product designs of weather forecasters, but they are also sculptures that visualize weather information. It is possible to integrate InfoVis and product design into one and communicate the information to users in an ambient and transparent way. The design can be charged up with innovative ideas and fresh metaphors. More important, the physical form and the detail information are harmoniously combined.

DISCUSSIONS

Nowadays, many products are highly interactive. The successful market experience of smart phones has motivated many industrial designers to always think toward tangible interaction with the touch screens or related mobile application designs. In this paper, we want to introduce a new perspective to consider the future of industrial design.

InfoVis emerged from studies in design, science and psychology domains. It has strong relationships with graphics design, but has not drawn enough attention from product designers. InfoVis has proven to be an efficient approach to dealing with large amounts of data. We believe it can also bring products to the next level of power to enhance user experience. Our world is multidimensional. We are surrounded by information. To gain opportunity, priority, and power, the world we face requires our being able to use and communicate information effectively. As technology advances, we will have much more choices on transparent, flexible, and handy display surfaces for us to use in the design for all kinds of activities.

We must maintain a balance between information richness and interface simplicity while designing InfoVis into the product. There are strong needs force us to integrate InfoVis into product design. It is also time to release InfoVis from the computer screen of domain professionals. We need to apply it to the small-product screen, to any kind of surface, or even to make it as a product, to benefit a much larger population. Thus future product designers will be responsible for this.

As educators, we should be inspiring and forethoughtful. Although there is no established literature to guide the domain and no polished examples to demonstrate, we should explore and introduce the new domain to our students at an early stage. Communicating and exchanging ideas with them will foster creativity and innovations. Products can be amplified by nicely designed InfoVis components. InfoVis can enter the physical world with a wider audience group as a result of different usages. Furthermore, InfoVis can be transparently integrated into products. We proposed a heuristic framework to review and access the interdisciplinary design domain based on other established design principles. With some student projects, we are able to discuss and introduce this new perspective. Working in this interdisciplinary area, we and our students are excited to see the much-expanded possibilities; we are thus motivated to explore more.

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