Design Process of the Future

Dan Siewiorek

1. The Role of Design

Design is the major differentiator between products and processes in the marketplace. Design is the creative process that determines the function, form, capacity, and ultimately the utility of a product or process. Decisions during the design phase impact the ease with which the product can be manufactured or a process or building can be operated. By the time that ten percent of the total effort is expended on a new product, over 80% of the decisions have been made. A poor design cannot be iterated into a superior product no matter how much down stream effort is expended. While manufacturing technologies have become more efficient there have not been complementary gains in design to the point that design has become one of the three most critical technologies for the U.S. semiconductor industry. Universities that recognize the key role of design and adapt their curriculums will become leaders in providing an education that becomes a competitive edge for both students and their employers.

2. Design in the 1980's

Design practice typically followed the "waterfall" model, where design, development, manufacturing, and distribution were performed by organizationally separate groups, with flow of information generally in one direction. This model resulted in very long lead-times and, frequently, an inability to respond to rapid changes in available technologies. Computational tools, with a few notable exceptions, addressed largely the analysis and evaluation components of the design process or automated routine activities, such as drafting and order processing. Furthermore, again with notable exceptions, the available tools formed "islands of automation", which required tedious and error-prone manual re-entry of data to the programs, thereby in many cases actually slowing down the design process.

3. Design in the 1990's

Business and technology have changed dramatically in the last decade. Vertically integrated industries have outsourced many activities such as subsystem design and manufacture to service companies (Electronic Commerce). Computer based design information makes it possible to transmit quickly a design description with sufficient detail to generate fabrication instructions (Rapid Fabrication). In product design, adaptive, computer controlled manufacturing processes can rapidly reconfigure to fabricate products economically in small batch sizes (Rapid Assembly). Moreover, products and processes are increasingly more tightly integrated with technologies from multiple disciplines. Communications technologies enable multidisciplinary geographically distributed teams to collaborate effectively (Design Systems).

The current state-of-the-art in design practice is characterized by increasing complexity of products and their fabrication processes resulting from both technological opportunities and economic and regulatory constraints. At the same time, rapid changes in supporting technologies and competition in the marketplace require increasingly shorter product cycle times.

4. User-centered Design: an Example from the Publishing Industry

Publishing books or papers in the 1960s was a team effort. The author would create a draft manuscript which would be sent to a copy editor to establish a style sheet with respect to type fonts, spacing, and page layout. The copy edited manuscript would be sent to a type setter who

would re-key the information according to the style commands. The resulting galley proof would be returned to the author for error-checking. The type setter would correct the errors and lay the article out in page proofs. The author would see the page proofs and have one last chance to correct errors. Sometimes weeks could pass between each of the stages in this production process.

With the advent of desktop publishing, the author is in complete control of the entire production process. The author can select type fonts, establishing spacing, and execute special assistance programs such as spell checkers. The author is in total control of the design and visualizes the developing paper directly on the computer screen. Table and drawings can be inserted. The final form of the document can be previewed in hard copy form as output from a laser printer. The document can even be printed in color. The results of the author's design efforts can be seen in a matter of minutes. Once satisfied, the author can submit the article to the publisher in electronic form.

We envision a similar revolution in the design of physical artifacts. The designer is in more direct control of the entire design and production process, eliminating the possibilities for misinterpretation by middle-men, and greatly reducing the entire design and production cycle. The next section elaborates on this vision for design.

5. Vision

We envision a time when the end user will interact with a computer based design system. The system will elicit design requirements by creating usage scenarios. The system will then generate an initial virtual design for the user to manipulate in a realistic virtual environment. The user will be able to modify the shape by sculpting. As the user modifies the shape, programs serving as design critics synthesize the design and analyze it's behavior. If the design has too little volume to house the electronics or there is insufficient surface area to dissipate the generated heat, the user will be notified through visual and haptic feedback (e.g. a six degree of freedom control stick or a data glove). The design critics are geographically distributed and communicate over computer networks. Once the design has been finalized, an electronic version is distributed in order to locate parts suppliers and service providers. Through electronic bidding in terms of cost and schedule, a supplier chain is established, the system fabricated, and delivered to the end user.

At a more distant point in the future, the design will be delivered to a desktop manufacturing facility that will fabricate the system from raw materials such as powdered metals, plastics, and electronic chips. The desktop system will fabricate a 3 D prototype directly from a CAD model with the same ease that a laser printer makes a copy of a document from powdered ink and paper.

At some point there could even be home desktop manufacturing machines (with larger models available for rent at the neighborhood Kinkos). By browsing through catalogs the customer locates a desired product, electronically contacts the company, and pays for the design instructions to be down loaded into their desktop manufacturing machine. The customer could use the design system to modify and customize the design. The product would be manufactured at home with materials provided by the end user and there would be no need for inventory. Note that at the turn of the last century, the Sear's catalog was a popular way to order patterns for dresses fabricated in the home.

In summary, in the future products and processes will be even more individualized with customers playing a key role in the specification of the product. The design process will draw

upon expertise in multiple disciplines to generate an effective solution. In the creation of new products and processes, industry must deliver:

"customized designs with the economy and high quality previously achieved only in mass production."

6. Challenges in Design

A number of trends must be overcome in order to achieve this vision.

> Increasing product complexity. The complexity of products and fabrication processes continues to grow due to increased expectation of performance as well as to affordability constraints and environmental impact. For example, each new generation of computers is more functional, uses less energy, is smaller and lighter than the preceding generation - and is in turn replaced by a newer generation. The visionary design system must scale with complexity.

> Rapid Obsolescence. Rapid changes in technology lead to rapid component obsolescence. Major electronics-based companies derive the majority of their revenues from components that are less than three years old. In addition, global competition can require almost continuous introduction of new components. Consumer electronic products often have a design and manufacturing cycle of less than six months. The visionary design system must automatically acquire new technologies.

> Increasing design process complexity. With the proliferation of tools for design and fabrication, a designer is faced with complex decisions in the selection of tools, components and services. Experience shows that completing a product design requires about the same level of effort as creating the design process (i.e., selecting the design tools, generating a compatible computing environment in which the tools can co-exist and translating outputs from one tool into inputs for another tool). The visionary design system must also automatically acquire new tools and manufacturing processes.

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