AC 2007-1987: UNDERGRADUATE LEARNING EXPERIENCES THROUGH RESEARCH IN EMERGING AREAS OF ENGINEERING DESIGN: PRODUCT PLATFORM PLANNING AND DESIGN FOR MANAGING PRODUCT OBSOLESCENCE

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Undergraduate Learning Experiences Through Research in Emerging Areas of Engineering Design: Product Platform Planning and Design for Managing Product Obsolescence

Abstract

In this paper, we present the learning experiences of six undergraduates who worked on research projects in the areas of product family and product obsolescence. These areas represent emerging fields in product design. Product platforms enable the planned development and deployment of families of related products whereas traditional design processes optimize on a single design. Design for Managing Product Obsolescence (DfMPO) helps in mitigating and preventing obsolescence of products due to rapid change in technology, thus promoting sustainability. Both product platform and DfMPO place an increased emphasis on management of information due to the reuse of design knowledge. The REU program gave the six students the opportunity to discover design principles and knowledge related to platform design and DfMPO. The students spent a semester applying novel design knowledge representation and visualization techniques to plan product platforms and design principles to prevent product obsolescence. The students worked closely with a faculty, a post-doctoral researcher, and graduate students in the research group. The six students include three freshmen, one junior, and two seniors. Five of the students are women and one is a man. The group represents a variety of engineering disciplines with majors in aerospace, mechanical and industrial engineering. This paper provides an overview of the research conducted by the REU students, the structure of the REU program, and the students' overall experience including the effects on student interest in graduate school.

Introduction

Basic research in Engineering Design is needed to advance our understanding of the fundamentals of the product realization process. One of the challenges to the research community is to create the necessary connections between the principles of design theory and the practice of design across the broad spectrum of engineered products through the creation of new tools and methods. Through a National Science Foundation sponsored REU (Research Experience for Undergraduates) supplement, 6 undergraduate students were given the opportunity to work closely with a faculty, a post-doctoral researcher, and graduate students in the realm of engineering design. This paper presents an overview of the research conducted by the REU students in the area of engineering design, the structure of the REU program, and the students' overall experience including the effects on student interest in graduate school.

Research Overview

The research projects for the undergraduate students (here after referred as REUs) are mainly concentrated in the areas of product family and product obsolescence. These areas represent emerging fields in engineering design. Product platforms enable the planned development and deployment of families of related products whereas traditional design processes optimize on a single design. Design for Managing Product Obsolescence (DfMPO) helps in mitigating and preventing obsolescence of products due to rapid change in technology, thus promoting sustainability. Both product platform and DfMPO place an increased emphasis on management of information due to the reuse of design knowledge. Basics of these two research projects are elaborated in next two subsections.

Product Family

A *product platform* encompasses the design and components shared by a set of products. An effective platform is the core of a successful product family, serving as the foundation for a series of closely related products. Products that share a common product platform but have specific features and functionality to satisfy different sets of customers form a *product family*. A product family typically addresses a market segment, while specific products within the family target niches within that segment. Figure 1a presents an example of a Sony walkman product family.

Product platforming provides product diversity through shared resources at a reduced price by sharing components, interfaces, knowledge, production processes, etc. Products that are "derived" using components or modules from the platform constitute a product family. Product platform planning (or product family planning) calls for the simultaneous, planned development of a set of related products that share features, components, and/or modules. Different than optimizing products independently, it requires integration of principles from both management and engineering design for developing a set of products that share common features, components, and/or modules.

Product platform planning is different from the conventional product development process in that it involves the planned design and development of a few different products at the same time. Being a currently developing methodology, it is rarely a part of the engineering curriculum. Considering its relevance in today's industry, it is important that it is incorporated in the education system. Platform planning involves management of design, and involves management concepts such as market research, customer needs, product management, etc.

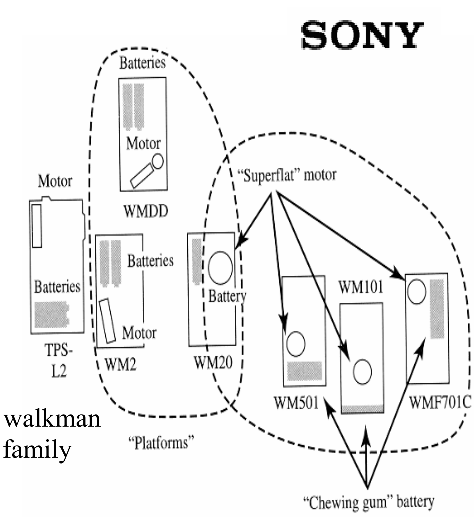
In product family design, modularity provides flexibility in leveraging a large number of product variations. For example, such flexibility can be judged from the fact that 20 computer components, such as motherboard, RAM, hard disk speed, and hard disk size, can result in an astronomical 8.8 trillion configurations of a PC . Properly used, modularization enables firms to minimize the physical changes required to achieve a functional change. It brings many benefits due to high serviceability, recyclability, and cost-effective technology insertion in terms of disassembly, separation, repair, and reprocessing along the product life-cycle.

A module can be viewed as an independent building block of a large system with well-defined interfaces. More specifically, modularity can be identified from three perspectives: systems, hierarchy, and life cycle. As none of these perspectives provides a stand-alone definition for modularity, a more comprehensive understanding of the phenomena can be utilized with simultaneous assessments of different perspectives. Being motivated to integrate such a multiple perspective-based understanding of modular product design strategy in engineering education, this research focuses on a learning-support tool: a graphical modeling environment. Visual modeling methods are recognized as an intuitive and productive means to address the challenges of product design decisions. The proposed visual modeling tool intends to guide designers in the simultaneous consideration of strategic and technical factors in conceptualizing modular products.

Design for Managing Product Obsolescence

Product evolution is pervasive due to rapid rate of technology change, constant improvements in the performance and functionality of products, and the transient and multi-dimensional nature of customer needs. Most high-volume consumer oriented products must adapt the newest materials, parts, and processes in order to prevent loss of their market share to competitors. For leaders, updating the design of a product is a question of balancing the risks of investing resources in new, potentially immature technologies against potential functional or performance gains that could differentiate them from their competitors in the market. While value added, the fast moving technologies also make commercial high-tech components and products obsolete quickly. Managing obsolescence should be a significant consideration in product evolution. The economic ramifications of product obsolescence are apparent and staggering. Industry experts estimate that over 200,000 components from over 100 manufacturers became obsolete in 2003 alone[1].

While the impact and pervasiveness of obsolescence is a growing problem, existing work on obsolescence has focused on reactively managing component obsolescence, i.e., minimizing the cost of resolving the problem after it has occurred. Product obsolescence and its management remains poorly understood in theory, and poorly addressed in practice. Governing principles and proven, teachable guidelines are needed for managing product obsolescence. These principles



a) Sony walkman product family

b) e-film

c) Mobiblu Mp3 player

Figure 1. Examples of product family and piggyback products a) sony walkman product family b) e-film and c) Mobi-blu Mp3 player

and guidelines when embedded into the architecture of a product will lead to proactive management of product obsolescence. This research addresses this area. Specifically, we are analyzing "piggyback" products, which have shown great potential in addressing the problem of product obsolescence (Figure 1b and Figure 1c.). The e-film cartridge is designed to work with conventional camera and combines the features of digital imagery (digital storage) with the best of conventional photography (e-Film). The mobiBLUs' MP3 cassette player is another example which illustrates the principle of piggybacking. This product combines the best of both worlds, i.e., digital storage of MP3 with high quality sound of cassette players and helps in sustaining cassette players (mobi-Blu DAH 220). This research is specifically focused on analyzing these piggyback products which can be used in conjunction with an existing product to increase functionality, extended the original product's lifespan, and in this way prevent its obsolescence. Rather than being forced to update to newer technology, these "piggyback" products are often an effect solution for product obsolescence. By analyzing the commonality among "piggyback" products discovered through web-based research, a working set of principles has been deduced that may contribute to the proactive management of obsolescence in designs of future products.

The six REUs were given one of two projects to focus their research and development activities. These two projects brought a depth of information along with them for the students to absorb. Two of the students created a graphical modeling tool for conceptualizing and analyzing modular product families. The other four students were given the task of discovering and exploring piggyback products.

Graphical Modeling Tool Research

A graphical modeling tool for modular product family design was developed using Microsoft Visual Studio. The modeling environment was planned to include a visual modeling window supported by knowledge management and reporting means. In this research, the visual modeling window was developed by embedding Visio 2003 in the Visual Studio. Knowledge management and reporting functions are achieved by embedded Microsoft Access databases. Our methodology also includes a simple data mining approach to identify product modules utilizing the information created and managed in the visual tool. In the end, captured design knowledge is organized and reported in Microsoft Excel to implement desired clustering algorithms and graphical analyses.

Two of the REUs were given assigned the task of creating a program using Microsoft Visual Studio and Microsoft Access that will provide the user with a way to visually display the systems that work together within a modular product and simultaneously capture the information into a database.

2 REUs spent the first month of the 4-month REU program to understand the purpose of the tool. The 2 REUs involved in this project were seniors and had basic knowledge of engineering design. However, the REUs were unfamiliar with the concept of product family design and modular product design. The students were introduced to some product platform and family and modular product design concepts by reading literature on product family and modular product development, and exploring the usefulness of understanding relationships between systems in a product. Similarly, the importance of being able to see these relationships visually was grasped.

The next three months of the project were spent developing the graphical modeling tool. The students had a general familiarity with C++ and Microsoft Visio which creates a visual display. Even with this general knowledge, most of the project was spent researching how to construct the tool. Some answers were found by researching similar visual product modeling tools already in existence. Most answers came from learning all the different commands and features that Microsoft Access, Visual Studio and C# had to offer. Through the whole project these REUs met a doctoral student twice a week to gather requirements for the tool and to show their progress in terms of code. Through continuous interaction and feedback during these meetings with the doctoral student they learned about various features of the tools and developed and tested the required features of the tool.

At the end of 4th month the REUs were finally able to develop the required tool. Figure 2 displays the current main user interface of the modeling tools developed by REUs in Microsoft Visual Studio. The goal was to keep the design of the visual modeling tool as basic and intuitive as possible. As shown in Figure 2, the modeling tool includes a menu bar for generic functions such as File, View, etc, a Visio modeling window, and a "Report" button to export the design information captured in the modeling window for modularity analysis. Because the Visual Studio includes both the language engine and the integrated development environment, using other systems (e.g. Visio and Access) in it "feels" the same as using them separately. Finally, the REUs also participated in writing a conference paper based on the developed tool[2].

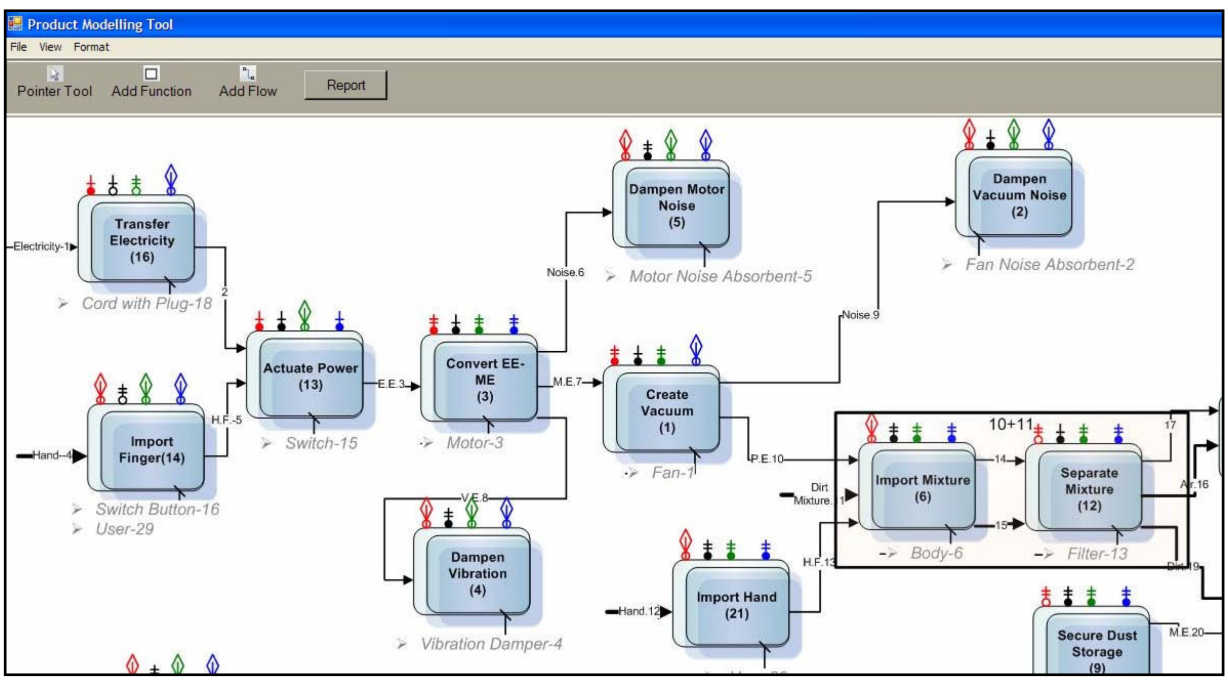


Figure 2. Graphical Modeling Tool snapshot

Piggyback Product Research

The second research project was to establish fundamental principles, teachable methods, and guidelines for designing product architectures that can evolve to cope up with the changing requirements to enable proactive obsolescence management. Technology is advancing at a faster rate everyday. In order to prevent a product from becoming outdated sometimes add-ons can be developed to increase the lifetime or functionality of a product. These products are commonly called piggyback products.

Four REUs were involved in this project including a junior and three freshman undergraduate students. The junior REU had some knowledge of engineering design. The freshman REUs had no knowledge of engineering design. All REUs spent the first month of the REU program (4 month) at Virginia Tech to understand basics of engineering design. The students were introduced to some engineering design concepts by reading engineering design literature and web based articles on engineering design. During this period they interacted continuously with a post doctoral researcher with their queries to clarify concepts in engineering design. Once they understood the basic concepts of the engineering design, the next month was spent on exploring the usefulness of piggyback products. During the second month they were introduced to the concepts of product obsolescence and how piggyback product can help prevent product obsolescence through the use of two simple case studies. They were asked to further research two products (Mobiblu Mp3 player and e-film) and understand how they work (Figure 1b and Figure 1 c.). Through weekly group meetings with the post doctoral researcher, they were learned more about piggyback products. During these weekly meetings the REUs clarified their queries, and discussed their understanding and observations about piggyback products.

Once the REUs were comfortable with the concepts of the piggyback product, they were asked to find more piggyback products through the use of web searches. This was a task not easily accomplished because one cannot simply type ‘piggyback product’ into a search engine such as Google and get a list of products since most products do not contain this expression in their description. The REUs spent the third month of the project identifying piggyback products on the web. They used a combination of search engines, reading product related blogs, browsing product catalogs of various companies to find piggyback products. During this third month they presented the results of their web searches during a weekly group meeting, gave feedback to each other and received feedback from the post doctoral researcher. At the end of third month the REUs had compiled a list of 80 piggyback products.

During the final month of the project the REUs in conjunction with the post doctoral researcher focused on developing a product dissection tool. Once a list of piggyback products has been collected for analysis, it is necessary to have a systematic method for extracting data from it and for organizing that data in a way that is convenient for comparison. For this purpose, a product dissection tool was created which provides a template for collecting the kind of data that will be helpful in understanding the facets of a product’s design which makes it impervious to obsolescence. This can then be used for formulating a list of principles. This data sheet tool is structured as a series of questions which are designed to lead an examiner towards specific information which is relevant to managing obsolescence. The REUs used brainstorming sessions for generating a questionnaire related to the product dissection tool. A comprehensive product dissection tool was developed during the first two weeks of the fourth month. The list of 80 products was narrowed down to 20 highly relevant piggyback products due to resource constraints. The product dissection tool was completed for these 20 products[3]. These results from the product dissection tool in the form of fundamental principles, teachable methods, and guidelines for designing new piggyback products were published in a peer reviewed conference proceedings[4].

REU Projects Structure

The structure of these research projects was not rigid by any means. The students were required to work 10 hours a week. The work was a combination of web-research, meetings and analyzing or putting to use the research. The students were not required to be in any sort of office to do the work and there was no set schedule for when they were required to do the work. Instead they had the freedom to do the work when and where it was best suited for them. The students met at least once a week with the other students and their respective doctoral or post doctoral mentors to discuss what they have found through their research and other ideas or problems they were having. They met their faculty mentors once every two months.

REUs Research Experience

The REU experience provided a non-intimidating environment to do research. All the students were unfamiliar at first with the topics they were researching. Each week as their research progressed they learned more and were able to contribute to the project in different and expanded ways which benefited the group and themselves. The way the research was conducted was different than they were used to for a class. It was much less restricted which the students seemed to enjoy.

The students gained a lot from their REU research experience. A new setting outside of the classroom was created for learning and development. This setting allowed for a different kind of interaction among peers and different desire to gain knowledge. In classrooms students generally strive for the knowledge to succeed with graded work or tests to obtain a good grade in the class. In the REU experience, students were given goals and new ideas and were asked to conduct research and discover new knowledge on their own. The students benefited from this in many different ways, such as: by thinking about research problems, searching for relevant research material, independently carrying out their tasks in groups, participating in brainstorming sessions, and writing research papers. During the feedback of their research experience during these projects, one student notes, "My research experience was unlike any other academic endeavor I have undertaken at the university." Another student wrote "Research is very interesting because a person is able to take interest in something that has never been researched or even look into." In fact, the students felt that more room for doing research that was not necessarily along the beated path towards the goal could make the REU program even better.

Interests in Graduate School and Perception of their University

Graduate school tends to be daunting and not well understood by undergraduates. However, the research experience helped students involved in the research projects to shed some light on what it was like to be a graduate student. The students gained a better grasp on what type of work is done as a graduate student and the pressures of timelines and deadlines that needed to be followed to stay on top of the work. Overall the students' participation in the program proved positive which, as one student wrote, "Only furthers and deepens the desire of education."

One undergrad was given the opportunity to accompany her PhD mentor and professor to a symposium in South Korea. On this trip she was indulged with information from a design world that she would have never known existed. She notes, "I am now much more interested in research mainly because I know what is out there and have heard about many of the issues they deal with first hand. It is important for students to know about all sorts of research that is going on in their field of study before entering graduate school. This could lead to a better sense of direction in terms of where their research will lead them and what is already out there." Similarly, students felt that there was another side of the university to be seen through the REU experience. They felt that even though every student gets to be in a class and work on projects for the class, there are countless other opportunities to be taken advantage of in college. The REU grant has allowed a few of the undergraduate students to be part of an important side of the university, the research side.

Interests in Design and Product Development

All of the students that participated in the REU program were engineers and some of them were familiar with the basic design process. However, it is common opinion among the students that the REU experience has drastically increased their knowledge depth of what the design entails. Students often learn in the classroom how different products were designed, but the REU experience gave the students the opportunity to explore and design something new and cutting edge which they found very rewarding. The students further appreciated working on real problems rather than a possibly outdated example found in a textbook.

Group Activity Benefits

Overall the students felt they benefited most from the group meetings and the discussion of the research with their peers. They discussed with each other how they were going through the design process and were able to help each other perfect their research techniques. The students found it very helpful to bounce ideas off of one another while brainstorming. One student noted "I found that by bouncing my problems off my peer she was able to come up with solutions that I may not have thought of and vice versa since we were working on the same project." Overall the students would prefer to have more time as a group to get a more collaborative understanding of the research.

Conclusions

The NSF sponsored REU program gave the six students the opportunity to learn about engineering design and discover design principles and knowledge related to platform design and DfMPO. In this paper, learning experiences of six undergraduates who participated in REU program was presented. The research projects were in the area of product family and product obsolescence. These areas represent emerging fields in engineering design. The students spent one semester learning and applying novel design knowledge representation and visualization techniques to plan product platforms and design principles to prevent product obsolescence. This paper provides an overview of the research conducted by the REU students, the structure of the REU program, and the students' overall learning experience including the effects on student interest in graduate school.

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