Product Design Conceptualization in a Computerized World

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ABSTRACT – The purpose of this paper is to explore the integration of conceptual modeling principles with computer-aided design applications. Most product designers prefer to work with traditional artistic forms of design, especially early in conceptual design. Computer-Aided Design systems have not reached the level of flexibility and easy of use where they can be freely and creatively used by a designer. But, CAD systems are critical components of the design process. This paper provides a process for importing design data into a CAD system.

1. Introduction

The automobile industry has been one of the main benefactors of product lifecycle management (PLM) software and solutions. Within “large-product” original equipment manufactures (OEM), such as the automotive, aircraft and defense industries, PLM solutions have been tailored to meet the evolving needs of design processes. These solutions help to speed time to market and increase quality while leveraging the global infrastructure of suppliers and designers.

Of all the PLM tools that are available to the automotive industry, the computer aided design (CAD) system is still the main source for generating design geometry. CAD systems have evolved over the last three decades from a tool primarily used for documenting design concepts to a tool used to conceptualize designs. With the advent of the personal computer in the early 1980s, the design community also saw the rise of PC based Computer Aided Drafting systems, such as AutoCAD and VersaCAD. Later developments within UNIX bases systems gave birth to parametric design systems, namely Pro/ENGINEER, CATIA, IDEAS, and Unigraphics. From the late 1980s to the present these four are the leading “high-end” CAD systems used within large scale original equipment manufacturers.

Despite the power of MCAD applications for capturing the intent of a design, the rigor of producing freeform geometry within such applications can hamper conceptual design. Due to this, most product designers prefer to work with mediums that are less technical and that provide for a faster means for conceptualization (Rohm & Hope, 1998). But, how are conceptual designs digitized for inclusion into CAD systems? To be competitive prototype models have to be CAD based (Vasilash, 2000). This paper explores a method for taking a product through the conceptualization process to the capturing of the product within an MCAD application. An undergraduate student at Central Michigan University used conceptualization techniques to design a concept car. He then used digitized data of the design and CAD freeform modeling tools to recreate the car within CATIA. The end result was a parametric model of a concept car.
II. Computer Aided Product Design

While high-end Mechanical CAD (MCAD) systems such as CATIA and Unigraphics are considered the primary engineering solutions for generating design geometry within the transportation industry, Industrial Design specific Computer-Aided Product Design (CAPD) applications are the primary tool for capturing the form and aesthetic aspect of a new product. Industrial design specific solutions such as Alias, Rhino and ICEM are used to develop the form of a design before the rigorous use of MCAD can be deployed to capture the geometry of the systems. Using top-down design approaches, a product is designed first then its varied subsystems are engineered with the context of their respective envelopes.

Traditional product design approaches involve the merging of aesthetic and engineering design principles. Most consumer products have to be both functional and attractive. Product designers, such as architects, industrial designers, and vehicle designers, are called upon to develop products that are aesthetically pleasing, ergonomically friendly, and functional. Most of their work involves the incorporation of art design principles toward the solving of design problems. Engineers, in turn, take concepts from product designers and develop the systems, structures, and mechanisms to make the designs work.

The use of computers for engineering design and analysis is common place. Many computer-aided design (CAD) systems have the capacity to create conceptual design models. In addition, many have the ability to perform downstream tasks such as finite element analysis, motion analysis, simulation, and computer-aided manufacturing.

CAD has also become commonplace in product design. But to what extent do designers utilize CAD as a first medium for performing conceptual design? Despite the best intentions by many CAD companies to incorporate design friendly tools into their applications, such as NURBS modeling, very little conceptual design work is actually done on a CAD system. While the surface modeling capabilities to construct complicated designs exists within some CAD applications, the time and effort to create such models can be a barrier to design creativity. Due to this, most designers still utilize traditional means of design work: sketching, rendering, and model building.

Clay conceptual models and prototypes of a design are used for the development of many products. Most large manufacturing and automotive industries use design processes that involve some aspects of the reverse engineering of a conceptual model. Today, MCAD and CAPD systems are used to digitally model designs. However, before the geometric components of a design can be modeled in an MCAD system it needs to be conceptualized. Conceptual drawings can be anything from a rough sketch to a computer rendering. Typically the more complex the part or design, the more time it takes in iterations and pre-digital design. The clay model will be used to develop a digital image of the concept that an OEM wants to produce. Pulling geometry from an actual object, such as a clay model, and designing from that geometry is extremely relevant to the field of product design.

III. Design Process Methodology

The requirement for this project was to integrate conceptual modeling with CAD surface modeling to design a concept car. The conceptual modeling tools consisted of sketching, concept drawings, and clay model sculpturing. The CAD portion required the reverse engineering of the clay model. This process required four steps: design concept development using sketching, design concept development using a clay...
model, electronically digitizing the clay model with a laser scanner, and transforming the digitized data into a parametric model.

The first step of the design process was using traditional sketching and freeform drawing techniques to capture the look of the concept car (Figure 1). The first designs or drawings of a product are the most influential and serve as a template for more refined drafts. During initial concept sketching there are many design iterations. Further iterations occur when applying rendering techniques to the design. The final ideas and details of visual appearance are usually close to completion before a scaled clay model can be constructed. But, the clay modeling still allows for addition iterations.

Figure 1. Concept Drawing

The second step of this process was using the sketched design concepts and renderings to generate a clay model. The creation of a clay model does a great deal for visualizing a design in three dimensions. Clay models are the primary source for all geometry that is to be eventually digitized. A clay model is created from drawings that are defined to a specific scale, in this case an orthographic template drawn at a scale of 1:8. For many product designers, clay modeling is a primary function of reverse engineering. Often, a clay model is built full scale and directly digitized into a computer application. The clay model used for this project was built at a 1/8 scale, which is relatively small in comparison to most professions models, which are usually at a minimum of 1:5 scale.

The medium used for this project was oil based car modeling clay. This form of clay is typically harder than that utilized for art sculptures. The final sculptured model ended up matching the technical design specifications well and stayed symmetrical across the cars center axis due to the usage of templates. The clay model was then digitized using a laser scanner.

There are many categories of digitizers available for capturing the geometric form of a clay model. At the low end off the scale are mechanical probes that allow for the input of single data points. A data point is one Cartesian coordinate location as expressed with X, Y, and Z values. A collection of points is referred to as a point cloud. At the upper end of the scale are forms of laser digitizers that allow for the capturing of thousands of individual data points in a short period of time. The scanner used in this project was a four column laser system primarily intended for digitizing human bodies. This scanner provided an adequate job capturing vertical surfaces, such as exists with a body, but a poor job with horizontal surfaces. Due to this, multiple orthogonal scans of the clay model had to be obtained.

The reconstruction of the design from the imported data was the final stage in the process. This step is usually referred to as reverse engineering. However, reverse engineering can apply to many fields. Computer programs and software can be reverse engineered to create new programs. Reverse engineering in mechanical design is utilized for the digitizing of mechanical components and parts from older generation designs. This form of design
revitalization is common within concepts of bottom-up design where existing mechanical components are utilized within new design concepts. In a typical design processes, the digitizing of a clay model carries a different function when compared to the reverse engineering of a preexisting mechanical part in that the digitized data is often the first computer generated image within top-down product design. Common to both forms is the taking of a product concept and reconstructing it for use within a computer application. With the importation of digital data a new model can be created from the clay prototype. This data is then used to rework and further enhance the original idea. Improved designs can then be achieved through the use of downstream computer aided engineering systems.

CATIA’s surface modeling tools were utilized to take the cloud of points to a final surface model. This is a four step process in CATIA that involves:

1. Manipulation of the imported point clouds.
2. Meshing of the point cloud.
3. Creating wireframe and curve entities from the mesh.
4. Creating surfaces from the wireframe geometry.

As with any systematic process, the quality of the final product is dependent upon the data that is input into the system. Good surfaces require the creation of good wireframe entities. Good wireframe entities require a good mesh. Adequate meshes require a well refined point cloud. So, it is critical at each step of the process to take care to do the necessary tasks that lead to downstream development.

After scanning, CATIA’s Digitized Shape Editor was utilized to manipulate and refine the point clouds. The clouds were aligned and merged into one cloud (Figure 2). Extraneous points were filter out or removed. After point cloud manipulation a mesh was created. This mesh was the base support from which curves and surfaces were defined (Figure 3).

CATIA’s Shape Reconstruction workbench was utilized to create wireframe entities. Curves were defined from the model’s mesh, which in turn were utilized to create surface features (Figure 4). Since this
project involved the design of a concept automobile, the majority of the tools utilized were of the freeform surfacing or NURBS variety. CATIA’s Freeform workbench has been tools for creating surfaces and curves with tangent or curvature continuity. In addition, CATIA’s Sketch Tracer workbench was utilized to match the profile of the car with orthographic scaled sketches. The final surface model incorporated parameters and constrains that could be further refined if necessary (Figure 5).

IV. Conclusions

The automotive and many other design oriented industries use systematic processes that help to bring an idea from concept to reality. In order to produce or build a product from an existing conceptual idea requires many modern engineering design tools. In product design fields ideas are proposed, models and designs are created, digitally imported data is generated with CAD systems, and engineering design applications are utilized to bring a design concept to fulfillment. The conceptual design process used by automotive companies and other discreet product manufacturers are both extensive and methodical. Companies place a high level of intention on both form and function. Customers are still concerned about how a product looks in addition to how a product functions. Computer aided product design systems still have not reached the level of development where a designer can perform detailed design directly within the CAD system. So, concept models are still a very real component of the design process. Due to this, it is critical for design quality and time to market that a conceptualized model is accurately integrated into existing MCAD applications. This process is realized through the use of digitizing solutions.

V. References