Establishing a New Digital/Virtual Product Development Process in Design Education

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Abstract—Industrial Design lies at the interface between the aesthetic elements of styling and appearance, and the innovation which is driven by science and technology. It requires the application of knowledge from a multiplicity of interdependent disciplines. The teaching Industrial Design of at our university, favours the heuristic approach taking inspiration from the natural world[1], the creation of virtual models, and the optimisation of design through repetition, as well as empirical testing of the Gestalt finding. Creative intuition drives students’ work at the university – based on knowledge, experience and skills – giving rise to strategic conceptual ideas, to be followed by preliminary design concepts and training in new, cutting edge product development processes.

Keywords:
• Digital, virtual product development process
• New product development process
• Concurrent, simultaneous engineering
• Computer Aided Industrial Design
• Design Education
• CAID, CAD, CAM, CAE, FEA, CFD, VR

1. INTRODUCTION

In the commercial world of professional practice, study projects can be oriented towards large scale industrial production and even the design of entire systems, or they can alternatively, result in crucial advantages for small-and-medium-sized enterprises by enabling their products or components to attain technical or functional superiority in the globally competitive environment.

Design students with sound knowledge of surface textures, materials and manufacturing technologies, as well as the ability to analyse sources of inspiration in nature and thereby envisage morphological strategic solutions[2], a major part of qualification involves professional skills in using Computer Aided Industrial Design (CAID) software and Rapid Prototyping technologies[3]. Graduates can contribute in a professional capacity to entire process chains (Concurrent or Simultaneous Engineering)[4].

2. THE DIGITAL/VIRTUAL PRODUCT DEVELOPMENT PROCESS

In recent years, the general parameters for the development of mass produced manufactured goods have been subject to a series of changes. To mention a few: international competition and globalisation, the world-wide distribution of development centres, a shortening of development lead-times (time-to-market), and the increased complexity of the products themselves (variable options, etc).

“Companies respond to these drivers and changing needs by developing new products and employing product development processes (PDPs) to coherently manage the risks inherent in their development. Well-designed PDPs reduce development time, create better products, generate profit, and increase market share.”[5]

“New product development (NPD) has long been recognized as one of the corporate core functions. During the past 25 years, new product development has increasingly been recognized as a critical factor in ensuring the continued existence of firms. The rate of market and technological changes has accelerated in the past years and this turbulent environment requires new methods and techniques to bring successful new products to the marketplace. IT improves NPD flexibility. New product development requires the collaboration of new product team members both within and outside the firm.”[6]
Numerous IT applications, which together facilitate Concurrent Engineering, enables various departments within an organisation and also external service suppliers to have continuous access to product development data.

Representative of these types of systems are Computer-Aided Design systems (CAD), which form the core element of digital product development.

"Today, the Computer-Aided Design (CAD) industry is a multi-billion dollar business with literally millions of engineers, architects, and drafters using these computer systems on a daily basis. The technology has clearly changed how many professions are practiced, predominately, but not in all cases for the better. [7]

CAD systems are surrounded by Computer-Aided Engineering systems (CAE), i.e. Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD) or Digital Mock-up (DMU), by Computer Aided Industrial Design systems (CAID) for initial form finding or Virtual Reality (VR) for design reviews and immersive interactions. Data administration is controlled by Product Lifecycle Management (PLM) or Collaborative Product Commerce (CPC) systems which also manage the flow of electronic data throughout the entire life cycle of the product and which interact with enterprise resource planning systems (ERP).

3. COMPUTER AIDED INDUSTRIAL DESIGN

During the 1970’s of the previous century, computer controlled tools had already been developed and were beginning to be used within manufacturing systems. Initially, CAD existed with two-dimensional drafting programs, which made the traditional drawing board obsolete. With the introduction of 3D CAD programs, based on mathematical calculations for 3D (free form) curves and surfaces using Bezier algorithms, the age of digital three dimensional design development for engineering and product development departments really began.

Since the advent of CAID around 20 years ago, design solutions have involved the use of innovative information technologies within an integrated virtual process chain leading to a new product development process. At the end of the 1990s the first IT systems for 3D design and modelling tasks could be developed, again on the basis of newly defined algorithms which made is possible to trace complex free form geometry by mean of NURBS algorithms.

For security reasons and also because of the need for specialization, design and initial surface definition departments of an enterprise have tended to work separately from the development and engineering departments. This division, together with a certain degree of resistance towards computer technology, is the reason why, at the present time, there is no universal data-based communication throughout the field of virtual product development. This means that numerous ‘gaps in the system’ prevent the existence of efficient generally viable process chain such as Concurrent or Simultaneous Engineering.

In future all designers, and not merely those in the automobile industry, must be competent in two things: the use of computers for 3D design concepts, modelling, analysis and visualization as well as interacting in a complex environment of multi-disciplinary (engineering) groups. The latest software programs, combined with the rapidly expanding graphic processing capacity of computers, make it possible for designers to sketch their initial design proposals and create three dimensional virtual models.

The status of a design and development process is checked and recorded by ‘milestones’. As digital technology has advanced, two main scenarios for the (design) evaluation of projects have become established.

- Digital reviews using visualisation based on real-time simulation and virtual reality.
- Physical rendering of component parts based on digital input using the rapid prototyping procedure.
Powerwalls allow photo-realistic designs to be visualized in real time, and subsequently analysed in Design Reviews using VR technology, i.e. CAVE.

Figure 4. Design review in a CAVE environment

This offers great advantages compared to complicated and expensive hardware modelling. It is possible to check technical details at an earlier stage, thus anticipating the way the process will progress (front loading) and also improving communication with other departments and outside service suppliers.

The same VR technology can be used by various departments further along the development process chain, so that a continuous flow of data can be achieved. In addition to the virtual data control model (virtual prototype, DMU) calculations related to aerodynamics, flow simulations and strength/resistance tests (FEA, CFD) can be presented much quicker. Plans and trials are already in progress for the application of these virtual techniques in visualizing building construction work as well as plant production systems (digital factories).

The latest internet based software applications, such as Product Data Management systems (PDM), give a framework for the integration of all departments of a company and outside suppliers which are involved in the process of bringing a product into existence. Furthermore, data is freely available throughout the product’s life cycle (i.e. PLM, CPC and ERP).

4. NEW DESIGN EDUCATION

Industrial Designers deal with an integrated process chain in the early development phase in an industrial context, which means that Concept and Design Departments play an integral role in the structure of the product development.

The various elements of the Industrial Design education at the University of Art and Industrial Design, Linz, Austria – scionic® Computer Aided Industrial Design, ‘Materials Science and Environmental Technologies’ and Ergonomics – supplemented with a design tutorial – are then combined in a semester’s project module.

The objective of Computer Aided Industrial Design is to make students aware of the methods applicable to digital product design procedures as part of an integrated digital/virtual product development process.

Graduates in Industrial Design shall be qualified to understand the interaction and function of aesthetic, scientific, technological, commercial and psychological aspects relating to a multidisciplinary and cooperative, product development process. They will be in a position to apply their knowledge working independently in the service of both large and medium-sized enterprises.

The below project will demonstrate the design approach which is being trained at the design education at the University of Art and Industrial Design, Linz, Austria.

Based on the layout for a recumbent bike, which has been developed by a retired engineer, we were developing a soft cover to improve the aerodynamic characteristic of bikes in general, here applied to this specific recumbent bike. The side effect is to protect the driver against wind and rain. The following figures will demonstrate a typical design development process, applying 3D CAID tools for the design process:

Figure 5. Two-dimensional layout for the recumbent bike

The two-dimensional layout (engineering drawings) represents the technical package, which was the basis for the core mechanical structure in 3D.

Figure 6. Three-dimensional package for the recumbent bike with a closed space frame for passenger seating
As described above, the group of four core disciplines at our university also includes ergonomics, like human-machine interactions. A recumbent bike only works properly, if the driver has optimal seat position and pedal access as well as proper steering. This can be checked in an early phase by overlaying the technical package with human ergonomics studies. 3D CAD manikins, like RAMSIS™, enables designer to address ergonomics, comfort and safety in an early design phase, yet avoiding expensive physical tests in the later prototyping phase.

In the early design phase, all ergonomics studies were performed with the single space frame, as designed by the engineer. However, the 3D simulation proofed, that the drivers view is negatively affected.

Based on the findings by the 3D ergonomics studies and simulations, various design changes for the passenger space frame has been performed. One proposal was to eliminate the top part of the space frame.
When analyzing the mechanical stability of the proposed passenger seating via stress analysis, we found out, that the max. load capacity was not sufficient for average human use (see Figure 14). The mounting joint would break, causing serious injuries to the driver.

As a result of above findings, a twin space frame for the passenger seating has been developed, yet providing enough stability and not affecting the drivers view.

The final design of the recumbent bike was the base reference for developing a soft shell cover, derived from inspirations in nature, i.e. leaves or clams. The soft shell cover provides flexibility for entering the recumbent bike; textile or ETFE membranes guarantee light weight construction and good visibility.

Since driving a recumbent bike is unsteady, especially when taking off and slowing down and during cross-wind situations, we are simulating the driving behavior via CFD analysis. For this particular task, we are collaborating with engineering departments, specializing in complex analysis processes. The 3D development of our recumbent bike is a pre-requisite to perform CFD analysis. Since CFD analysis is a time consuming engineering task the calculation is still on the way. We hope to have suitable results until end of July 2011, being able to present the findings during the 2011 IDA Congress Education Conference and yet, showing the digital design process as being trained at our university.
5. ACKNOWLEDGMENT

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Due to our generic research, the findings shown here are all based on our experiments and analysis.

Photos and Figures: scionic® I.D.E.A.L.

6. REFERENCES


[2] Thallemer, Axel; Danzer, Martin: “Teaching industrial design through research inspired by nature”, Taipei, Taiwan, October 2011


