PRODUCT MODELLING AND VISUALISATION

产品建模与可视化

（英文版）

Edited By

Xiu-Tian Yan
Fayyaz Rehman
Conrad Pace

NORTHWESTERN POLYTECHNICAL UNIVERSITY PRESS
西北工业大学出版社

FASTAHEAD project funded by European Commission

Product Modelling and Visualisation

图书在版编目(CIP)数据

产品建模与可视化＝Product Modelling and Visualisation:英文/阎秀天,(英)雷曼(Pehman,F.),(英)佩斯(Pace,C.)编. —西安:西北工业大学出版社,2008.3

ISBN 978-7-5612-2364-2

Ⅰ.产… Ⅱ.①阎…②雷…③佩… Ⅲ.①工业产品—计算机辅助设计—英文 Ⅳ.TB472-39

中国版本图书馆 CIP 数据核字(2008)第 034956 号

出版发行:西北工业大学出版社
通信地址:西安市友谊西路 127 号 邮编:710072
电　　话:(029)88493844 88491757
网　　址:www.nwpup.com
印 刷 者:陕西向阳印务有限公司
开　　本:787 mm×960 mm 1/16
印　　张:12.75
字　　数:221 千字
版　　次:2008 年 3 月第 1 版 2008 年 3 月第 1 次印刷
定　　价:30.00 元

Preface for the Book Series on Advanced Design and Manufacture

FASTAHEAD (A Framework Approach to Strengthening Asian Higher Education in Advanced Design and Manufacture) is an project led by the University of Strathclyde, involving: University of Malta (Malta) and Troyes University of Technology (France) in Europe, and GIK Institute of Engineering Sciences and Technology (Pakistan), Huazhong University of Science and Technology (China), Islamic University of Technology (Bangladesh), Northwestern Polytechnic University (China) in Asia as partners. The project aims to develop a framework solution to engineering higher education demands in Asia, by developing a new curriculum in Advanced Engineering Design and Manufacture for Asian and European MSc education, upgrading the skills of university teaching staff in Bangladesh, Pakistan and China, split training Asian PhD students in European Institutions, comparing educational policies / systems / programmes among various countries, and enhancing the overall management of Asian Universities. The core problem to be addressed in this project is the shortage of well-educated engineers and teaching staff at the postgraduate level with advanced knowledge on Engineering Design and Manufacture in least developed countries and developing countries in Asia. The project is to develop a framework to address the above problem, which will provide a total solution to the huge demands for postgraduates with high level of advanced design and manufacture knowledge and skills. For further details of the project activities and other related information, please consult the following project website: http://www.dmem.strath.ac.uk/asialink/fastahead.

As part of an project team effort, FASTAHEAD project team, sponsored by the European Commission under the Asia Link Programme, involving seven project partners and over 40 project academic staff, undertook an ambitious

project of designing and delivering over 11 modules in the area of advanced engineering design and manufacture. Teaching materials in the form of MS PowerPoint files, animation video files etc. have been developed and produced. In addition accompanying learning materials have also been written by the project staff in order to help students to understand the lecture materials presented by their professors and lecturers. This series of books collect all these written accompanying reading materials and hence form an important part of the teaching and learning materials for these modules developed by the project staff.

The project staff would like to express their sincere gratitude and appreciation of financial support provided by the European Commission through the Asia Link Programme. The editors also would like to thank staff from Northwestern Polytechnical University China, for their financial support, and editorial support from the Northwestern Polytechnical University Press. In particular, they would like to thank Professor Runxiao Wang, Dr. Dongbo Wang and staff at the NPU Press for their professional help. Without these support, it would have not been possible to produce and print these books in their current format and in such a short time frame.

The project has designed and divided the teaching and learning materials in Advanced Design and Manufacture at Master level into eleven self-contained yet integrated and coherent modules. Each module development has been assigned and delegated to a group of experts within the project team. These experts then take on the responsibility of developing both teaching materials and learning materials. Whilst it has been difficult to coordinate such an ambitious project, in particular in developing so much teaching and learning materials, involving so many project staff from a wide range project background, we have tried to standardise the outcomes of these materials and aim to produce high quality teaching materials. To help students and other readers to revise and understand the lectures better, the learning materials in the form of this book have also been produced. It is the aim of the editors that the book is intended to be used in conjunction with attendance of lectures so

that key points can be revised and self-study can be facilitated by these course notes. Due to this intended use, you might find the notes are somewhat brief. Due to the large number of project staff involved and the topics covered in the project area include a wide range of materials, hence the format and style of the teaching materials produced varies from one book to another, though we have tried to standardise these as much as we can. We hope that readers can appreciate this and read each of these books as a standalone book for the module that you study.

Xiu-Tian Yan, FASTAHEAD Project Manager
Fayyaz Rehman, FASTAHEAD Project Coordinator
February 2008
Glasgow, United Kingdom

Preface to the Book

The second book in the series is on Computer based product modelling and model visualisation, which is results of recent computer modelling advancement and software development in an effort to create a virtual product modelling and simulation environment to support product development in a much faster fashion and less costly manner.

Computer product modelling is used to represent the idea/final design of a product using computer graphics in a digital environment. Modern computer modelling methods and techniques not only provide platforms where designers can visualise, evaluate and appreciate their designs geometrically even before they are manufactured, but they also can simulate the performance and functionality of the final manufactured product in the digital computerised environment. These techniques help the designers in not only identifying the problems and correcting them but also optimising their design with specific goals and objectives. Therefore it is absolutely imperative to have a basic understanding and to know and be able to use modern tools and techniques of computer based product modelling, simulation and visualization in order to benefit from these advancements. The contents of this book present in detail eight broad topics related to the field of "Product Modelling, Visualisation and Simulation" and are developed as course notes of one module (Modelling, Simulation and Visualisation) of MSc in Advanced Design and Manufacture funded by European Commission through their Asia Link-FASTAHEAD project. After attending lectures and reading through these topics the reader will be able to:

- *understand a multi-perspective view of product modelling using CAD modelling facility and other system and approaches;*
- *be able to use modern advanced CAD tools competently to create a complete functional product model with sufficient details and visualise it in a computer environment;*

• *have an introductory understanding of modelling and analysis, such as finite element modelling and analysis and kinematic modelling using advanced visual functions and methods;*

• *have basic appreciation of dynamic modelling of mechanical systems using computer based tools;*

• *enable to visualize the actual working of product and process using simulation techniques/tools;*

• *give introduction to role of computer graphics in product visualisation.*

As the book uses extensively the PowerPoint slide images in the book as a reference, it was decided not to provide individual figure caption for each image. This is unnecessary as the book follow by an explanation notes to the slide to help the learner to understand the essential meanings of the image. As a picture is worth more than a thousand words, readers are encouraged to read the PowerPoint point slide and use your imagination to interpret the meanings of these slides. It is hoped that through this enquiring study approach, learners will have a better and deeper understanding of the contents provided.

We are thankful and highly indebted to all the contributors (Dr. Fayyaz Rehman (UK), Dr. Xiu-Tian Yan (UK) and Dr. Conrad Pace (Malta)) of this course material for their valuable time and effort in preparing the contents of these notes.

Fayyaz Rehman, Xiu-Tian Yan

February 2008

Table of Contents

1 Computer Modelling Environment & its Effect on Product Development

1.1 Product Development

Product development is a process through which a new product undergoes through a series of phases, starting from idea conception to actual manufacturing of the product(Figure 1.1).

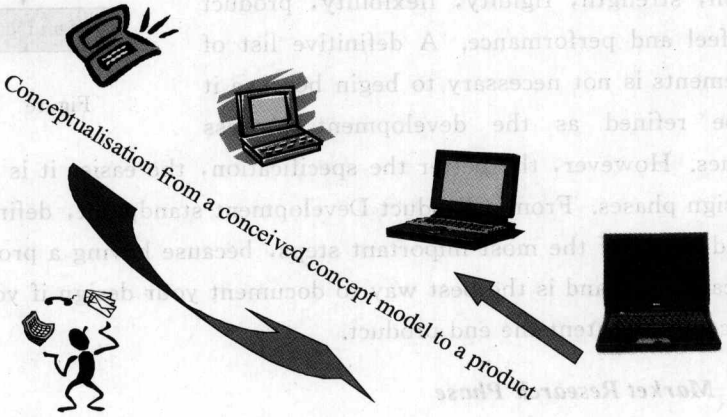

Figure 1.1

1.2 Phases of Product Development

Broadly speaking there exist six (6) phases of product development. At the end of each phase of product, a specific output results, whether it is a piece of sketch, model or information/knowledge about the proposed product. This subsequently serves as an input for the next phase of product development until a successfully tested product is manufacture for commercial use(Figure 1.2).

1.2.1 *Idea Generation Phase*

This phase involves generating/thinking/identifying a "bright" idea for a new product, when currently available products do not fulfil the demand of customers/market

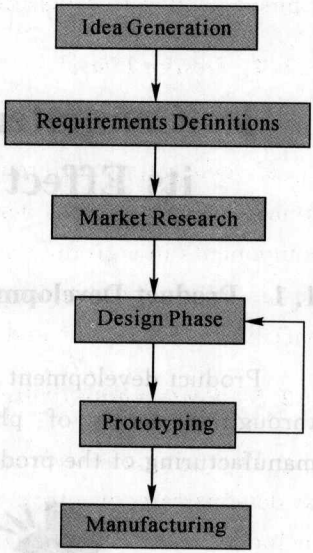

Figure 1.2

1.2.2 *Requirements Definition Phase*

The next step is to list product attributes, requirements and goals. The list is non-exhaustive but should include customer requirements, life span consideration, product function, strength, rigidity, flexibility, product look, feel and performance. A definitive list of requirements is not necessary to begin because it will be refined as the development process continues. However, the better the specification, the easier it is to complete the design phases. From a Product Development standpoint, defining what is required is one of the most important steps, because having a proper product specification in hand is the best way to document your design if you intend to sell, license or patent the end product.

1.2.3 *Market Research Phase*

To enhance the requirements list defined in the previous stage, some specific outside information is needed. Typically, a patent search and some market research are appropriate. There are many patents of products that inventors did not get into the market. Searching these could provide valuable information as a starting point of source information. Depending on the scope of the project, market research is usually desired. This includes competitive analysis, market availability, costs of getting the product to the consumer, etc. It should also include some justification (in hard numbers) as to why your product will be able to penetrate the market. The summation of gathered outside information, combined with the product specification, should result in

a business plan that justifies continued effort on the product.

1.2.4 *Design Phase*

The next step is to design the product and involves conceptual designing (i. e. generating different concepts and evaluating them to select a final concept), embodiment designing (i. e. selecting a definite layout of different components in a product out of several different preliminary layouts) and detail designing of the product (including preparation of manufacturing drawings, part list specifications and manufacturing instructions).

1.2.5 *Prototyping Phase*

Prototyping is the design verification phase of Product Development, used to demonstrate or prove aspects of a design. Typical prototyping methods include clay (or other) mock-up, fabrication & machining, and rapid prototyping. Mock-ups are typically done very early in the design process to explore visualization, feel, and to allow adjustments or fiddling with shape and size. Fabricated prototypes are typically functional versions that may or may not look like the final product but give the opportunity to test function and prove that some functional aspect of the design works.

The term "Rapid Prototyping" encompasses a large group of technologies that create 3D physical parts directly from the computer. This is becoming very popular because of the speed and accuracy available. These can be done in almost any shape and can be finished to look exactly like a production part (though usually much more fragile).

Depending on the product, a prototype may or may not be necessary. Perhaps more importantly, it may be that only parts of the design need prototyping. This is not to say that prototypes should not be built, just to emphasize that prototyping is costly in both time and money so its need should be evaluated.

In many industries the products are quite complex and require several iterations of design, prototyping and testing. The auto industry, for instance, uses several variations of prototypes to evaluate the design and to find areas of improvement. In the case of automobiles, the complexity of the design and the

amount learned in testing from each version easily justify the time and cost incurred.

1.2.6 *Manufacturing Phase*

The manufacturing process usually includes the following steps. Details for these steps differ with each product and its schedule.

(1) Final production quotes;

(2) Vendor selection and kick-off;

(3) Design of special tools and/or fixtures (where needed);

(4) Inclusion of final design input from manufacturers;

(5) Component verification and sign-off;

(6) Assembly validation and sign-off;

(7) Launch of production.

Choosing the right production process for the specific needs and quantities of each product is key to success. The production processes and costs will differ widely for each product, manufacturing process and location. Some items (like plastic injection moulds or casting patterns or dies) can take months to make and be very expensive. Some items require special tooling or fixtures that must be designed and validated along the way. In any case, the production process is always involved and is usually time consuming. It can also be quite costly.

1.3 Modelling

Modelling is a representation of some part or aspect of an object or system which can be based in reality or imagination. Also defined as to design and develop models of real and imaginary situations.

Modelling refers to the process of generating a model. A model is a pattern, plan, representation, or description designed to show the structure or workings of an object, system, or concept. A model could be a scaled up/down representation of a real physical object or an abstraction or conceptual object used in the creation of a predictive formula.

Typically a model will refer only to some aspects of the phenomenon in

question, and two models of the same phenomenon may be essentially different, i. e. the difference is more than just a simple renaming. This may be due to differing requirements of the model's end users or to conceptual or aesthetic differences by the modellers and decisions made during the modelling process.

Computer Modelling

Computer modelling entails making a description of the behaviour of some aspect of a real world object or process using mathematical relationships/algorithms. It is "creating an analogue to a real object".

Computer modelling is used to make a virtual recreation of an object, its real world/behaviour and its interaction with different elements of real world environment on the computer screen.

Although it varies from object to a particular process/phenomenon, the following are the basic steps in computer modelling:

(1) Background Understanding of the object/process which needs to be modelled;

(2) Evaluation of the important features of the system, how they interrelate, the influencing factors or variables (input variables) and the outcome or results;

(3)Constructing a mathematical model in the form of equations comprising constants and variables that describes the behaviour of a real world process or object;

(4) Converting the mathematical model into a computer model using an appropriate programming language or software.

1.4 Use of Computer Modelling in Product Development

Practically, computer modelling is used in only following three stages of product development:

(1)Design phase;

(2)Prototyping;

(3)Manufacturing.

Computer Modelling in Design Phase

(1) Due to the introduction of concurrent engineering philosophy in product development, designing a product and designing its manufacturing process are done simultaneously. This is done to reduce manufacturing costs and lead time and to allow better coordination between the design and manufacturing stages of the product.

(2) This idea of concurrent product and process design of a product involves the use and generation of different design and manufacturing models related to different aspects of product.

(3) Since concurrent product and process design of a product requires a vast amount of knowledge/information generating and sharing amongst each other, use of computer based tools is an appropriate technology to manage and handle the information stored in and processed by these product and process models.

1. Advantages of Computer Modelling in Design

Computer modelling has following advantages:

(1) It speculates about "How the actual object/system behaves/works" through the use of simulation technology;

(2) Allows to appreciate what is involved in the thing that is being modelled;

(3) Computer Models can show/highlight deficiencies/drawbacks in an object virtually before actual production starts thus saving time and cost which would have incurred in redesigning and remanufacturing the product;

(4) Running a simulation through a model can illustrate whether the model fairly represents the real-life situation that has been modelled;

(5) Also facilitates what-if scenarios and predictions.

2. Knowledge Maintenance

By having a computer model in the design phase, all information and knowledge related to different stages of design process can be easily maintained for each subsequent design phase model. Design is an iterative process and it is essential to maintain all the knowledge/information generated during individual phases of design process for future reference and working. Manually it requires