Integral Digital Design and Fabrication Methods for Teaching Product Design

Shengfeng Qin
Department of Design
Northumbria University
Newcastle upon Tyne, UK NE1 8ST
Sheng-feng.qin@northumbria.ac.uk

Jinsheng Kang
School of Engineering and Design
Brunel University
Uxbridge, Middlesex, UK UB8 7PH
Jinsheng.kang@brunel.ac.uk

Abstract

During a product/engineering design process, each design stage requires a different set of suitable design and model making tools no matter they are manual or digital in order to achieve best design efficiency and quality with a minimum project cost. Therefore, various digital fabrication methods in education need to be taught through design project-based teaching practice in context of a desktop digital design and product development process. This paper introduces an integral digital design and fabrication method for teaching Product Design students at university/college level, to enable them to gain good understanding of the roles of CAD and digital fabrications, pros and cons of using various digital fabrications at each stage in the design process, and what best benefits can be obtained with proper interaction between design and fabrication. Project examples are given to show how different design and fabrication tools were used in two product design processes and what the students learnt from them in terms of key points of understanding. This systematic approach of exploring digital fabrications in design education has been recommended.

Author Keywords

Digital design; digital fabrication; design process; integral digital design and fabrication

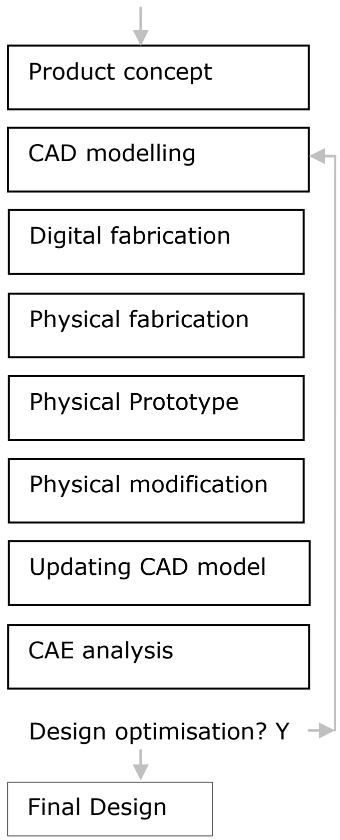

Figure 1. Integral digital design and fabrication

ACM Classification Keywords

K.3.1 Computer Uses in Education: Computer-Assisted Instruction (CAI). J.6 Computer-Aided Engineering: Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM).

Introduction

The use of digital fabrication in education has gained a growing popularity in schools and university colleges [1]. It is believed that educational approaches embedded with digital fabrication and 'making' could foster creativity and inventiveness by bringing powerful ideas, literacies and expressive tools into a project-based and student-centered learning process. This educational approach has been empowered by the recent development of low-cost digital fabrication tools [2]. Most popular tools are laser cutting and 3-D printing [3]. But, in general, tools for makers [4] in a Makerspace [5] include digital design tools such as CAD, hand tools such as file card and digital fabrication tools such as 3-D printing, 3-D scanning, laser cutting, and CNC machines.

Since Stanford University launched the FabLab@school project in 2008 and the Maker Media launched the MakerSpace in 2011 (makerspace.com), countless schools over the worlds utilize digital fabrication in teaching. The projects [1] are ranged from designing and making a simple product such as keychain to a complex one such as a robotic flute. Due to limited resources and students' knowledge and skills in engineering and design, digital fabrication used in school projects are somehow regarded as a 'cheap' manufacturing method, not well integrated in a product design and development process. At university and college level, digital fabrication has been incorporated in teaching and learning in many disciplines such as Architectural Studies [6]. However, digital fabrication needs to be taught and appreciated in a desktop digital design and product development process (Fig 1) with in depth understanding of its pros and cons in this context and its interaction with design.

In this paper, we present a new integral digital design and fabrication method for teaching Product Design within the Department of Design at Brunel University, UK. The teaching is for the final year Product Design students in two semesters with an emphasis on the integral digital design and fabrication (Fig 1).

Integral Digital Design and Fabrication

Integrating form design and digital fabrication: Form/style design normally involves concept design sketch, foam/soft clay model for sculpting and final creation of CAD models. We aims to integrate digital fabrication (in this case, 3D printing) into a design process with iterations. The key points of understanding for learning are: (1) a general form/style design process, (2) how to quickly transfer a design concept to a virtual CAD model by integrating concept design sketches into a CAD modelling process? (3) how to convert a closed surface model into a solid model and what are pros and cons of both surface and solid modelling? (4) What is a common neutral file formation for 3D printing and what are key information held in a STL file and what information lost when converting a smooth surface model to a tessellated STL model? (5) how can surface quality in terms of surface roughness and continuity be controlled? (6) understanding material properties of ABS powers and physical properties of 3D printed model with ZCorp printers, (7) what are the shortcomings of current commercial CAD

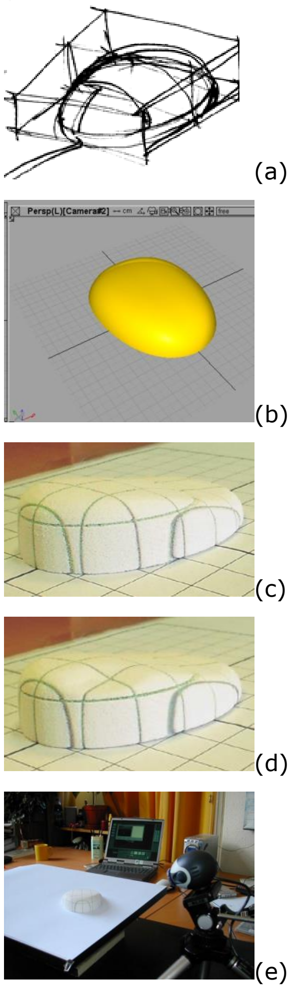

Figure 3. Integrate form design with digital fabrication

software for updating a CAD model from a corresponding modified physical model? And (8) understanding of the research needs and current issues in integration of design and digital fabrication.

The integrated form design and digital fabrication process is illustrated in Figure 2. The results from a project work are shown in Figure 3.

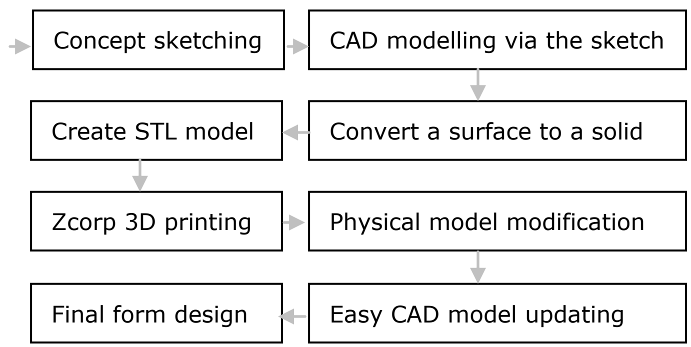

Figure 2: The integral form design process with digital fabrication (3D printing)

During the form design process, students on the project started their concept design with freehand sketching in either digital or paper-based format. Next, they needed to know how to transfer a design sketch into a CAD model either with a surface or solid modeler. For the form showing in Fig. 3a, representing a freeform object, a surface modeling package such as Alias thus was selected to use. By then, the students realized that there is still a challenge to automatically transfer a freehand sketch for a freeform curved object to its corresponding CAD model and there is a research need to do so. The current software solution is to use digital sketches as reference in an interactive modelling process, thus, all paper-based sketches need to be digitalized via either taking digital photos or scanning. Figure 3b shows a CAD model in Alias. In order to physically and tangibly test and evaluate the form design, physical prototype models were required. However, conceptually, a surface model is a skin model without material and thickness information while a 3D physical model has to be converted from a solid model. Therefore, at this stage, the students were challenged to transfer a freeform surface model into a 3D printing model through a surface to solid model conversion, a native solid to STL model conversion and a digital fabrication method selection. In this example, a closed surface model was converted into a solid without a hallow heart. ABS power material was chosen for 3D printing with a ZCorp 3D printer. Figure 3c shows a printed model. This model of ABS power was soft and could be sculpted with knifes. After that, the digital fabricated model was evaluated and physically modified (Fig 3d) by sculpting. Finally, the physically modified model had to be transformed back into its corresponding CAD model. Although a general purposed 3D scanner can be used for this task, a lightweight and easy-to-use desktop 3D scanner system in development was used for demonstration. Through this project, some research needs were recognized and it benefited for research student recruitments.

Integrating product design and digital fabrication: the second project aimed to explore various digital fabrication methods in a more general product design process. Based on the first project, students were already equipped with some basic knowledge and skills in digital fabrication. But they were not aware of a wide spectrum of interaction issues in integrating various fabrication methods into product design practice. In this

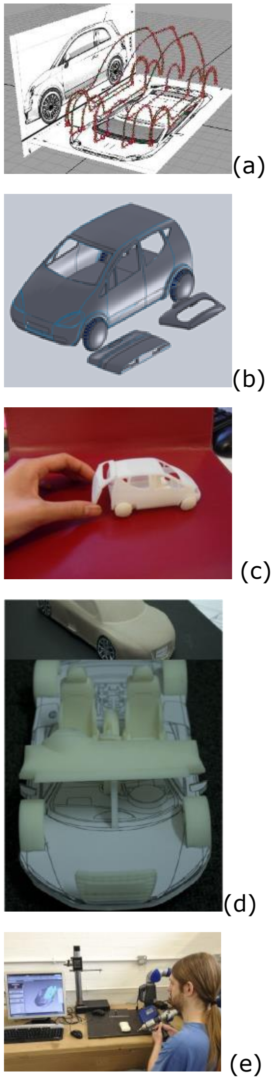

Figure 4. Examples

project, key points of understanding for learning are (1) when to use both surface and solid modelling for a complex product design, (2) how to integrate surface models and solid models into an product assembly, (3) how to scale down a part model dramatically to fit the dimension limits for digital fabrications and what problems will be faced in doing so (actually, surface models have many problems after scaling down for digital fabrication), (4) what need to be considered in connection with different fabrication methods to determine the thicknesses of parts for both reducing materials and speeding up fabrication processes, (5) whether a transition model is needed to remove some fine details, to alter design feature sizes for fitting, and to give proper thickness to parts, by considering factors such as scales, materials, surface quality requirements and relative feature sizes for producing assembly easily, cheaply and efficiently, (6) whether it is needed to consider the use of existing standard parts or reuse of some recycling parts into working prototype development for rapid and economic model development? (7) how to incorporate reverse engineering (RE) technology with digital fabricated models (scale down already) back to CAD models and (8) comparison of digital fabricated model analysis and digital analysis.

Figure 4 gives some examples of the integral digital design and fabrication. With reference to Figure 1, Fig 4a gives a case of product concept design and its CAD modelling process in a surface modeling package while Fig 4b exemplifies a choice of a solid modeling package such as SolidWorks for a car design. All parts in solid were then scaled down and digitally fabricated and finally assembled with physical fabrications such as use of pins and glues (Fig 4c). While in Fig 4d, it shows a different story. Key parts of a car were first analyzed and then the main body was modeled in a surface modeling software and fabricated by a subtractive fabrication method with CNC milling. The other parts were modeled as solids and 3D printed. A scaled layout drawing was used to coordinate physical and manual fabrication with outsourced parts for connecting all digital fabricated parts into an assembly. Fig 4e gives an example of using a 3D scanner to convert a digital fabricated model back to CAD model.

Conclusion

These two projects were used in teaching for six years. From students' feedback, this method provides in-depth learning in digital fabrication, and is recommended for teaching various engineering and design subjects.

References

[1] Blikstein, P. (2013) Digital Fabrication and 'Making' in Education: The Democratization of Invention. In. *J. Walter-Hermann & C. BÜching (Eds.), FabLabs: Of Machines, Makers and Inventors*. Bielefeld: Transcript Publisher (2013).

[2] Gershenfeld, N. (2007) Fab: *The Coming Revolution on Your Desktop—from Personal Computers to Personal Fabrication*, Basic Books (AZ)

[3]. Lipson, H. and Kurman, M. (2013) *Fabricated: The New World of 3D Printing*, Wiley.

[4] Anderson, C. (2012) *Makers: The New Industrial Revolution*, Crown Business.

[5] Maker Media. (2013) Makerspace Playbook.

[6] Hemsath, T.L. (2012), Searching for Innovation Through Teaching Digital Fabrication. *In CAAD Curriculum-eCAADe28.*