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ScienceDirect

Procedia CIRP 36 (2015) 35 – 40

www.elsevier.com/locate/procedia

CIRP 25th Design Conference Innovative Product Creation

New Approach to Introduction of 3D Digital Technologies in Design Education

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Abstract

In addition to traditional methods in product development, the increasing availability of two new 3D digital technologies, namely digital manufacturing (3D-printing) and digitizing of surfaces (3D-scanning), offer new opportunities in product development processes today. With regard to the systematic implementation of these technologies in the education of students in the field of product development, however, only a small number of approaches exist so far. This paper explores several ways in which 3D digital technologies can productively be used in design education. The innovative aspects here include that the students assemble and install the 3D-printers themselves, and that they are introduced to an approach that combines 3D-scanning followed by 3D-printing.

Peer-review under responsibility of the scientific committee of the CIRP 25th Design Conference Innovative Product Creation

Keywords: Additive manufacturing, Design education, CAD, 3D printing, 3D scanning, Reverse Engineering

1. Introduction

A number of different generative manufacturing methods, also referred to digital or additive manufacturing and rapid prototyping, have become established in the market in recent years. These allow actual sample parts to be produced directly from CAD part models. This eliminates various process steps required with conventional, i.e. subtractive methods. For example, there is no longer any need to set up machine tools or program tool paths for cutting tools. This saves a significant amount of time [1]. The materials currently used in digital manufacturing range from various metal and plastic powders through to polymer plaster composites and paper.

There are many different sized machines for digital manufacturing DM systems in the market at the moment. These range from products for private users through to professional solutions for industrial users which are capable of producing both sample parts and series components. In addition to this, a large number of systems that have come on the market in recent years allow private users to access the world of 3D printing for less than EUR 1000 [2]. “Build-it-yourself” kits that can be put together by technically-versed private users in a matter of hours and put into operation are the cheapest option. Apart from these, there are also plug-and-play systems, such as home 3D printers, that are all set up and ready to use. This attractive option is playing a key role in generating the current hype about 3D printing and 3D scanning in daily newspapers and on the TV, which is helping to popularize this new technology [3].

1.1. The application of 3D printing in education

In respect of theoretical education at universities, these new possibilities and processes are now taking hold in many lectures and textbooks, like e.g. [4-5]. The use of 3D digital technologies in practical education and research at universities has been concentrated on the development and use of expensive professional systems in laboratories to date. Students have the chance to familiarize themselves there with the new technologies through practical work. As the amount of this laboratory work is limited due to the usually low number of systems in laboratories, only a few students have been able to gain hands-on training to date.

Peer-review under responsibility of the scientific committee of the CIRP 25th Design Conference Innovative Product Creation
doi:10.1016/j.procir.2015.01.045

With the prices of systems continuing to fall, universities have been in a position recently to purchase a greater number of reasonably-priced DM systems for training their students. The aim can be to provide each student in a laboratory with his or her own ready-to-use home 3D printer connected to the CAD system. In this way, each student has his or her own computer with a CAD system and 3D printer available to them, similar to in a CAD laboratory. Students are able to use and grasp the advantages of the new technology, namely the ability to turn virtual models into actual sample parts, quickly and affordably. This means that models can be printed directly from the CAD system. Subsequently, the 3D models can be used for analysis and evaluation. Students receive direct feedback by means of a physical model, allowing them to test and optimize their designs. At the same time, the students learn in a visual and intuitive manner about the new design options on offer from generative, i.e. layer-by-layer processes in such a laboratory. This puts an end to frequent criticism that students are not able to benefit from the new creative freedom provided by generative approaches.

The use of 3D printers has been a tried-and-tested way of supporting design projects in the teaching of mechanical engineering for some years [6]. By using 3D printers with Fused Deposition modeling FDM technology, there is no need for intricate handmade models, which means considerably less design and optimization time and effort [7]. Furthermore Kriese et al. were able to demonstrate that students produced better results through the use of prototypes during the development phase while the work pressure has been considerably reduced [8].

Individual printers made available to a large number of students are usually used. Therefore, each individual student only has limited access to a printer, making it more difficult for him or her to understand how they work and the ways in which they can be used for design purposes. In addition to this, if there is only one printer available then there is not much opportunity to try fast and simple print experiments, e.g. to test a design idea.

The use of DM technologies to train students is also being examined in comparable disciplines, such as architecture [9]. The advantages when using design versions are especially emphasized in this. It was shown in a comprehensive study on the impact of this new technology on the training of architects that students are more integrated into the design process and also become more creative. Additionally, they are enthusiastic about the new ways in which models and prototypes can be generated and benefit from direct feedback through the physical, and therefore “tangible”, models [10].

There has been a range of approaches recently to using greater quantities of 3D printers to train students as well at various universities around the world [11-13]. For example, the Vaal University of Technology (South Africa) set up a laboratory with 20 personal 3D printers in 2011 [2]. In recent years there are repeated reports of plug-and-play 3D printers being purchased by universities. Therefore, the main aim of these approaches is to have the devices used. However, as it is difficult to teach the way in which they work through this, the resulting guidelines on the design of parts for 3D printing can only be imparted to a limited extent.

Obviously, the disadvantage to this way of teaching about 3D printing in universities is that it may not be possible to give students a deep insight into the technology through the use of plug-and-play 3D printers. However, in-depth understanding of how the systems work and the tools used is precisely what is needed in the area of digital manufacturing to convey the right approach to design according to the relevant production task. Hence, this paper describes a method for teaching students about how a digital manufacturing system works and the tools used. In addition to this, design and practical use are also taught so that students know how to critically evaluate designs using the new technology. The aim of this is to give students practical design skills and teach them about design options but also inform them of the limits of digital manufacturing.

1.2. The application of 3D scanning in education

Through using the individual devices in the labs of the university, students could also gain experience in how to work with 3D scanners, to realize the advantages of this technology in the collection of data. However, the same limitations that apply to 3D printing used in teaching also apply to 3D scanning. Here too, widespread application of this new technology in education does not yet take place. In general the laboratories are only equipped with a small number of scanners. The reasons for this are among other things the high acquisition cost of professional hardware and software.

The use of 3D scanners in the field of design education has already been discussed for several years. The studies by Ertu et al. show, for example, that students develop a better understanding in the evaluation of drafts and designs through the use of 3D scanners. This applies in particular to complex surfaces as are e.g. increasingly to be found with modern vehicles. [14]. Rodrigues et al. show how artifacts can be captured by 3D scanning. They can then be provided to the students via a web browser [15]. Fang et al. demonstrate how the process chain from 3D scan to reverse engineering to CAD can be used to present the current status of 3D measuring to students [16]. However, in all these cases only the application of 3D scanning in teaching is discussed, but there is no link to 3D printing.

2. Process chain in 3D-Printing and 3D-Scanning

At the beginning a 3D data model is always needed for 3D printing. The process chain in 3D-Printing begins with a virtual 3D model of the part to be produced. The second step is to transfer the 3D model in a data format that can be read by the 3D-Printing device. The manufacturing process is divided into pre-processing and the actual, generative manufacturing of the part (see Fig. 1).

The virtual model can be created with the help of a CAD software system or by 3D scanning of an existing component. In pre-processing, usually executed using system-specific