AN INTEGRATED DIGITAL DESIGN AND MANUFACTURE STUDIO FOR EDUCATING FUTURE PRODUCT DESIGNERS

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ABSTRACT
A difficulty that often exists with the teaching of a product design engineering course is presentation of its contents as one homogeneous entity in order to allow the students to clearly grasp the relationships between each topic. This paper describes a new design and manufacturing studio, recently created at the University of Strathclyde, and proposes that it can be used as an aid to achieving this homogeneity and providing students with an experience of how product design, visualisation, and manufacture can be efficiently integrated by exploiting the latest digital technologies. The philosophy, design, and effectiveness of the facility as a teaching and learning tool are considered. The paper describes the concept, physical layout and components of the studio by the use of sketches and illustrations, it explains the hardware, software, and other aspects and clearly shows the flow of data and information within the studio. The detail included on rationale, implementation, and experience in use, should be of interest to anyone already considering implementing such a system, or it may provide an inspiration to others to explore the possibility of creating such an environment.

Keywords: CAD/CAM, Design Visualisation, Rapid Prototyping, Design Teaching

1 INTRODUCTION

In product design engineering education the importance of providing the students with the capability of transforming their theoretical designs into physical products is self-evident. The Department of Design, Manufacture, and Engineering Management has always had a comprehensive conventional workshop capability and provided "hands – on" experience in model making to allow students to build up relevant tacit knowledge through using a variety of hand-tools, machines, and materials. However over the past few years the importance of other aspects of the design process has become obvious. For example the Department has increased the amount of rapid prototyping equipment employed for student project work and for commercial use. In parallel with this, student CAD skills are being developed at the concept and detail design stages with the use of software for parametric and surface modelling, rendering, animation, analysis, and simulation. Additionally the students are increasingly encouraged to improve their computer based visualisation and presentation skills. Finally an awareness of the advantages of capturing three-dimensional data from existing artefacts and other objects for reverse engineering has been provided. The opportunity of being able to integrate all of these aspects in the one physical location recently arose and subsequently the Digital

Design and Manufacture Studio (DDMS) was created. During the planning stage a further opportunity was seized to invest in a large screen stereoscopic display system and this will be discussed later.

2 THE CONCEPT

Figure 1 shows the concept of the studio in the form of activities and information flow with the student workstations at the centre of the system.

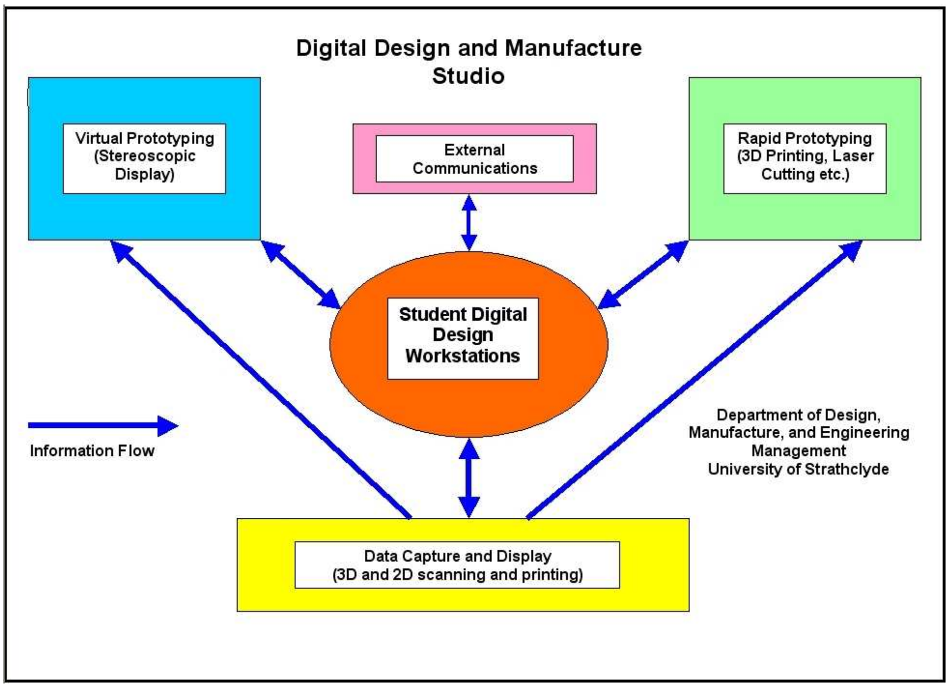

Figure 1. Elements of the DDMS and Information Flow

As can be seen information flows out from the design workstations to the printing, display, prototyping, and external communications equipment (e.g. videoconferencing and the internet), and information can flow in from the scanning equipment and the external communications links. Each of these elements has its clearly defined physical location within the facility although of course the communication links permeate the infrastructure.

3 THE PHYSICAL ELEMENTS OF THE DDMS

The room is located close to the Department's other teaching and workshop facilities and occupies a total of around 300m^2, it is approximately square and one side is almost completely glazed with large easterly facing windows. Figure 2 shows the layout and indicates the relative positions of the main elements.

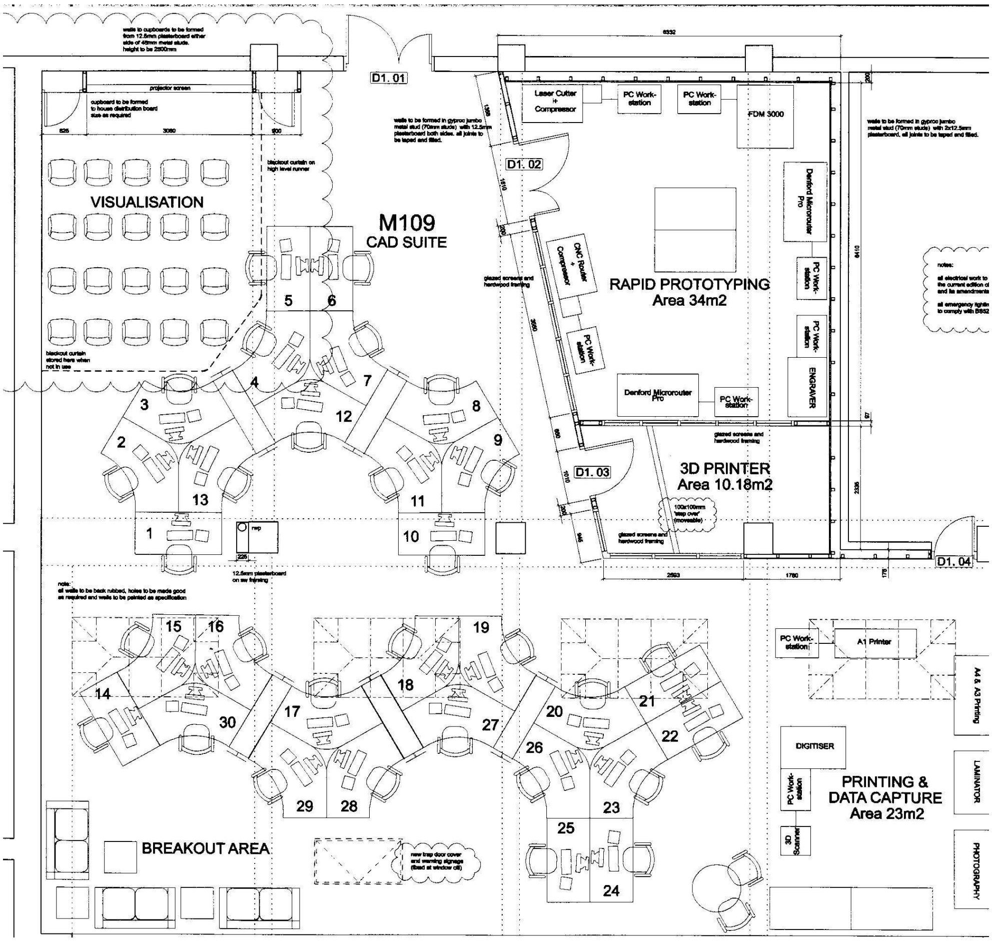

Figure 2. Physical Layout of The Digital Design and Manufacture Studio

In the central area of the studio there are the design workstations and moving clockwise from the main entrance at the top of the page we have the rapid prototyping area, the data capture and printing area, breakout areas, and the visualization area. These are now described in more detail.

4 DESIGN WORKSTATIONS

There are 30 fully networked workstations comprised of 3GHz Pentium dual core PCs with 2Gb of RAM, 128Mb graphics cards, and 80Gb hard disks, they all have 19 inch flat screens. As can be seen from the figure they are organised in clusters that provide ample desk space and easy access.

Software used includes AutoDesk Inventor and Pro-Engineer for parametric drawing and design. Inventor is used by first year students due to its relative ease of use and the fact that some of the students are already familiar with the package from school. Pro-E is used by second year students and by the time the students reach third and subsequent years they can choose themselves which package to use. For surface modelling we use Rhino, for rendering and animation we use 3D StudioMax, for real-time stereo visualisation we use VR4Max, and for design analysis we use ANSYS.

5 RAPID PROTOTYPING

The Departmental aim is to allow students to access the rapid prototyping facilities autonomously with some limited supervision, rather than the traditional procedure where drawings and files were submitted to technicians for processing. Thus the strategy for equipment selection had to consider not only providing a comprehensive capability, but also ease of use and safety together with whole life cycle costs. Specific equipment used is as follows.

A *laser cutter and engraver* provides the capability to cut and engrave 2D profiles on a variety of materials, predominantly acrylics. It is simple to use and has found such a wide variety of applications that the technical staff have compared its importance to that of a lathe in a conventional workshop. The simplicity of use and almost maintenance free operation, coupled with the ability to use low cost materials make this an ideal prototyping tool for student use. Disadvantages of the process include a limited amount of material that can be processed, the requirement for extraction to remove harmful fumes, and the inability to cut to a specific depth. A level of supervision has to be maintained to ensure students do not attempt to process potentially corrosive or harmful materials such as PVC or PTFE.

A range of *routers and milling machines* allows the subtractive rapid prototyping of 3D models in inexpensive light modelling materials such as polystyrene and polyurethane foams. Unlike the rapid prototyping technologies that manufacture in layered processes, the geometry and detail of components is limited here by cutting tool sizes and inability to access undercuts etc. Milling and routing processes provide a quick, safe and inexpensive method of producing development models thus encouraging experimentation with design iterations. Some of the systems with their integrated CAM software provide a good interface that is quickly grasped by the students

The dramatic cost reduction over the last few years of *rapid prototyping 3D printers* has made investment in this technology possible. Machines that only a few years ago would have cost £60 – £100K can now be purchased for around £20 to £25K. In the DDMS we have two machines, one utilises powder, adhesive, and inkjet technology (often simply called a “3D printer”), and the other is a fused deposition modelling (FDM) machine. These processes can create almost limitless geometric complexity by constructing components layer by layer. The base material costs remain relatively high and therefore use is restricted to the more refined stage of design development work. In our experience the powder based system has the most cost effective and fastest 3D printing process, however the required oven curing and post process infiltration requirements results, in reality, in a somewhat lengthy process. We also found that the cost of producing larger volume models was around a third compared with the FDM process. The disadvantage of the powder based process is that while FDM produces components that provide both form and functional characteristics, the powder based components provide little mechanical strength and are suitable only for providing visual representations. Putting the significant element of cost aside, the FDM machine provides a much safer, more flexible, simpler process for students to use.

6 DATA CAPTURE AND PRINTING

Many organisations, from the games industry to heavy engineering, are utilising the capability of 3D scanning technology to capture complex geometry of objects that would otherwise be difficult to generate accurately using CAD software. To facilitate the design process, the data capture zone of the studio provides methods of digitising physical objects through the use of a non-contact laser scanner and a touch contact scanning tool. Students can create models in light modelling materials such as foams or clay, or use existing objects, then use the scanners to transfer dimensional data to the CAD package or directly for manufacture in a more robust material. While for some geometry this is a straightforward process, there are many limitations such as undercuts and hidden surfaces that require time consuming and patient post processing. It is seldom the "quick fix" that it appears to be and this limitation has led to low utilisation of this technology amongst our product design students.

This area also hosts, photography equipment, a flatbed scanner, and printers where students can produce a range of outputs including posters for their design presentations.

7 BREAKOUT AREAS

Although they have larger recreational areas outwith the DDMS these breakout areas have been provided as locations where students can relax and discuss their work with each other in close proximity to all the design tools at their disposal. They can also be used by students if they are waiting on the availability of a piece of equipment already in use. One of the breakout areas can be seen in Figure 3 below. In the distance in the middle left is the visualisation area, middle right is the rapid prototyping area, and far right is the data capture area.

Figure 3. A panorama of the Digital Design and Manufacture Studio

8 VISUALISATION

An interesting feature of the studio is the large screen stereoscopic display. This utilises twin projectors with polarising filters, a screen with a surface that maintains the light polarity, and sets of polarising spectacles for the audience. The projectors are driven from a PC containing a graphics card and software capable of providing a left eye viewpoint to one projector, and a right eye viewpoint to the other. As well as being an aid to rapid comprehension of the spatial aspects of a student's product designs, the feature also appears as though it will be a stimulus to multidisciplinary cooperation. The nature of the installation is such is that it has attracted a wide range of interested people from throughout the University keen to enjoy the stereoscopic experience, this has resulted in a number of discussions on how it could be used for research in collaboration with other disciplines. This all takes place within a teaching environment such that students can easily understand the applicability of the display.

Thus, where physical prototyping is not a practical option, users of the studio have the option of visualising their designs in true 3D depth effect by creating "virtual prototypes". The department is only beginning to exploit this technology through undergraduate projects and projects based with industrial partners.

9 THE STUDIO IN USE

At early stages in student teaching the integration of Computer Aided Manufacturing (CAM) technology has been introduced with Computer Aided Design (CAD) to allow students to develop their design skills by realising physical models quickly and use this to feedback into the design process. For example first year students embark on a project whereby they design an object using hand sketches, or create a rough physical model by hand, this may be based on an object or animal from nature. They then translate this sketch or model into a CAD model in digital form using the scanners, workstations and software provided. This information is sent to the rapid prototyping area where the digital design is translated into a physical model. At this point the young designers usually exhibit a reaction of pleasant, or unpleasant, surprise at how the physical model looks and feels. After examination and consideration by the student an iterative process occurs in that the student will now use this new information as input to a new version of the design. We can also now allow the students to create virtual prototypes and view these on the stereoscopic display system, before they embark on the creation of a physical prototype.

10 DISCUSSION AND THE FUTURE

The DDMS offers significant potential for the future development of product design engineering education. This may be illustrated by considering another example of the use of the studio for a class titled “Global Design”. Although, at the moment, the example has only utilised the external communication and videoconferencing facilities of the studio, it may indicate some future possibilities. This class focuses on product development in a global context and part of the class “The Global Design Project” is conducted in collaboration with Stanford University, CA, and Olin College, MA, USA. A PolyCom teleconferencing system was set up in the visualisation area of the studio. At the end of the project each team made a video-conference presentation to students and tutors at participating team sites.

If we now extrapolate from this example by considering the potential of the DDMS facilities we can see the possibility of creating a very interesting design environment of the future. Assume for example a collaborative project involving a number of teaching institutions in various countries. The stereoscopic projection facility could be used for both displaying virtual computer generated prototypes, these could be created anywhere in the world and displayed almost instantaneously in the DDMS, and also for conducting full size stereoscopic teleconferencing (or telepresence) meetings and stereoscopic display of remotely located physical prototypes and products. Also the remote collaborators could send dimensional information on their own objects, gathered either from their own CAD information or from 3D scanning, to our rapid prototyping facilities and we could recreate them in order to evaluate them as physical objects. This scenario hints at the possibility that in the near future, in the DDMS, we can conduct collaborative design projects and design education with students, tutors, and designers on a global basis where “telepresence” will mean not only virtual representations of remote objects and people but also physical replicas of remote inanimate objects.

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