Applying 3D Scanning and Modeling in Transport Design Education

Ertu Unver[1], Atkinson Paul[2] and Tancock Dave[3]

[1]University of Huddersfield, eunver@hud.ac.uk
[2]University of Huddersfield, p.atkinson@ hud.ac.uk
[3]University of Huddersfield, d.j.tancock@hud.ac.uk

ABSTRACT

Advanced 3D Laser Scanning processes have developed over the last decade and are now available and affordable for medium to large companies as well as education. This study examines the overall efficiency of the 3D scanning process and potential value for use in design education. The potential effectiveness of the 3D laser technology for education is also assessed with live projects.

This article explores a reverse engineering approach for product form design. Three-dimensional models of design concepts are created in clay, and data points on the surface of the model are then measured using a non-contact 3D scan device. The resulting data is then imported into an appropriate CAD design package for further design development.

Keywords: CAD, Laser Scanning, Reverse Engineering, Transport Design, Design Education

1. INTRODUCTION

Although the scanning process itself is not new, the processing power requirements of the captured cloud data is enormous, and only now, with the development and affordability of high powered computers, can the software be used effectively and efficiently. In virtually all applications, a 3D laser scanner will improve speed and accuracy thereby improving productivity. This has led to an increase in the potential of 3D modelling and animation via cloud data capture.

The use of 3D software applications for modelling, rendering and animating product ideas has become an essential everyday aspect of most industrial design activities. However, the use of 3D laser scanned data for building 3D models is not as widespread in education as the use of 3D modelling software. The ability to integrate 3D scan data with 3D software and technology now gives users in all design fields the potential to construct complex organic shapes, which may only possible when using advanced 3D surface modelling software in the past.

There are many difficulties in modelling 3D organic shapes such as gloves, shoes, human faces, etc. for use in design work. In our experience with student design projects, the following approaches to design are usually taken depending on experience and capability levels:

- The use of more freehand drawing and model making to keep creativity as the top priority
- Simplification of the project resolution according to the limitations of available software and manufacturing process
- The use of appropriate 3D design software to model design proposals

Even if students use the full potential of appropriate software, there are still many design limitations in using solid and surface modelling applications. For example, in transport design the general approach is to use clay modelling to explore surface form, while in other design disciplines, students have a wider choice of strategies [1, 2,3]. The ability to capture complex shapes easily would enable students combine the best of both worlds, allowing them to achieve a higher resolution of their design within existing project time spans while maintaining the benefits of more traditional creative techniques.

This paper describes the results of an investigative study into the use of laser scanning for the 3D design courses at the University of Huddersfield, in order to deliver 3D organic shapes to 3D CAD packages easy and quickly. Laser scanning is a terrestrial laser-imaging system that quickly creates highly accurate three-dimensional data (Cloud Data) of an object for use in standard computer-aided design software packages. Included in this paper is a description of the technology, and a discussion of the application of this experimental approach to transport design. The methods applied for evaluation and testing of the 3D laser scanner for 3D design courses are described, and the results of the user experience are discussed. Recommendations are also made as to the potential effectiveness of connecting 3D scanning methods to 3D CAD packages and Rapid Prototyping technology in an attempt to develop new learning and teaching methods to enhance the future of 3D Design education, in particular Transport Design.

Students in Art and Design usually require detailed 3D models for visual renderings, presentations and animations of their final design, rather than for analytical purposes.

2. THE USE OF SCANNING IN THE DESIGN PROCESS

The scanner at Huddersfield uses laser triangulation to plot the contour of the scanned surface to produce a point cloud, which is then edited to form the scanned object. Typical scanned objects for design applications are shown in the Fig. 1.

Fig. 1. Group of objects scanned.

The 3D laser scanner captures an object's surface in the form of 3D points. These points are developed from a laser beam capable of generating and capturing thousands of points per second. It is proposed that this data and the resulting CAD models they inform, can be of significant value to the creative design process.

A typical Transport Design process consists of:

- Analysis and research into branding, market place and market analysis, checking rivals, confirming design specification
- Idea generation, initial sketches
- Concept selection
- Development of selected concepts, accurate packaging, sketch modelling, initial layout drawings

Then traditional approach includes:

- 3D clay modelling, realisations of the final design
- Generation of final freehand renderings, CAD renderings, animation presentations and drawings (CAD is done alongside clay)

In a reverse engineered approach, the process might consist of:

- Laser Scanning of clay model
- CAD model generation, CAD rendering and 3D animations all generated from captured cloud data

It is the differences created in the final two stages of this process which hold the key to the advantages of this reverse engineering approach of using scanning in the design process. Instead of creating a complex clay model by hand, and then recreating the same form in a time-consuming CAD solid modelling activity, the clay model is directly used to generate the relevant data for a CAD solid model, and which is then also used to create final renderings and animations.

Much research has been focussed on the impact of CAD on design education [4,5]. In particular, the work of Michael Tovey et al at Coventry University has looked at CAD in relation to transport design education. A series of articles have considered the implementation of CAD procedures to enhance the design process without inhibiting the visual and creative approaches used by designers [6]; and the use of CAD in the initial concept stages of the automotive design process and the consequent limitations on the production of multiple design possibilities [7]. A later article provided an in-depth analysis of the initial sketching process itself as used by transport designers, deconstructing the process in order to explore the potential capability of CAD software to create solid models from two-dimensional sketch information such as form lines and shadows [8].
This last article has perhaps the most resonance with the aims of the research carried out here. Both explore methods of more efficiently creating CAD models by taking the haptic design activities of sketching and clay modelling as directly providing the source data for solid modelling by a computer. In this way, both attempt to provide a way of working with computer software which is more in tune with the intuitive, creative processes normally adopted by designers.
The type of research described in this section is fruitful and of great relevance to design education per se. However, due to its very nature, the value of any research into the effects of computer technology onto the design process has a limited lifespan of relevance, as the pace of change of technological developments acts to constantly improve the efficacy and value of new CAD processes and their application to creative design work. Indeed, the extent to which CAD is currently employed in the creative production of conceptual design outputs might have been considered unrealistic a decade ago. As an agent of constant change, then, the application of CAD technology to design requires constant reappraisal.

3. 3D LASER SCANNER AND SOFTWARE

3.1 Non-contact 3D Laser Scanner

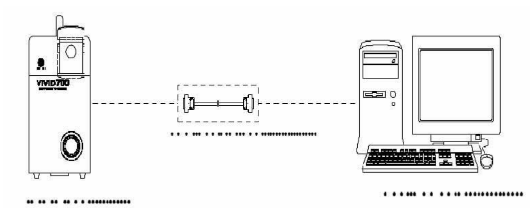

Fig. 2. Diagram of a 3D laser scanner connection.

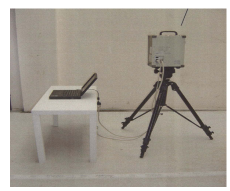

Fig. 3. Image of laser scanner on tripod.

3D non-contact lasers are used to capture shapes by repeated scanning of the required objects from different angles. The 3D laser scanner used in the School of Art & Design is a tripod-mounted portable device, which can be rotated 360° on a ball and socket joint. The device has three interchangeable lenses; a wide, a mid- range and a telescopic lens for use in focusing on different sized objects and to enable the scanning of objects up to 2 metres in diameter. The scanner can be quickly and easily connected to a laptop or a PC computer system as illustrated in Fig. 2 and Fig 3.
The scanner captures the surface of the object from a single position, so suitable adjustments via height and lens selection may be required. Once activated, the laser beam moves quickly across the object, and the light is reflected back and captured as data in the form of a ‘cloud’ of points (cloud data). This data initially describes the 3D shape of the object.

3.2 Scanning Software

Geomagic Studio software is used for the scanning, ‘cleaning’ and processing of the captured data. This allows easy manipulation of the resulting 3D scanned image and enables the creation of highly accurate models of complex curved surfaces, which is particularly suitable for transport design applications.

4. EXPERIMENTAL STUDY

4.1 Discussion of the methods applied in the 3D Transport scanning experiment

From earlier studies where a variety of objects were scanned, some experience was gained in assessing the laser capability in terms of the following parameters:

- Distance/depth range,
- Shapes / forms of objects

- Colour and lighting conditions
- Material and surface texture
- Solid and live objects
- Scanning duration

4.2 Testing of scanning process on production vehicles

Tests carried out on full size production vehicles established the effectiveness of details that could be obtained from internal and external structures with the scanner. (Fig.4a and Fig.4b) For external surfaces, problems were experienced regarding certain colours (black and reflective finishes, including glass) and surface condition.

Fig. 4a. Exterior scanning.

Fig. 4b. Interior scanning.

The interior proved problematic due to difficulties of access and in obtaining sufficient data to provide adequate detail for visualisation purposes of certain plastic and textile components. The access problem could be overcome by a different type of scanner e.g. A robotic arm mechanism or hand held device, rather than the general purpose machine used, but the problems with colour and surface detailing could still be an issue. For commercial applications, surfaces would need to be painted or covered in an appropriate film e.g. Dynoc . This, however, may lead to other surface imperfections. For this educational study, where ¼ scales models are normally produced in clay, the problems above are minimised. (See Fig.5a and Fig.5b). However, for interior detailing, 3D modelling using CAD or standard model making techniques may still be the preferred method.

Fig. 5a. Clay modelling.

Fig. 5b. Clay model with “Dynoc” film.

4.3 Nissan Clay Modelling and Scanning Project

The study was setup in the 3D division of the School of Art & Design by BA(Hons) Transport Design students at The University of Huddersfield in collaboration with Nissan Design, Europe. The project, based on the theme of Performance Art, involved individuals creating concept proposals that were evaluated by David Godber, Design Director of Nissan, to identify a chosen direction for student group working.

Fig. 6. 2D and 3D Sketch modelling.

The 12 week project, undertaken by four student groups on the third year of the four year degree course, culminated in the design of a high performance sports car requiring both exterior and interior detailing. The student groups were selected based on previous project experience.
The groups' chosen concept directions were further developed in 2D and 3D sketch modelling (Fig. 6) to resolve form and surface issues which resulted in ¼ scale models being produced in styling clay (Fig. 7).

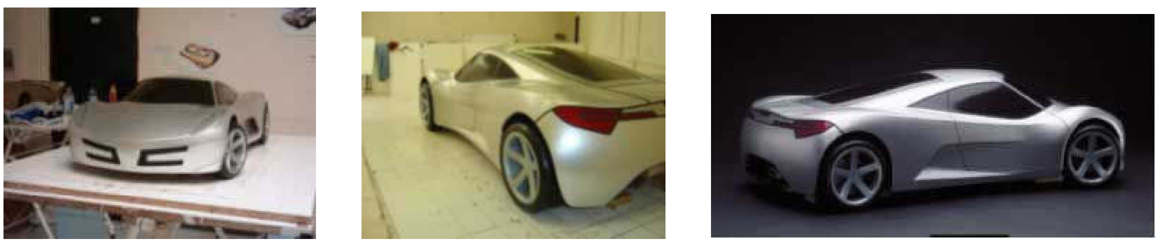

Fig. 7. Clay models with "Dynoc" film.

Although the 3D department has a separate scanning and 3D printing room, the Transport Design clay modelling studio was used to setup and conduct the study in order to minimise potential damage by moving heavy models - an advantage of using a portable scanning device.

4.4 3D Scanning Process

4.4.1 Data Capture
Normally scans from eight different rotations of a car clay model supplies enough data to composite the surfaces into the accurate surface which represents the whole car. To scan one car body from these eight different positions takes around 15 minutes.

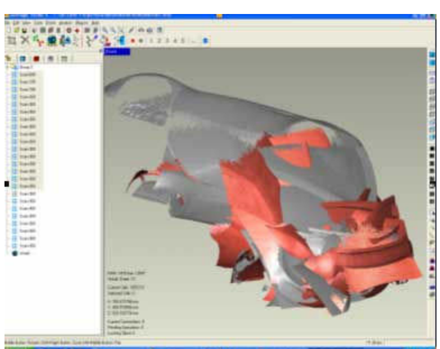

Fig. 8. Typical 3D scanned data.

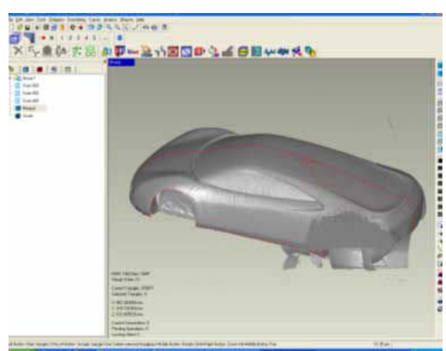

Fig. 9. Registered 3D scanned data.

It is difficult to establish the exact number of scans required from design concept work even with experience. Fig. 8 shows the initial data captured picture from 24 different positions for the design concept selected here. As the scans develop it becomes apparent what additional data is required. Although each scan takes about 3 seconds, the total scanning time for this model took approximately 20 minutes due to the body rotations.

4.4.2 Data processing

The scanning process used in this study consists of several stages, which are necessary to manipulate the scanned surface data using Geomagic software. The process involves point data collection, polygon editing and surface generation for the scanned object to be exported as a 3D NURBS (Non-Rational B-Spline) model for further 3D CAD modelling and animations.

The recorded scan data file is automatically opened in the Geomagic software and the 24 alternatively angled body surfaces appear in the interface/workspace as a collection of 3D data clouds. To make data cleaning easier, all scan surfaces can be hidden from view until ready to be edited. The unwanted background information is cleaned with a tool by selecting areas and any unnecessary data can simply be deleted. When all the scans have been cleaned the next stage in the process is to align the scan surfaces, using the registration tools. Manual and global registration tools improve the relationship between the roughly aligned scans, refining their alignment to minimize deviation when merging the scan data together. (Fig. 9).

After the data is merged, the inaccuracies in the surface of the object become visible. Holes and other irregularities in the object can be cleaned, filled and smoothed if necessary.

During this stage of the process, a mesh is created from which the surface is formed. Once the mesh is completed, the NURB surface, the data from which you can transfer the model to virtually all modelling software, can be created. (Fig.10) This process can take a couple of hours to a full day depending on the students' CAD skill levels and experience, and on the complexity of the scanned objects.

Fig. 10. NURB surfaces creation.

NURBS surface creation is important to enable IGES or STL files etc. to be exported to other 3D modelling an animation packages which students have already acquired during their CAD modules and design work. Students in Art and Design usually require detailed 3D models for visual renderings and presentations, which might include animations of their final design, as opposed to students in engineering disciplines who would normally use the data for analysis purposes.

4.5 Data Transfer and CAD development

4.5.1 Generation of 2D visuals

The data obtained from NURBS surface is a rough model, and requires the addition of details such as doors, windows, interior features, and wheels. This is because the clay model has surface imperfections as well as unfinished surface details due to limitations in the clay modelling process. Transferring the date into Alias Wavefront Design Studio software enables these imperfections and missing details to be added and the surfaces to be re-constructed. Time taken for this part of the process is difficult to quantify. Styling issues such the colour, lighting, texture, remodelling of the parts to meet the design requirements all influence the processing time. After creating the above details the models are rendered to create 2D visuals and basic 3D animations. (Fig. 11).

Fig. 11. Rendering of NURB surface in Alias.

4.5.2 Generation of 3D animations

Although Alias Wavefront Design Studio is well suited for modelling and surface creation, 3D Studio MAX is commonly used by students for renderings and advanced animations.

The Alias model is transferred to 3D Studio MAX in IGES format. Then colour - material / shaders, texture, lighting, cameras, particles and other features are added to create photorealistic renderings and animation presentations. Then film editing software is used to edit the animations, add film effects, text and sound. The Fig-12 illustrates a film sequence of 2 minutes.

Fig. 12. Thumbnails captured from the animations.

5. CONCLUSIONS AND RECOMMENDATIONS

The objectives of the experimental study were to test the scanner hardware and software in order to develop methods and guidelines for creating 3D surfaces to aid future teaching and learning, and research. Undertaking this case study has enabled the potential problems students might face in using laser scanning to be anticipated. Awareness of the difficulties encountered in employing the wrong scanning techniques and the effects of material colour on the scanning process allow the most efficient use of resources to be planned.

Multiple scans were made of the clay car models to ensure all the data was available, due to the curvaceous nature of the surface. This allowed for easy scan registration. From experience, it has been found that the material type and colour of the objects to be scanned are also problematic, as black plastic has proved to be a difficult surface to scan. To overcome this, a very thin coat of matt grey primer can be applied to the sample object, which dulls the plastic surface and reduces the effects of shadows and glare, producing a more even scan.

It would be fair to say then, that for a large proportion of students in 3D design, laser scanning offers the potential for a more efficient method for the surface modelling of design solutions, and that for students studying transport design, the process may prove to be very beneficial as it enables the students to use the same geometry for clay modelling, rendering, and animation purposes.

The benefits of reducing the time required in CAD labs in creating complex 3D forms will need to be carefully weighed against the problem of over demand on the laser scanner, which at present remains a limited resource as it is a shared facility. Use by other design courses within the faculty such as 3D, multimedia, fine art, architecture etc. and problems arising from scheduling, technical support and faulty scan issues all affect the efficiency of the operation.

It appears that a significant advantage of laser scanning technology may lie in its use as an alternative tool for reaching design solutions where especially complex surfaces are an important part of the project. The study has shown that in particular, laser scanning can be used cost effectively, for surfaces difficult to model such as transport vehicles or organic forms. The current scanning process, however, would appear to be far less suitable for the modelling of basic objects such as tables, desks, or other objects consisting of geometric forms which are straightforward to create using existing CAD modelling techniques. Improvements which could be made to the existing scanning process, i.e. the use of a motorised turntable which can be connected to the system, are now clear. The time taken in registering and merging the scanned data could be drastically reduced by automating this part of the process, although this would only be suitable for smaller and light weight static objects.

We are currently continuing this research, studying the role of colour on the quality and accuracy of scan data, and testing a wide variety of materials, which will hopefully enable a database of the most effective scanning methods for particular design solutions to be compiled.

Fig. 13. Final presentation.

6. ACKNOWLEDGEMENTS

This project was carried out in collaboration with Nissan. We are particularly grateful for the support and encouragement of David Godber of Design Director at Nissan Europe, and his team (Fig.13).

7. REFERENCES

[1] Fu, P., Reverse Engineering in the Auto Industry, Time-Compression Technologies, Vol. 12, No. 2, 2004, pp 12-14.

[2] Jaselkis, E., Gao, J., Welch, Z. and O'Brien, D., Pilot study on Laser Scanning Technology for Transport Projects, Proceedings of the 2003 Mid-Continent Transportation Research Symposium, Iowa State University, 2003.

[3] Jiun, S., Chuang, C., H., A reverse engineering based approach for product form design and, Department of Industrial Design, National Cheng Kung University, Taiwan, R.O.C, Design Studies Vol., 24 No. 2 March 2003.

[4] McCallum, B., Nixon, M., Price B. and Fright R., Hand-held Laser Scanning In Practice, Applied Research Associates NZ Ltd 47 Hereford St, PO Box 3894, Christchurch, New Zealand

[5] Monti, C., Fregonese, L. and Achille, C., Laser Application on complex shapes of Arhitecture profiles extraction processing and 3D modelling. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol xxxiv-5/W10.

[6] Tovey, M., Styling and Design: intuition and analysis in industrial design, *Design Studies*, Vol. 18, 1997, pp 5-31.

[7] Tovey, M. and Owen, J., Sketching and direct CAD modelling in automotive design, *Design Studies*, Vol. 21, 2000, pp 569-588.

[8] Tovey, M., Porter, S. and Newman, R., Sketching, concept development and automotive design, *Design Studies*, Vol. 24, 2003, pp 135-153.