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Comparative Analysis of Mobile 3D Scanning Technologies for Design, Manufacture of Interior and Exterior Tensile Material Structures and Canvasman Ltd. Case Study

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Technical Report on behalf of CANVASMAN Ltd

Crow Lane, Otley, West Yorkshire, LS21 1JH

Project Report by:

Dr. Ertu Unver, Andrew Taylor, Prof Andrew Ball

Project Title:

Comparative Analysis of Mobile 3D Scanning Technologies for Design, Manufacture of Interior and Exterior Tensile Material Structures and Canvasman Ltd. Case Study

ADA Team:

- Dr. Ertu Unver, PhD, MSc, PG Cert, BSc (Hons), HEA, School of Art, Design and Architecture, Product Design course, University of Huddersfield e.unver@hud.ac.uk
- Andrew Taylor, MSc, BA (Hons), PG Cert, HEA, University of Huddersfield School of Art, Design and Architecture, Surface Design, University of Huddersfield a.taylor2@hud.ac.uk
- Prof. Andrew Ball, PhD, B.Eng. University of Huddersfield, a.ball@hud.ac.uk

Collaborated with:

Canvasman Team: Chris and Fran Salisbury. Directors

3M Buckley Centre Team: Andrew Longstaff, Simon Fletcher

Date: 21/Jan/2016

Funded by Santander Collaborative Innovation Fund

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1. Abstract:

This report aimed to investigate mobile 3D Scanning technologies to improve the 3D data capture and efficiency into Canvasman's CAD design and manufacturing processes with focus on accurate resolution. The Santander funded Collaborative Venture Fund (CVF) project has provided research, survey data, evaluation and analysis for Canvasman Ltd. on 3D portable scanning hardware and software. The project solutions recommended in this report offers impartial product information on the current appropriate 3D scanning technology that potentially could improve efficiency of data capturing, design and manufacture of interior and exterior spaces, boats, vehicles and other similar constructions for creating and installing flexible coverings and indoor and outdoor structures.

2. Introduction:

This research project is funded by Santander Innovation Vouchers of £5000. This report provides an overview of the project and the testing and results generated through the research. The research funding was shared in an interdisciplinary collaboration with 3M Buckley Centre for Precision Technology /Engineering Department staff and School of Art, Design & Architecture academic staff.

The collaborative team members and their expertise are outlined here; The Art, Design & Architecture research team leading this project are Dr. Ertu Unver and Andrew Taylor. Ertu's areas of responsibility include, machine tools, manufacturing technologies, CAD/CAM, moulding design and industrial, and Product Design Engineering. Andrew's research and design led practice contributes to research in teaching and learning focusing on 3D scanning, 3D modelling, and rapid prototyping for Surface, Fashion and Textiles design and manufacture, results of 3D related research are illustrated in figure 5. The team published a number of research papers on the subject area of digital technologies and 3D scanning. (See references Taylor, A., Unver, E. (2005), Kus, A., (2009), Unver, E., Taylor, A., (2012), , Taylor et al (2014), Taylor et al (2014b), Taylor, A., Unver, E.(2015), Unver, E. et al (2006), Taylor A., Unver, E. (2006), Unver, E., (2006))

Prof Andrew Ball was invited onto the ADA CVF team and contributed in providing mobile 3D scanning equipment and consultation. Andrew's personal research expertise is in the detection and diagnosis of faults in mechanical, electrical, and electro-hydraulic machines, in data analysis and signal processing, and in measurement systems and sensor development.

The 3M Buckley Centre Team are Principal Enterprise Fellow Dr Andrew Longstaff and Senior Research Fellow Dr Simon Fletcher the Centre for Precision Technologies completed complementary research, and are producing a report and presentation into precision scanning methods and also low cost photogrammetric app solutions.

There are increasingly a large number of 3D scanners available for many different markets and applications covering, Art, Reverse Engineering, Automotive, Archaeology, Product Design, Architecture, Fashion Design, Body Measurement, BIM, Civil Engineering, Metrology, Forensics, and National Security. There are limitations, advantages and disadvantages to each scanner such as resolution, scan area, mobility, data capturing speed, tolerances. (3D scanning Comparison, 2016).

The aim of the research is to investigate the market for mobile 3D Scanning technologies and to evaluate how to improve the 3D data capture and efficiency for Canvasman's CAD design and make processes with a focus on ease of use, user experience and resolution.

3. Company Background

Canvasman is a SME limited company based in Otley, near Leeds in West Yorkshire, UK.
The company offers product design development and manufacture services for :

- Boat cover
- Upholstery
- Shade sails
- Miscellaneous covers
- Shop canopies
- Garden canopies & covers
- Vehicle covers

Figure 1: Canvasman Ltd: Outdoor product projects. www.**canvasman**.co.uk

The company is led by Directors Chris Salisbury and Fran Salisbury working together with a small team of skilled CAD designers, cutters, sewing technicians, and fitters. Canvasman design, develop, manufacture and improve innovative textile products which provide protection from the elements by using the latest and most effective materials and technology available and the company also offers a full refit and upholstery service to complement all types of covers. (Canvasman, 2016)

The 3D ADA team visited the Canvasman company in June 2015 and the Directors and specialists on their staff demonstrated the current design and manufacture processes. The images below show the evaluation of workflow from on-site visit; recording, sketching, photography, and digitisation using the Pro-liner portable wire based measurement device.
During the last 5 years the company has used Pro-liner portable wire based measurement device for data capture of straight, curved, and convex shapes, measuring in horizontal and vertical positions without using targets outdoors and indoors. The Pro liner technology and the methods the company have developed to capture necessary data are effective although could be improved. Using this current technology the user must be experienced in design for manufacturing, due to visiting difficult locations and scanning limitations such as boats and scanning only the most relevant edges therefore other data is often missed or has to be sacrificed.

Figure 2: Site Visit, Sketching, Digitising,

The Proliner demonstration was of particular interest to this research. The wire based measuring device can be pulled up to 7.5 metres using a metal pen. Straight curved and convex shapes can be measured in horizontal and vertical positions without using any targets. This device and process is not complex and can be operated by staff with basic training. The user of the device, does require experience in 2D and 3D design processes specific to Canvasman and understanding the amount data and extent of the measurements required from each individual project and client is essential to data collection. Figures 2 – 4 shows demonstration of the design, development and manufacturing process the company currently employ. The company currently integrate cloud data files into Rhino 3D modelling software, Optitex pattern design & cloth simulation software is used for pattern design and lay plan for cutting, Assyst Bullmer Ply cutters, digitiser tablet, and the Pro liner measuring device for capturing data.

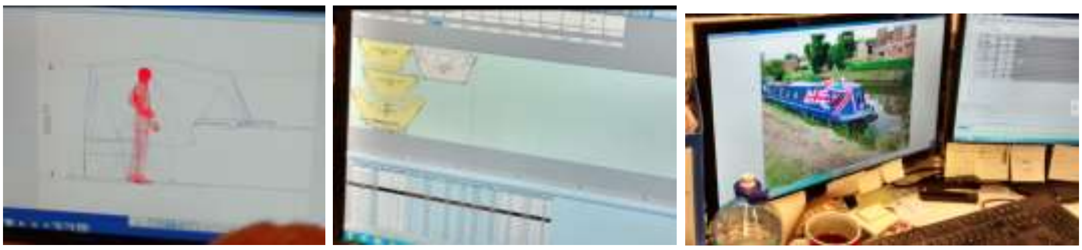

Figure 3: Producing 3D CAD data and patterns

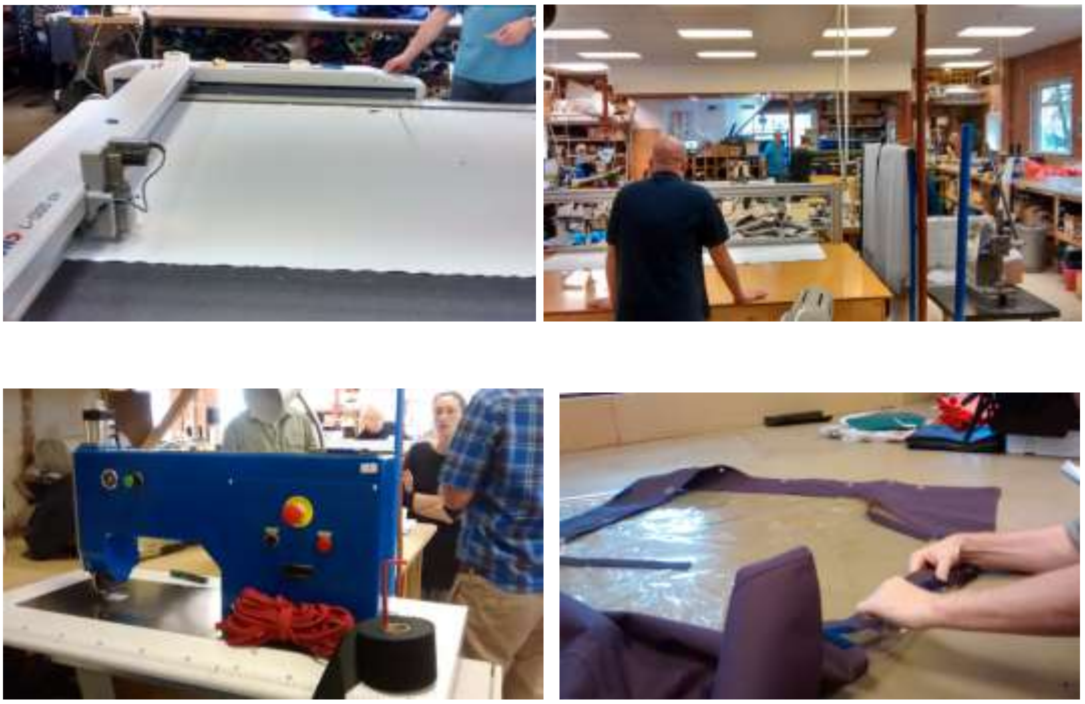

Figure 4: Manufacturing process at Canvasman

4. Research Project: Brief Development

The Santander Innovation voucher was initiated through an enquiry by the company for student placement and further a recommendation from Assyst Bullmer for Canvasman directors to contact Dr. Unver in the School of ADA. Canvasman directors Fran and Chris Salisbury arranged a visit to School of ADA. Their aim was to understand how to improve their efficiency on design and make processes, and potentially to recruit student placement or recent graduate from interior, product design or textile design to the company.

Assyst Bullmer supply and maintain Canvasman plotting and ply cutting machinery and are also long term suppliers of software and hardware to School of Art, Design & Architecture long term industry collaborations to the University in teaching and research shown in figure 5, and providers of technology to Canvasman with solutions for 3D Design & cutting for Manufacture. (Taylor, Andrew et al, 2013), Following the initial meeting the company was guided through the application process for Santander Collaborative Venture Funding support for further agreed consultation and research that would benefit the company and the University.

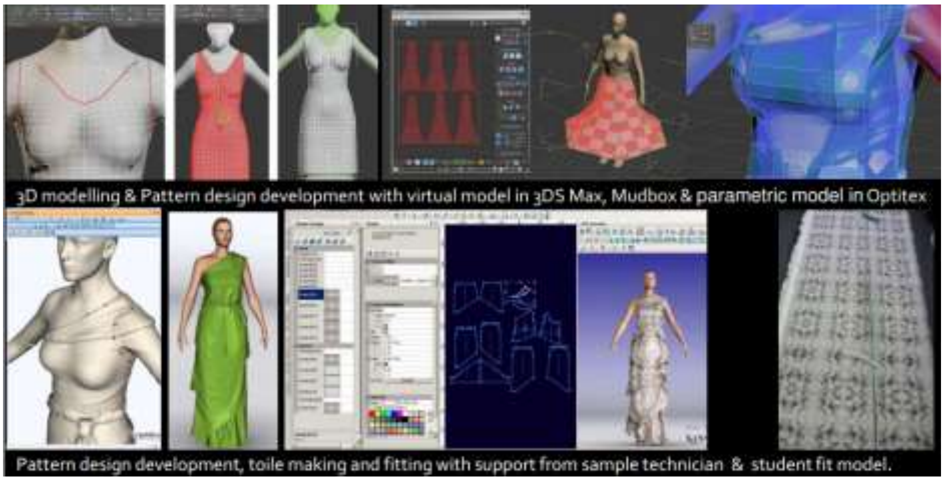

Figure 5: 3D pattern development using Optitex PDS, and a range of 3D modelling tools

Research and Enterprise Development Manager of University of Huddersfield Barry Timmins then invited academics and technical team from 3M Buckley Centre Metrology department, engineering, product/3D, fashion & textiles. At this meeting the Directors explained the background to the company, the design and product development processes and then focused on explaining the specific problem areas regarding 3D Scanning equipment and limitations of their current methods in the outdoor environment.

The University team in this project is interdisciplinary between 3M BIC Metrology department researchers and School of Art, Design & Architecture 3D Design research team. The 3M BIC Metrology (Andrew Longstaff & Simon Fletcher - Metrology) solutions initially offered evaluation of the problem using high tolerance scanning systems. ADA 3D Design team (Ertu Unver & Andrew Taylor) proposed low cost and low resolution hand held 3D scanning systems to test integrate data effectively into the Optitex and Rhino 3D modelling programs that Canvasman can utilise to develop their business. A project brief was developed that incorporated research and subject expertise from both teams in order to provide a range of solutions to the company and the University. Building on the earlier research conducted by the academic team in 3D Design ADA staff on 3D data capture devices; we developed the following criteria to test and evaluate the scanner(s).

Figure 6: 3M Buckley Innovation Centre. Centre for Precision Technologies.

- Portable or fixed
- Cost (very low, low, middle or expensive)
- Scanning speed
- Weight
- Manuel or auto stitching,
- Resolution, tolerances, points accuracy, 3D accuracy over distance
- scan area length and working distance
- Target and markers usage and distances
- Software, functionality, ease of use and support
- lighting environmental conditions
- Ability to scan various colours, surface patterns, *material types, shiny, glass, black*
- Ability to capture texture and Colour information
- Ability to see the screen while scanning with the device (Lap top or Tablet integration)
- How the unit is powered.

5. External Visits for 3D Scanning Technology Evaluation

Firstly, in order to investigate and understand the brands of 3D scanning technology and the user functionality effectively visits were made to a UK trade exhibition and also to local companies.

5.1 The Manufacturing & Engineering North East trade Event, Newcastle

The Manufacturing & Engineering North East in July 2015 provided the perfect forum for us to review handheld 3D scanners and discuss technical capabilities and suitability with sales demonstrators and technical teams. At the Engineering trade show FARO, CREAFORM &

GEOMOS Atos 3D scanners were evaluated. Attending the Manufacturing & Engineering North East trade in the Metro Arena exhibition provided the 3D ADA team with direct access to Faro, Creaform3d, GOM ATOS, and also iMaterialise for 3D printing, major market leading suppliers in 3D Scanners, and printing. During the day at the trade event four 3D Scan technology provider stands were approached and the ADA team were given live demonstrations of the range of 3D Scanners by representatives and during the demos we requested a range of 3D data to be sent to the team and also recorded the information exchange as shown in Figure 4.

Figure 7: FARO Freestyle Demonstration

3D Scanner Demonstration 1: Faro Freestyle

ADA researchers approached Faro on their trade stand, we discussed our requirements, and the reps gave us demos on the freestyle 3D scanner. An invitation to the University and to Canvasman was arranged for a later date, and this visit and demo was successfully completed at Canvasman business in January 2016 See Section

Figure 8: FARO Freestyle Demonstration

The FARO Freestyle is a mid–high resolution handheld 3D scanner. It quickly and reliably documents smaller areas such as rooms, internal structures, and product objects in 3D and creates high-definition point clouds. In our initial evaluation we felt that it is suitable for design and product development applications in which were objects are measured from various perspectives. (Faro Freestyle, 2016)

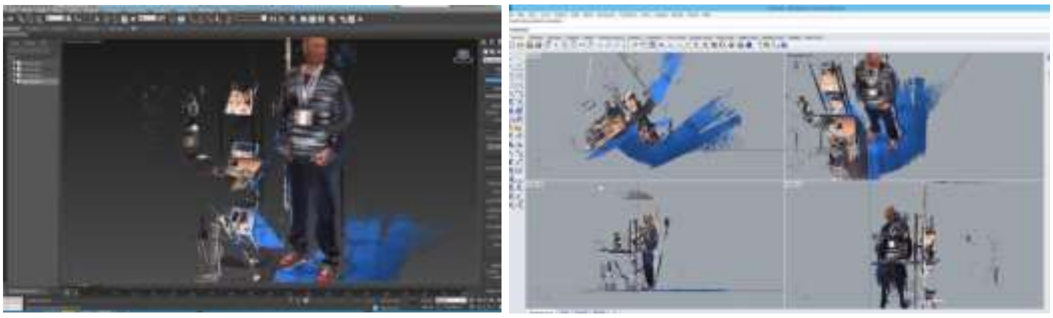

Figure 9: FARO Freestyle 3D cloud data for testing

At the exhibition stand, Faro demonstrated the scanner range and we were also given full access to freestyle to test for ourselves. We scanned the space and objects on the stand, table, objects on table, and human bodies as seen in figure 9. The scanner was very easy to handle during scanning due to a lightweight carbon fibre body; the handheld scanner weighs less than a kilogramme and is highly portable and mobile. The Windows Surface Pro 3 was used to connect the scanner and control the device, in particular for powering the scanner no extra power source is required, and battery consumption is economical at 3 hours of scan time under normal conditions of use.

Figure 10: Faro Free style Features and Functions

This device and tablet which includes SCENE cloud capture software by Faro which is very simple, clear and very intuitive to use during scanning and this is important particularly for inexperienced operators. Images below in Figure 10-11 shows Faro Freestyle Product Information features and functions.

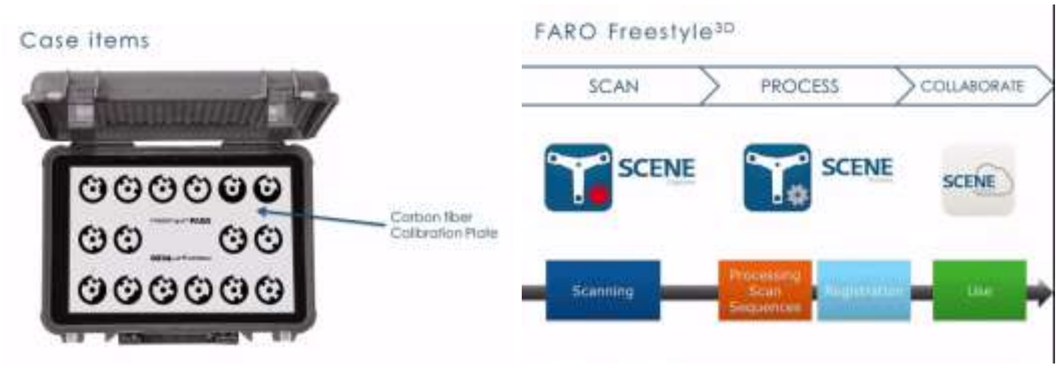

Figure 11: Faro Free style workflow and scanner targets

Turning lights off improves the quality of the scan results. If the light is not sufficient or in dark conditions the scanner has a flash on/off. The flash was tested and this improved data capture results. Data is sent automatically to the SD card. The 3D cloud data was opened in Faro Freestyle cloud editing software on the laptop shown in Figure 9 above. In the Faro cloud software editing of unwanted areas in the scan can be deleted, and all remaining surfaces are merged automatically taking under 5 minutes. The 3D Data file captured was very large totally 3GB which included point cloud data, colour RGB and textures in the scan data. Data transfer was for specific packages was discussed including Rhino, Solidworks, Autodesk Suite. Technical team demonstrated the how the data can be transferred using Autodesk RECAP 360 to other 3D modelling packages. The company recommends users to various software packages to open, edit and transfer the data. The scanner cost around £9000 (Cost of Faro FreeStyle, 2015)

- **Portable or fixed :** Portable
- **Cost (very low, low, middle or expensive)** around £10k (including tablet)
- **Scanning speed :** Fast
- **Weight: Under** 1 kg
- **Manuel or auto stitching :** Auto
- **Resolution, tolerances, points accuracy, 3D accuracy over distance:** Mid
- **Scan area length and working distance :** 0.5 – 2m
- **Target and markers usage and distances :** None, can be used
- **Software, functionality, ease of use and support:** Basic software Included but additional software required for data compatibility and processing
- **Lighting environmental conditions:** Can be used indoor & Outdoor (not sensitive to light)

- **Ability to scan various colours, surface patterns, *material types, shiny, glass, black:*** *YES*
- **Ability to capture texture and Colour information:** Yes
- **Ability to see the screen while scanning with the device (Lap top or Tablet integration) :** Using a Microsoft Pro Surface Tablet PC Very Flexible
- **How to power the unit?** No External Power needed

3D Scanner Demonstration 2: Creaform 300

The Creaform product range offers high scanning detail and data results and is very flexible to use. From the demonstration, it was clear that this scanner is specifically developed for reverse engineering and product design and engineering applications. The setup time to scanning was quick and easy to start to operate. As shown in Figure 11. The system uses many targets to focus and merge individual scans areas automatically in the software. The Creaform 300 handheld we tested was not suitable for larger areas such as rooms or outdoor conditions.

Figure 11: Creaform 300 demo showing high tolerance measurements

Creaform, is a portable 3D measurement solutions and offers 3D engineering services with HandySCAN 300 and HandySCAN 700, and GoScan Series scanner high accuracy, resolution and substantially higher measurement rates—all in a highly portable device. Professional-grade measurements: Creaform scanners provide an accuracy of up to 0.1 mm (0.004 in.) and resolution of up to 0.2 mm (0.008 in.). Handyscan 3D scanners can be used at all stages of product lifecycle management including:

- Concept: Product requirements as well as concept design and prototyping
- Design: CAD designs, prototyping, and testing, simulation, and analysis
- Manufacturing: Tooling design, assembly/production, and quality control

5.2 Company visit 1: Set Vision Imaging Studios. Bradford

Set Vision are a CGI Art and CGI Illustration and visualisation company based in Greengates, Bradford, UK. Set Vision and the Product design course at University of Huddersfield have collaborated in past and the company use various 3D scanning technologies in data capture for product visualisation. Set Vison are experts in 3D; producing set design, styling, build and decoration, photography and post production and bespoke visualisations for large room sets such as kitchens, bedrooms and bathrooms.

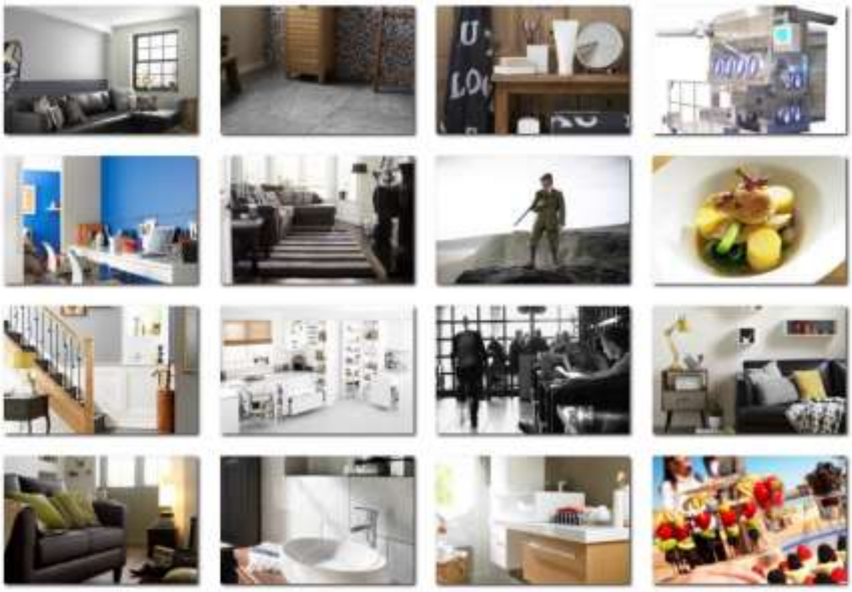

Figure 12: Setvision ltd

3D Scanner Demonstration: Artec Eva

The team contacted the SetVision company and were given a product / interior demonstration of the Artec 3D scanner by 3D designer Danny Austin focused on our criteria.

Figure 13: Eva Artec Scanner

From the visit to Setvison, our experience of testing the Artec Eva 3D scanner is that it provides a quick, textured and accurate scan without markers or calibration. It captures objects quickly in high resolution with colour and texture and is suitable for many applications and Canvasman. Artec™ Eva 3D Scanner is similar to a video camera which captures in 3D data aligning these automatically in real-time, which makes the process of scanning easy and fast producing data for detailed textured models.

During the visit we setup experiments in a small room next to photo studios. The Artec scanner was opened out of the box and quickly setup with a long power cable and connected to a laptop. 3D scans were then recorded of a seated human body, bathroom products and room scanning.

Figure 14: Human scan using Eva Artec Scanner

Figure 15: Cloud data exported to 3D modelling package from Artec Eva Scanner

The cloud data exported very quickly and easily from the Artec software. The Figure 11 shows the data imported into 3DSMax. The scanner captures high resolutions and therefore detail such as hair, folds in fabric, colour shaded objects all providing successful results. The human body was quickly scanned for testing in 5 - 10 mins. For a more complete scan with cleaner cloud data further time would be required. The following criteria list provides test results and easy to use details for evaluating the scanner(s).

- **Portable or fixed :** Portable
- **Cost (very low, low, middle or expensive)** around £10k
- **Scanning speed :** Fast
- **Weight:** 0.85 kg
- **Manuel or auto stitching :** Auto
- **Resolution, tolerances, points accuracy, 3D accuracy over distance:** Med - High
- **scan area length and working distance :** 0.4 – 1m
- **Target and markers usage and distances :** none
- **Software, functionality, ease of use and support:** Extra add on to purchase
- **lighting environmental conditions:** Testing done in door less sensitive
- **Ability to scan various colours, surface patterns, *material types, shiny, glass, black:*** *YES*
- **Ability to capture texture and Colour information:** YES
- **Ability to see the screen while scanning with the device (Lap top or Tablet integration) :** Using a Tablet PC but Restrictive
- **How to power the unit?** External Power Required

6. 3D Scanner Testing: IPhone & Tablet Based

Structure SDK 3D Sensor is one of the first 3D sensors for mobile devices started with an KickStarter campaign that made it one of the top grossing campaigns of all time. Structure SDK Sensor costs around £250 and it is one of the first 3D sensor for mobile devices. This scanner clips onto the back of an iPad Air 2 providing 3D depth data for basic but true 3D scanning data. There are a few apps currently available with the Structure Sensor for scanning and mapping, as well as virtual reality gaming. This device is originally intended for software developers but recently attracted many product developers where low cost 3D scanner needed.

Structure Sensor contains a small infrared sensor made by PrimeSense that reads near-infrared or structured light which changes based on the distance between the objects. The software uses a complex algorithm to turn this data into a three dimensional model. (See: Structure 2016, Gizmodo (2016), Scan Review (2016)) iSense is a similar product Cubify, a 3D Systems brand for 3D scanning on iPhone or iPad CUBIFY, (2015). The infrared laser projector casts a specific pixel pattern on the objects in front of it. The sensor uses the dots to detect distortions in the environment being scanned as the scanner is moved around the object. This sensing of the dots and the distortions produces a depth map of the scene which is, of course, the 3D aspect. The Structure Sensor functions when connected via the camera of an iPad which collects colour information of the environment, and compiles it with the rest of the data collected.

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Figure 16: iPad or iPhone mobile scanners

Experiments using Structure SDK Sensor for 3D data capture

The following criteria was used to evaluate the Structure SDK Sensor scanner.

- **Portable or fixed :** Portable
- **Cost (very low, low, middle or expensive)** around £1k (including tablet)
- **Scanning speed :** Fast
- **Weight: Under** 0.5 kg
- **Manuel or auto stitching :** Auto
- **Resolution, tolerances, points accuracy, 3D accuracy over distance:** Low
- **scan area length and working distance :** 0.4 – 3m
- **Target and markers usage and distances :** none
- **Software, functionality, ease of use and support:** Included
- **lighting environmental conditions:** Can be used indoor & Outdoor (not sensitive to light)
- **Ability to scan various colours, surface patterns, *material types, shiny, glass, black:*** *YES*
- **Ability to capture texture and Colour information:** YES
- **Ability to see the screen while scanning with the device (Lap top or Tablet integration) :** Using a Tablet PC but Restrictive
- **How to power the unit? No e**xternal power needed

For testing the Structure scanner a range of environments indoor and outdoor were captured focusing on a range of scales and objects; including car, boats, room, furniture, products and humans. The scanner has two scanning modes:

- **Product scanning mode** (Detail but small scale) – Area is selected with a cube to identify area to be scanned.
- **Area/ Space scanning mode** (Less Detail) - This function captures everything in the scene as you move.

Figure 17: 3D canning an office with SDK Structure Sensor connected to iPad

3D Scanning of Desktop Printer:

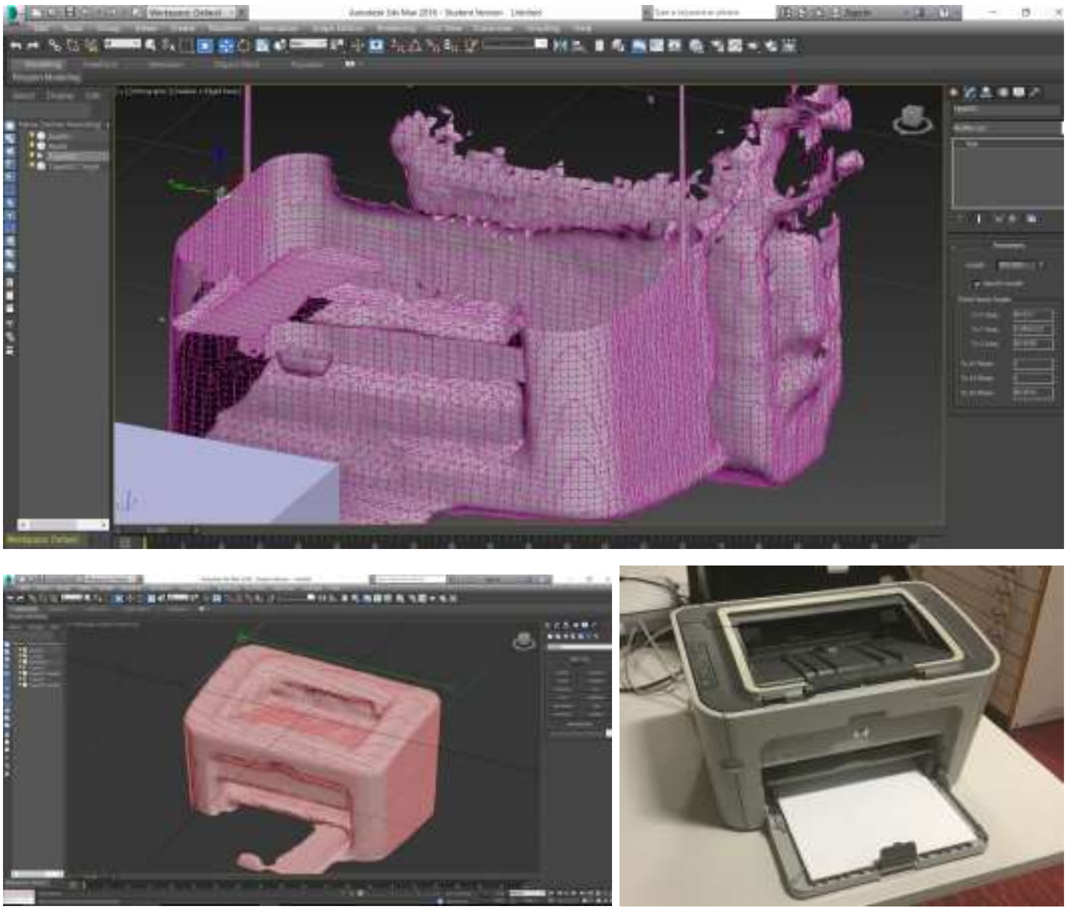


Figure 18: 3D Scanning using Structure SDK Sensor

Scanning the desktop printer was fast completed in seconds and easy. The data captured at this scale was accurate for overall dimensions equal to mm tolerances and our measurements taken by hand with a tape measure. Further measurement should be conducted with callipers if required. Ability to record and not experience tracking issues produced positive results. Unfortunately data captured is low quality and the important features such as button details, screws and power socket were lost as the capture resolution is low.

3D scanning of desktop speakers:

3D Scanning the desktop speakers as a small scale experiment was also fast and completed easily in seconds. The data captured at this scale was medium quality due to low capture resolution not recording enough points.

Figure 19: 3D Scanning speakers using Structure SDK Sensor

Unfortunately 3D scanner didn’t capture important component product features such as button details, speaker details, and power cables. This scale of 3D scan data is only useful for using as a template reference when modelling other relevant products.

3D scanning of a Fan:

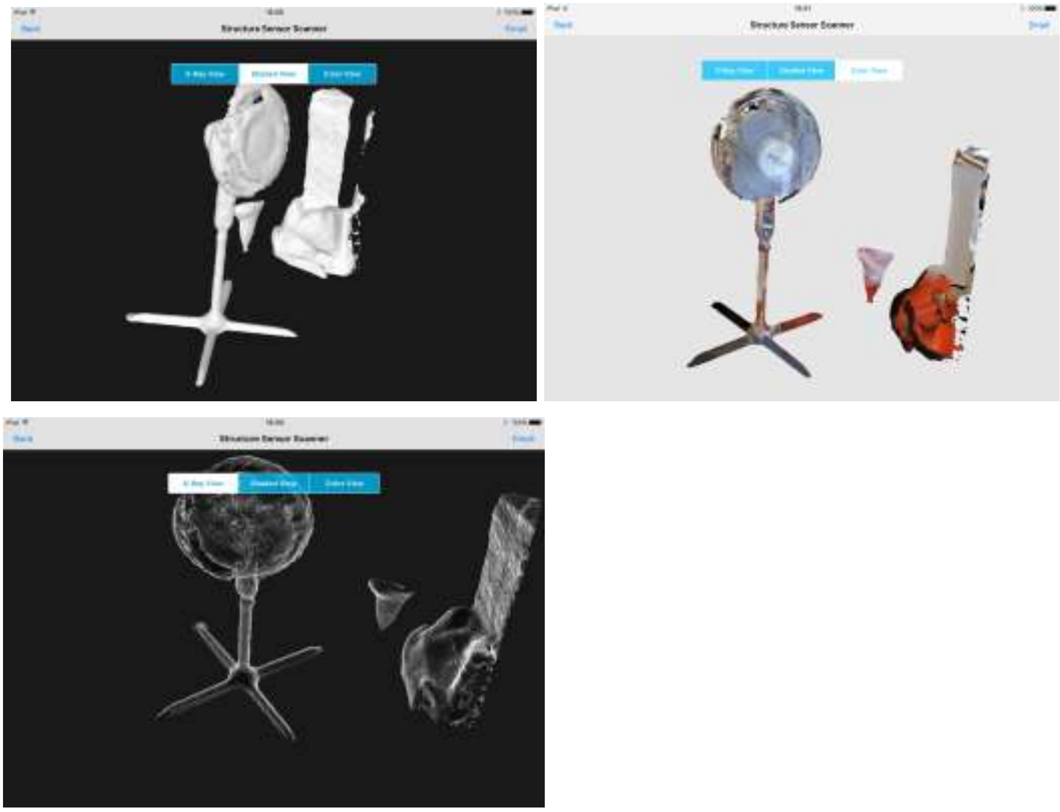
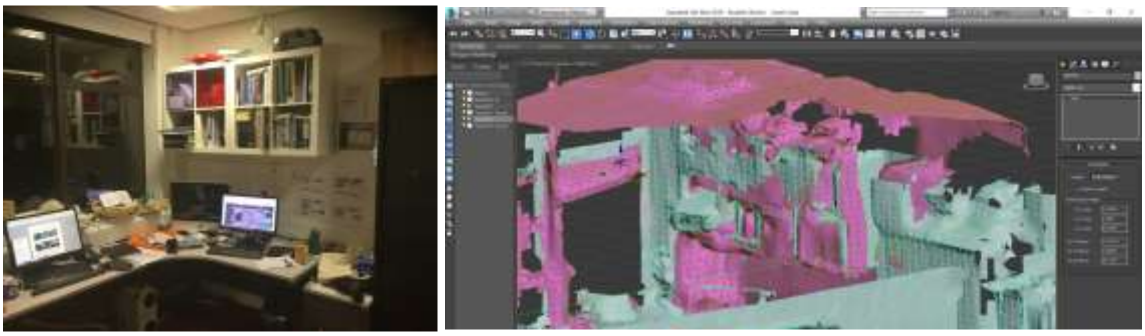


Figure 20: 3D Scanning fan using Structure SDK Sensor

Scanning the desktop fan was relatively slow as the product contains very complicated wire structure was not easily captured. The quality of data captured was very poor on some sections as 3D scanner cannot read the wire details and sizes but was adequate with the capture of solid components such as the stand.

3D scanning of Interior spaces:

University staff office as shown in image 21 was scanned using the Structure SDK Sensor.



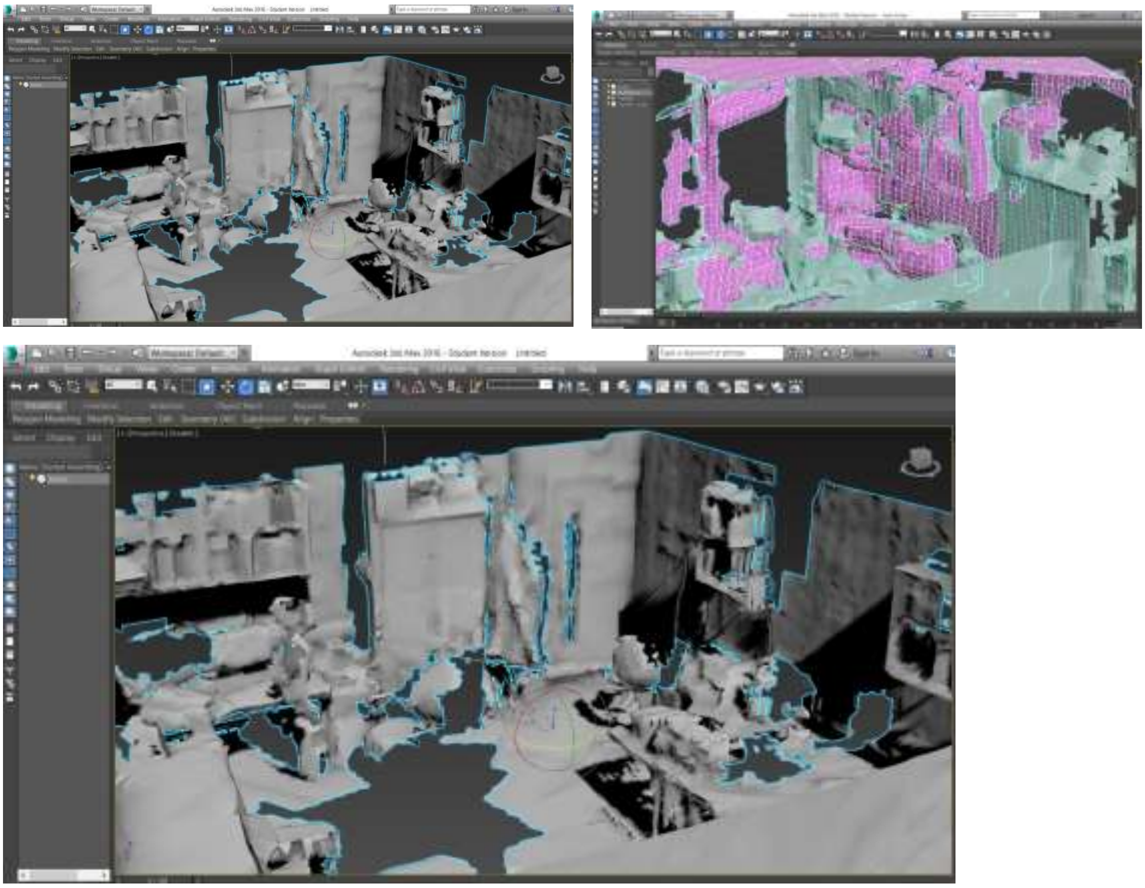


Figure 21: 3D Scanning of office with the Structure SDK Sensor

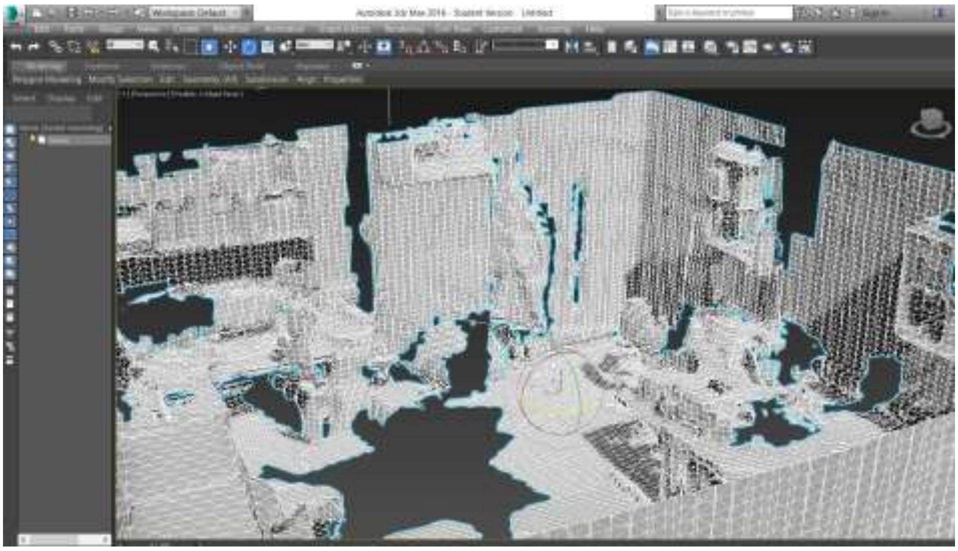


Figure 22: 3D Scanning office using Structure SDK Sensor

Indoor scanning of an office space was carried out. We have captured extensive data to evaluate the quality of data that can be captured at a scale of 5 x 6 metres. The scanning happens as the user moves around the room slowly and continuously in motion until all data in the room is captured including floor and ceiling. Windows and transparent surfaces were not captured although frames surrounding did record structure. Space Area mode was used and results captured are unclear and unusable. Using a tape measure we compared measurements of the office cabinet were the variance of data results measured around 1cm. Overall room sizes we found that there was more than 5cm variance between wall to wall dimensions of measurements. Outcome of Strucutre Sensor the data captured is variable, sometimes unclear and rough with small and large objects, therefore these tolerances are not acceptable for Product design or Engineering.

3D scanning Outdoor Vehicles and Boats

For effective data capture and association of the relevant data to Canvasman manufacture. Outdoor scanning experiments were carried out on a car, a minivan and a barge.

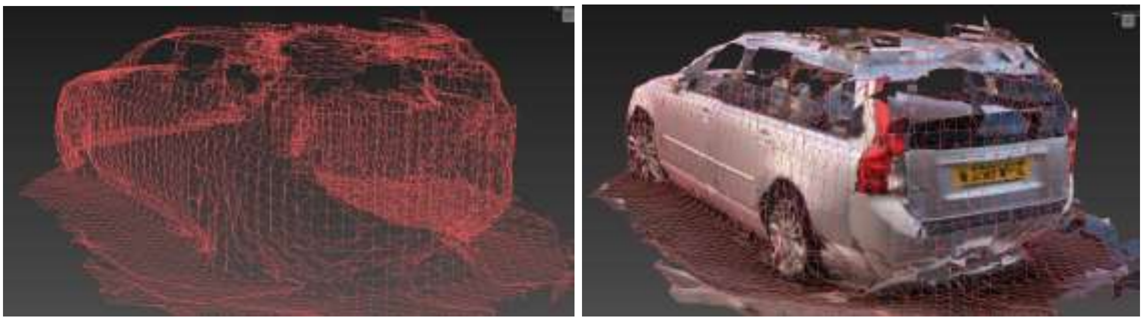


Figure 23: 3D Scanning of car with the Structure SDK Sensor

Scanning the car and the mini van in process with the iPad tablet was easy, although resulted in unclear and limited data capture as shown in image in Figure 23 and 24. Space Area mode was used and results captured are unclear and unusable.

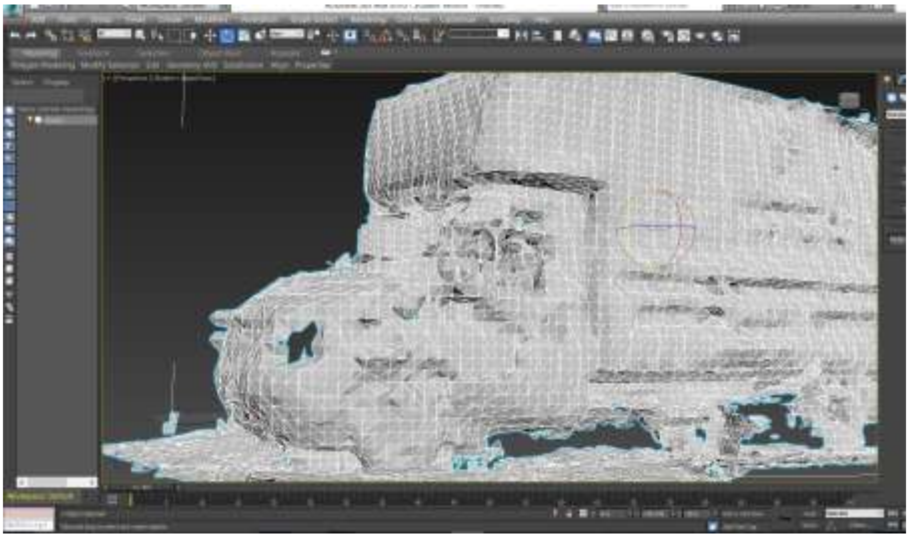


Figure 24: 3D Scanning of a mini van with the Structure SDK Sensor

Outdoor scanning of a barge from the canal in Huddersfield Aspley Marina was setup, unfortunately only part access to the private boat and the we were unable to walk around the boat resulted in limited data capture as shown in image in Figure 25. Data capture was limited as scanning was directed from port side only. Space Area mode was used and results captured are unclear and unusable.

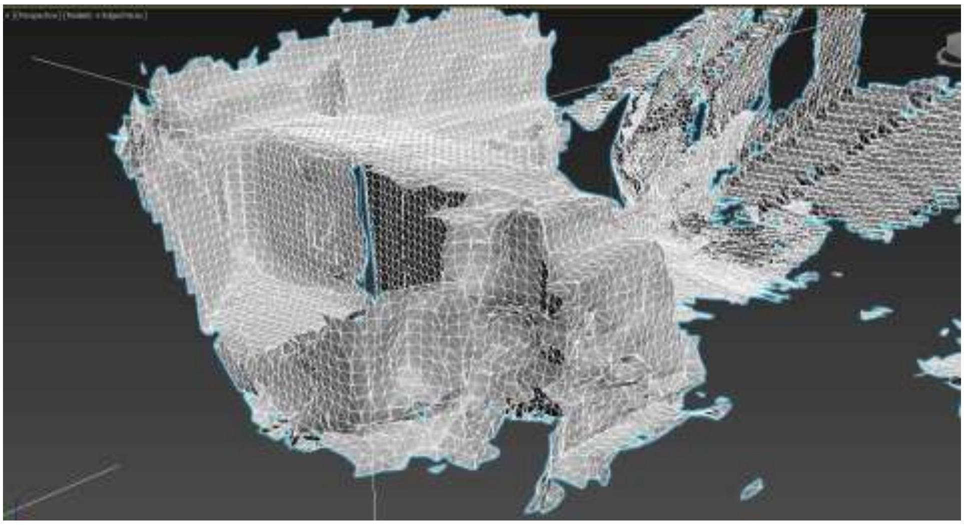


Figure 25: 3D scanning barge using Structure SDK Sensor

7. CVF FINAL CANVASMAN VISIT & VISITING FARO PRODUCT DEMO

The ADA 3D Design team and 3M BIC team visited the Canvasman company, on Wednesday 20th January 2016. The visit was arranged to finalise the CVF project and to present the final draft CVF report. A product demo was also arranged with a representative from FARO to present live scanning of an outdoor site using the Focus 3D and to test 3D capture data.

Figure 26: Faro's range of scanning products & applications.

Faro Focus 3D

Faro provide a range of scanning products & applications for fast and accurate indoor and outdoor measurements in three dimensions. The smallest and lightest laser scanner they provide is Focus3D X30. The Focus3D offers everything needed from a professional 3D laser scanner. With a scanning range of up to 30 meters, the Focus^{3D} X 30 is ideal for a variety of short-range scanning applications such as architectural preservation, as-built documentation, building information modelling (BIM), engineering, facility management and forensics. Focus3D is also offered as 130m and 330m range with integrated GPS and Class 1 "eye-safe" laser. The FARO Focus3D is specially designed for outdoor applications due its small size, light weight, extra long range, extended scanning possibilities even in direct sunlight and easy positioning with the integrated GPS receiver. The Focus^{3D} X 30 enables fast, straightforward and accurate measurements of interiors, such as small architectural façades, complex structures, crime scenes, mechanical rooms, and production and supply facilities.

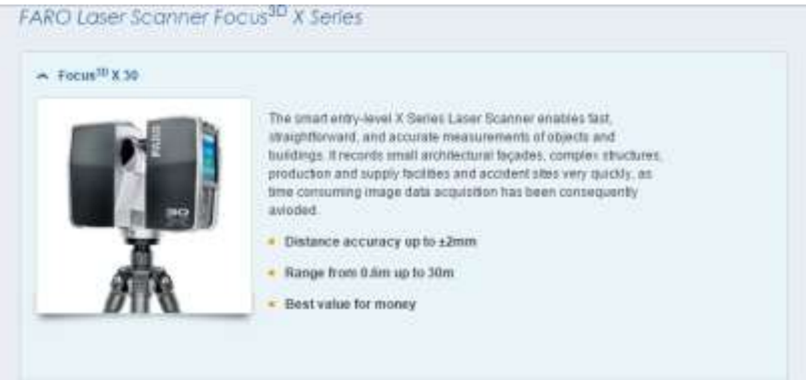


Figure 27: Faro’s X 30 3D

Features of the Focus^{3D} X30:

- **Portable or fixed :** Portable (with Tripod and fixed location)
- **Cost (expensive)** around £20k
- **Scanning speed :** Fast
- **Weight: Under** 5 kg
- **Manual or auto stitching :** Semi-Automatic
- **Resolution, tolerances, points accuracy, 3D accuracy over distance:** very heigh
- **scan area length and working distance :** 0.6 – 30m
- **Target and markers usage and distances :** none
- **Software, functionality, ease of use and support:** Add on to be purchased
- **lighting environmental conditions:** Can be used indoor & Outdoor (not sensitive to light)
- **Ability to scan various colours, surface patterns, *material types, shiny, glass, black:*** *YES, only 130 and 330 provides texture information*
- **Ability to capture texture and Colour information:** No
- **Ability to see the screen while scanning with the device (Lap top or Tablet integration) :** N/A only after the full scan, the 3D data can be seen on the screen.
- **How to power the unit?** Battery, No external power needed

During the visit the team viewed and discussed a metal tubing frame and canvas fixing and fastenings and the tolerances for scanning shown below in Figure 28.

Figure 28: Demonstration of boat frame and fixings

The team setup the Faro 3D X30 scanner in the carpark outside. The conditions were in bright sunshine, Chris Salisbury Canvasman Director requested that his car be used to test the scanner. The scanner captured his car and also the surrounding buildings, other cars, people, the trees, and birds in the trees.

Figure 29: Setup of Faro scanning X30

The Faro X30 is setup on tripod and the red laser is projected by rotating mirror in the scanner as it rotates to cover 360 degrees. The scanner was positioned in three key point locations to register the selections. The first scan was the full area scan, at low resolution and the speed of capture was less than 2 minutes, for testing quality and calibration. The next three scans captured the car at higher resolution; these scans were timed at around 8 minutes each. These settings can adjusted; higher quality can be collected although time of scanning is increased.

Figure 30: Faro scanning setup

Figure 31: Faro’s X30 scanning car

Figure 32: Faro X30 point cloud 3D data.

8. Conclusion

Canvasman required 3D scanning solutions to improve on current manual data capture technology. Following an agreed brief the 3D ADA research team have produced the report which outlines findings on Artec, Creaform, Faro, and the Structure Sensor. The CVF project has provided research, evaluation and analysis into recommending a suitable 3D scanner for Canvasman to improve efficiency of data capturing for interior and exterior spaces, boats, vehicles and other similar constructions for creating and installing flexible coverings and indoor and outdoor structures. We have concluded that mobile 3D scanners can be used by Canvasman. There two main options:

- Low cost portable hand held scanners (from £200 to £10k) such as the Faro Freestyle or Artec Eva.

- Professional surveying equipment such as the high resolution 360 degree automated processing scanner such as FARO Focus 30 Laser Scanner currently priced around £20k, or Leica (see Jacobs, G. 2016) survey equipment or similar.

Both these type of scanners can be used effectively, but, the resolutions and tolerances required by the Canvasman company will be achieved by investing in a higher resolution survey scanners as outlined in this report.

The research data and recommendations in this report are published to suit the direct requirements of Canvasman design and manufacturing process and workflow. The selections, developmental testing and methodologies we have used in the research were undertaken in collaboration with Canvasman Directors. The resolutions may vary with different user experiences, environmental conditions, and scanner settings.

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