Taking Off The Boat's Lines

Part 2: Having discussed simple ways amateurs can reproduce the shapes of boats, Andrew Wolstenholme considers today's professional methods. He's seen the future. And it works.

In W145, I described my manual method for taking off hull lines and how the measurements acquired can be used to create a lines plan drawing. Now, I would like to consider today's high tech methods of laser scanning and photogrammetry. For this I am indebted to Stuart Norton for his help with photogrammetry techniques, and to Geospatial Survey Systems Ltd and Deri Jones & Associates Ltd for their assistance on laser scanning.

Photogrammetry...

... has been around in various forms since soon after the birth of photography and involves the creation of 3D data from 2D photographic images. Stereophotogrammetry was the first use of the method, using just two images with the viewpoints in slightly different positions. The stereoscopic images taken by wartime reconnaissance aircraft are a good example of how this method allowed the intelligence services to estimate the size of structures and installations on enemy territory. By using more images from varied angles an increased amount of 3D detail can be produced and this is the method that is of interest to us.

In the last 20 years, improvements in digital photography and the increase in cheap computing power has allowed photogrammetry to become a viable and cost effective method of capturing 3D data. Photogrammetry software relies on being able to identify the same feature in multiple images and to work out the camera positions from which the images were captured. Once the camera positions are known the 3D depth of the object being captured can be determined. There is no need for the camera to be set up at a known position – this is all worked out from the recorded images. The result is a 'cloud'; a galaxy of data points, It's all seriously clever stuff.

There are many photogrammetry software packages available but the stages of the process are similar to all:

- Image capture
- Sparse cloud generation – calculating camera positions by detecting features.
- Dense cloud generation – calculating object depth detail using known camera positions
- Surface meshing – making a surface mesh from the point cloud
- Mesh texturing – blending and applying the photo to the mesh.

In order to capture a hull, it is necessary to photograph it from all directions and heights and the greater the variance in angles the better. A set of 300-500 photos normally works well and having the camera on a pole with a remote shutter can be a great help. Shiny surfaces can be problematic so clean hulls may need marking up prior to photographing; an old hull with plenty of surface defects works better but clearly growth – like barnacles

Previous page: *Stuart Norton used photogrammetry to create this rendering of the 65' (20m) iron-hulled steam launch* Esperance
Above*: Also rendered for conservators at Windermere Jetty, the 72' (21.7m) steam workboat* Raven *was built for the Furness Railway in 1871 to carry goods to lakeside farms and villages and serve as an ice breaker for the railway's passenger steamers in winter.*
Below: *Stuart combined photogrammetry and laser scanning techniques to create this accurate rendering of the canal narrowboat* Ian.

– needs removing. To be able to set a scale to the resulting 3D model, images should include a tape measure or known measurement points. Any unwanted objects which may occlude the hull should be removed, as should anything that may move during the capture, such as an unlashed rudder.

Stuart has done most of his work, using a mid-range Nikon D3200 with a standard 18-55mm zoom lens but uses it in its wide angle setting which helps in getting overlaps. The f-stop is set at f8 or higher to ensure good depth of field, and the ISO setting kept low to reduce noise. Images need to be sharply focussed and checked and taken again if necessary. A well diffused flash is helpful on internals or badly lit areas. As with all processes there is an art to getting this right and it is common for the algorithm to fail to align the images, often due to insufficient overlap or not enough photos. So it pays to take more photos than you think are needed and from as many awkward angles as your knees and back can handle.

Agisoft Metashape Standard Edition is the software that Stuart uses. Once it has successfully aligned the camera positions, it can then generate a Dense Cloud – which can be millions of points – then mesh the point cloud to give a surface, and then texture the mesh from the original photo set. It demands considerable computer power and memory, so he will often leave his computer processing overnight but if that process all goes well that is the project completed.

The resulting 3D mesh model can now be analysed and a faired surface model developed around it as required. For many purposes the photogrammetric images may provide all that is needed but if a set of faired hull lines are required then more work is needed. Stuart uses Rhino to slice the mesh and create station, buttock, and waterline contours which can then form the basis for constructing a fully faired surface model. At this stage, he in the same position as with manually measured data points – see W145 – where some interpretation will be required to fair the hull, taking out

Above & Below: *Photogrammetry renderngs from bow and stern views used to accurately re-create the lines of the nobby* Aileen.

deformities in the hull's shape which may have crept in since she was built.

Photogrammetry serves well for recording heritage vessels undergoing restoration as it captures so much visual detail. I was amazed by Stuart's renderings of *Raven* and *Esperance* from the Windermere Jetty collection, and the Lancashire nobby *Aileen* at Maryport in Cumbria.

It is a remarkable process which is now being widely used for recording heritage projects in all fields and for documenting historical monuments and artefacts. After the dreadful fire at Notre Dame cathedral in Paris, I understand that the French authorities are now recording all their major historic buildings should there be similar disasters.

Laser scanning...

... is a more recent development, having started in the 1960s in land surveying with the introduction of total station laser theodolites capable of accurately measuring both angles and distance to a point. By the mid 1990s the process was partially automated with machines capturing hundreds, then thousands of points, and today's machines can record

around two million points per second. Equipment costs have reduced over the years but it still represents a serious investment and is in the realm of the specialists. The scanner that Geospatial used in 2006 cost £60,000, weighed 55lbs (25kg) and needed mains power; their current, compact battery-powered model still cost £25,000.

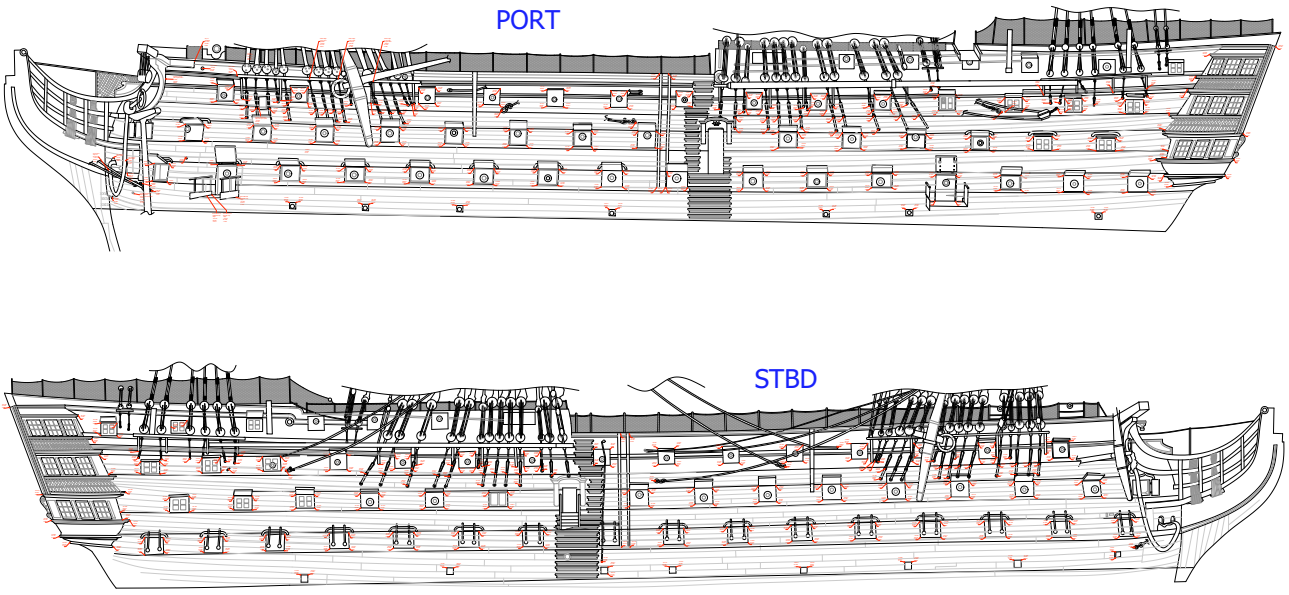
As with photogrammetry, there is no need to record the position of the scanner and the resulting scans are fitted together by matching common areas. However, it is usual to use spherical or chequerboard targets around the object being scanned to provide defined reference points. For craft up to 65' (20m), it is usually acceptable to use the targets only for stitching the scans together, but on larger vessels or where great accuracy is required, a separate total station instrument is used to accurately locate the targets to a common frame of reference.

Geospatial and Deri Jones would expect an accuracy of +/-4mm ($^3/_{16}$") on a small ship. Such accuracy is required if the laser survey is being used as the basis for modifications to the ship such as a 'cut and shut' stretch or other major structural change. For a typical 33' (10m) vessel, anywhere between 8 and 20 scans could be required, depending on how much of the hull is obscured by scaffolding or cradles and how far the scanner can be placed from the hull. For more complex projects, such as a ship's engine room, they can easily record over 200 scans. Each scan, at a range of 16' (5m), typically contains some 120 million points just over $^1/_8$" (3-4mm) apart.

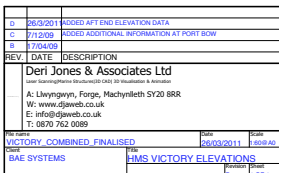
The requirements for preparation of the hull surface are the same as for photogrammetry with polished surfaces being problematic. It's necessary to remove as much clutter from around the boat as possible by minimising the number of hull supports and access staging to ensure a clear 6' (2m) around the boat. The time taken for a scan will depend on the size of the vessel but they can manage three or four small hulls in a day if they are set up near each other.

When the scanning has been completed, a considerable amount of computer work is required to align, clean and then model the hull to a stage where it is ready for further naval architecture use or CAD work. There are a variety of methods for aligning the point clouds:

- Cloud to cloud: This uses common features between each cloud to align them, shuffling the data until any errors in alignment are minimised. This is typically fast and can be semi-automated using modern software. However, incremental errors in alignment can creep in and result in inaccuracies significant enough to cause problems if the resulting point cloud is to be used for fabrication.
- Target based alignment: Using spherical targets of a known diameter or chequerboard targets, the point clouds can be aligned manually, ideally back to one scan that contains all targets. This is a reasonably robust and quick method for smaller vessels where good lines of sight are available, producing a clean point cloud at reasonable accuracy.
- Alignment to reference target sets: For projects where a high degree



Facing page & above: *In 2009, Deri Jones & Associates recorded the hull of Nelson's flagship* HMS Victory *above the waterline to provide the restoration team with accurate 3D locations for gun ports, rigging points and other fittings to ensure they were refitted correctly. The laser scanning was carried out over two nights to avoid disruption to this popular tourist site.*



of confidence in the dimensional accuracy of the resulting point cloud is essential, for example modelling a hull prior to splitting for lengthening, where the new section is pre-fabricated and has to be accurate to +/-4mm ($^3/_{16}$"). Here the locations of the reference targets are recorded using a separate total station at a higher degree of accuracy than the scanner can command. All the scans are located to this reference framework, minimising any risk of incremental error and confirming the critical dimensions from two independent sources.

Once the various scans are aligned, any extraneous points can be deleted and blocks/cradles/people/rigging digitally removed, so only the vessel remains. The resulting cloud can be aligned to whatever origin and reference axis is required – levelling to the waterline or a known vertical if the vessel is sitting out of square. The finalised point cloud is then used to model up a working CAD surface model using Rhino 3D.

Laser scanning arguably provides the most accurate method of recording a vessel available. With careful targeting and processing, practical accuracy of 4-5mm ($^3/_{16}$") across the whole vessel is achievable with results verifiable against measurements taken with a theodolite/total station. Items such as hull fittings, rigging points, bolts... can be accurately located in 'boat space'. For modelling, sections can be taken at any point in any plane to check against the CAD model. Subtle differences in port and starboard hull shapes can be compared by mirroring the point cloud and identifying differences in 3D curvature.

Some of the latter benefits also apply to photogrammetry but laser scanning is regarded as the more rigorous of the two methods. Both techniques have their advantages and it is a matter of deciding which is the most suitable for a particular application. Photogrammetry provides a photorealistic scan of the object and provides ample accuracy for many uses but arguably will not provide the level of accuracy needed for ongoing large scale structural design and fabrication work. Laser scanning can also be used to provide photorealistic images but this isn't as easily achieved as with photogrammetry and is more time consuming.

Both methods are fascinating examples of how modern technology is being used in boat and ship building, but are likely to be beyond the means of the average amateur. However, it's not so long ago that it seemed CAD techniques and precision CNC cutting of kits of hull parts had no relevance to home builders. Look what's happened since then.

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