

Visualizing high resolution multibeam shipwreck data

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ADUS

(A joint initiative between the Universities of St Andrews & Dundee, Scotland, UK)

Following involvement in 2001 with the ScapaMap multibeam sonar survey of the wrecks in Scapa Flow <http://ccom.unh.edu/index.php?p=111%7C180&page=scapa.php>, the Archaeological Diving Unit (ADU) at the University of St Andrews undertook a series of independent multibeam surveys of wrecks in United Kingdom waters during successive field seasons. Although the overall standard of these surveys was good, the quality of the data was variable and many factors (human, engineering, operational and environmental) were later identified as influencing the quality of collected data. Similar factors were noted by ADU when using side scan sonar during a series of empirical experiments undertaken jointly in 2001 with the Centre for Maritime Archaeology, University of Ulster

<http://www.science.ulster.ac.uk/cma/quinn%20et%20al%202005%20control%20experiment.pdf>.

The original ScapaMap project revealed to ADU the potential of high-resolution metrical multibeam data as a key tool for marine archaeological investigations. The ability to collect the data necessary to produce basic measured site plans more quickly and more accurately than traditional tape surveys by divers, was an obvious advantage. Equally important was the ability to generate images from the data that both aided specialist interpretation and lay understanding, helping to make our underwater heritage more accessible to a wider audience.

Between 2003 and 2005, the ADU focused on the application of multibeam sonar to the investigation of wrecks and other submerged archaeological sites and ADU Survey (ADUS) was founded. In partnership with the School of Geography and Geosciences at the University of St Andrews, and as part of a project funded by the Marine Aggregates Levy Sustainability Fund, during 2005 and 2006 ADUS undertook an analysis of factors that influenced the value of multibeam data. This involved empirical research on an artificial test site set out on the seabed in Plymouth Sound on the south coast of England, <http://www.st-andrews.ac.uk/rasse/> as well as a series of surveys of wrecks in different depths of water (Figure 1).

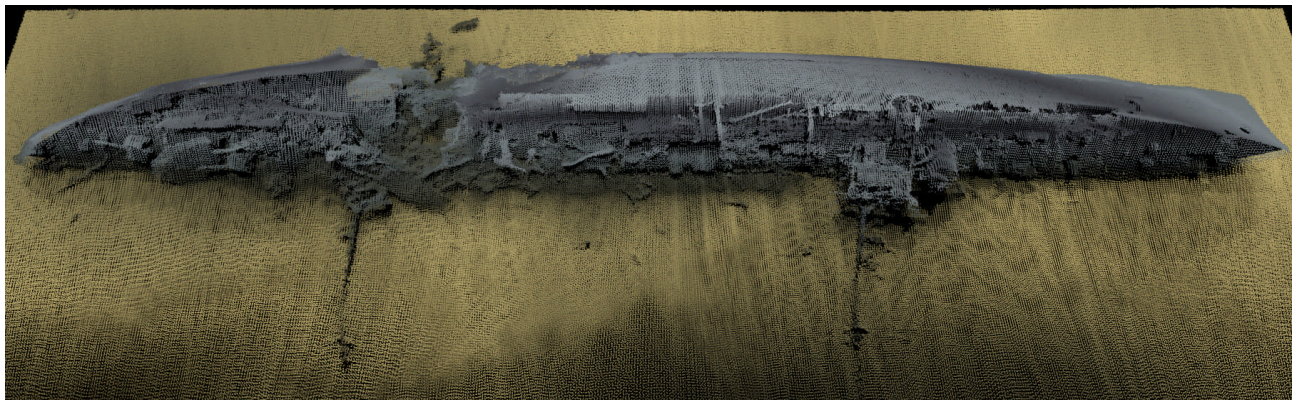


Figure 1 – Image from 2006 ADUS survey of the wreck of SMS Köln in Scapa Flow, Scotland, UK.

Many factors were identified that influence data quality but some were not easy to quantify, such as the skill of the helmsman or the surveyor, and their enthusiasm for the work in hand. Many factors were common to both multibeam and side scan surveys, including the evidence that you seem to get what you pay for regarding equipment quality. With multibeam, this applied not just to the sonar system, but also to the ancillary equipment such as the positioning and the inertial navigation systems. *Low 'n' slow* proved to be a useful maxim with both side scan and multibeam sonar; the closer the sonar head and the slower it passed the target area, the better the data density and resolution.

Experience with a variety of multibeam systems led ADUS to identify the Reson SeaBat 8125 as the instrument of choice for high-definition surveys of wrecks. Even with good equipment, the 2005 research identified the need for more advantageous methods of deploying the sonar head, which led to the in-house development of the Independent Sonar Head Attitude and Positioning System (ISHAPS). This is a device with sonar head, inertial navigation system and Real Time Kinematic (RTK) antennas combined in one structure. The overall length can be adjusted by inserting or removing fixed-length, machined modules (Figure 2), a useful feature when changing between vessels of opportunity with different drafts. It also reduces mobilisation time dramatically because the offset lever arms (X & Y) between the various components remain constant and need only be measured once, with compensation only being required for changes in the Z value. With the ISHAPS, the sonar head can be set at the optimum depth for a specific survey and can then either be towed, albeit at very slow speed, or attached to a survey vessel (Figure 2). With an extension of up to 10m, high quality results can be achieved on wrecks in less than 30m of water, and good results achieved in depths up to 50m.

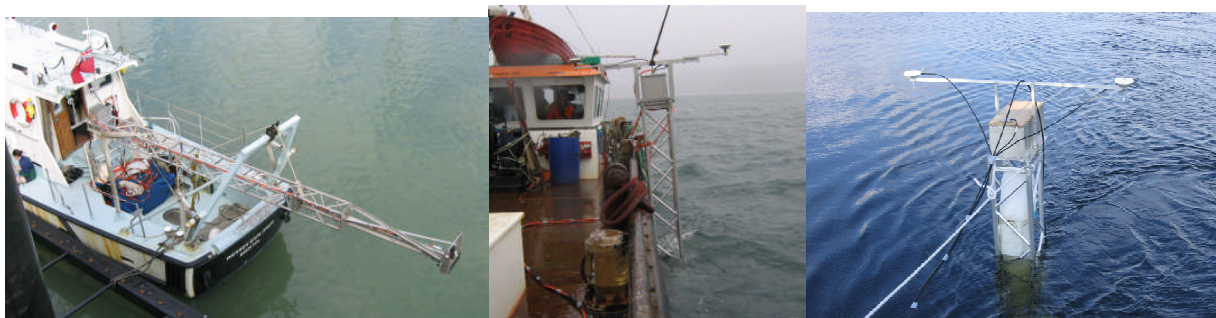


Figure 2 - ISHAPS in air; attached to the side of a survey boat; and being towed.

ISHAPS was developed to help improve the data quality in relatively shallow water by reducing range to allow a faster 'ping' rate and to reduce the size of each beam's footprint; these two issues being linked to data density and resolution. A complimentary factor identified as being of vital importance is the way data are visualized and, in 2005, the ADUS team expanded to include digital imaging expertise from the nearby University of Dundee. It is possible to make multibeam data of shipwrecks even more comprehensible, particularly to the average person who has no detailed knowledge of ship construction, using techniques developed in the computer games and animation industries.

Software used by marine surveyors to visualize multibeam data conventionally involves the rendering of surfaces. This is understandable as it provides excellent representations of the seabed, but it does not supply the same level of information about wrecks as do point clouds. Rendered surfaces have the disadvantage of gaps in the data that represent actual holes in a

structure can sometimes be filled in automatically, and overhang elements on a wreck are transformed into solid features that do not exist (Figure 3). Multibeam data is safer to analyse forensically if nothing has been added or subtracted.

One of the key advantages of point cloud data is that it has to be interpreted by the viewer and not the software. Although the human brain has to work harder when viewing point clouds, shapes and features of a wreck become more apparent, particularly when the images are 3-dimensional and move; an advantage that animation brings to the study of multibeam wreck survey data.

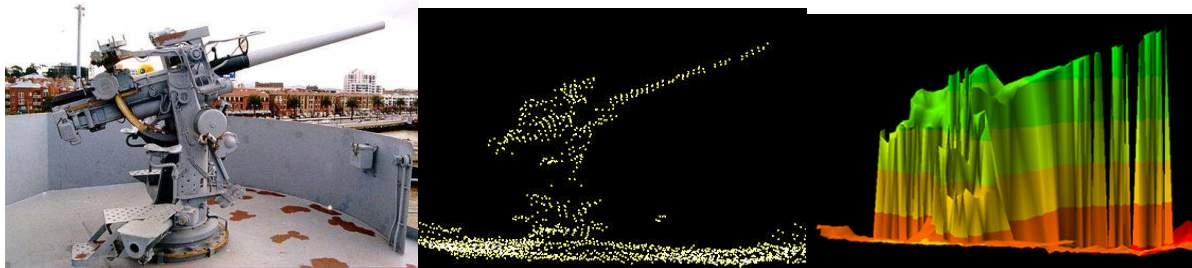


Figure 3 - The 3" gun on the Liberty ship SS Jeremiah O'Brien in San Francisco harbor, compared with point cloud and rendered surface visualizations from survey data of an identical gun type on the wreck of the Liberty ship SS Richard Montgomery.

Most hydrographic survey programs, sensibly, have vertical color ramping so that shoal waters are easily differentiated from the deeper bathymetry, but this can cause problems when used on wrecks that are not sat upright on a level seabed. It is often beneficial to customize each wreck data set so that the color ramping is oriented to the main axis of a wreck, or even part of a wreck, so that features that might otherwise be overlooked are emphasized. The avoidance of bands of colours on sloping surfaces make data easier to relate to, as do subtle colors on images of shipwrecks that reflect the close-to-monochrome view familiar to those who dive on them (Figure 1 & 4).

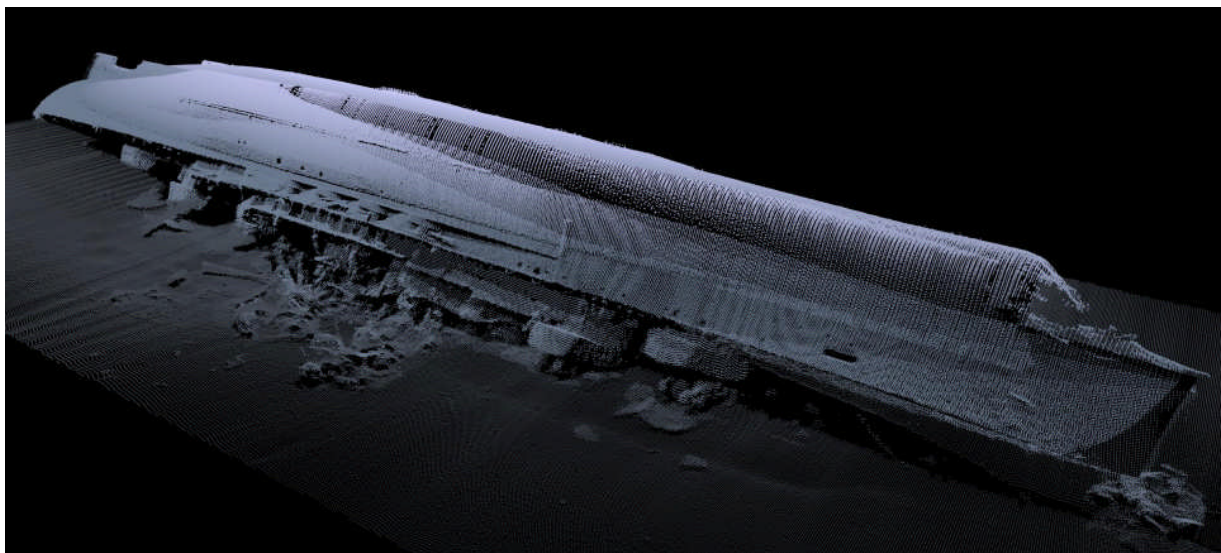


Figure 4 – ADUS survey of HMS Royal Oak for MOD SALMO (Crown Copyright). The point cloud image incorporates occlusion masking to make the hull appear solid, together with angled color ramping using subtle tones.

ADUS uses many other optical clues to help with perspective in animated and still point-cloud data. Visual depth cueing techniques are used to clarify the orientation of wreck structures, such as the use of wide-angle lenses in a virtual 3D camera to reveal the scale of the wreck. Other digital cinematography techniques include composition, depth of field (which can be simulated by light decay over distance), shadows and controlled camera movement. For instance, when point cloud images are rotated in animations, the relative speed of movement between foreground and background points can be adjusted to provide the optimum viewpoint distance for a realistic human perspective.

A key factor in making wreck images easier to interpret is the use of occlusion masks within solid objects, such as ship's hulls, as this helps improve the depth perception for the viewer. Dense point cloud data normally consists of points of equal size, irrespective of their distance from the camera. Those on the other side of a hull can appear in the gaps between points closer to the camera, inviting potential confusion for the viewer, but occlusion masks can overcome this problem (Figure 4).

ADUS is continuing to explore ways of improving the definition of data obtainable from readily available, off-the-shelf, multibeam systems, as well as improving data visualisation. Current research includes a partnership with the UK's Ministry of Defence Salvage and Marine Operations (MOD SALMO) team using ROVs to undertake high-resolution surveys of wrecks in deeper water. This has led to a number of major projects, including joint collaboration with the Russian Federation in a forthcoming survey of the sunken Russian nuclear submarine K 159 at a depth of 280m in the Barents Sea, off Murmansk.

The methodologies for collecting high-resolution data that have developed over last few years are obviously not ideal for all types of hydrographic surveying. Some of the techniques are very labour intensive and the dense data may provide irrelevant detail for many purposes. The volume of data can also be problematic to handle when surveying large areas. Very high-resolution multibeam sonar surveys may only be of interest to a limited number of specialist groups concerned with objects lying on the seabed, but the combination of advances in sonar technology and developments in survey methodology, makes this an exciting time for those in this field. Particularly now that such progress can be further enhanced by visualization techniques developed in other industries.

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See also <http://www.wrecksight.com> for a free download of ADUS' *WreckSight* animation software incorporating survey data of the SMS *Brummer* in Scap Flow. This was visualized using the techniques outlined above