AESTHETIC 3D RENDERING OF HISTORIC SHIPWRECKS (AN ARTIST'S INTERVENTION IN MARITIME ARCHAEOLOGY)

Chris Rowland

Evidence of our maritime heritage can be found in the thousands of historic shipwrecks that lie beneath the oceans around our coastline. Developments in sonar technology have provided opportunities for high-resolution data to be gathered which can be used to produce accurate 3D images of these important shipwreck sites. This paper describes how an aesthetic approach to visualising data can make our submerged maritime heritage more accessible.

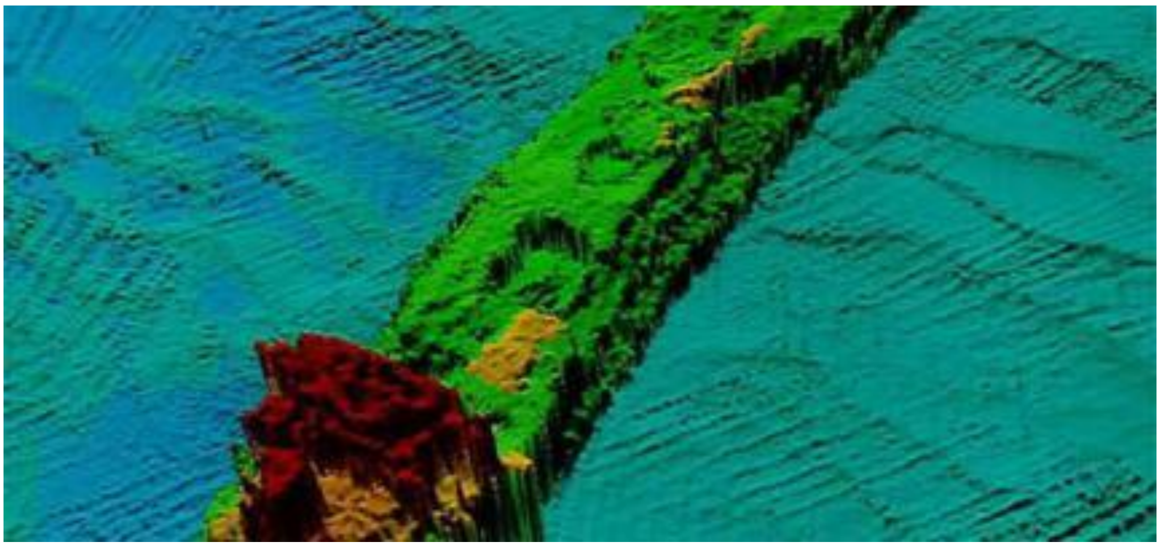

Fig 1. Sonar image of MV California. Copyright C Rowland/ADUS.

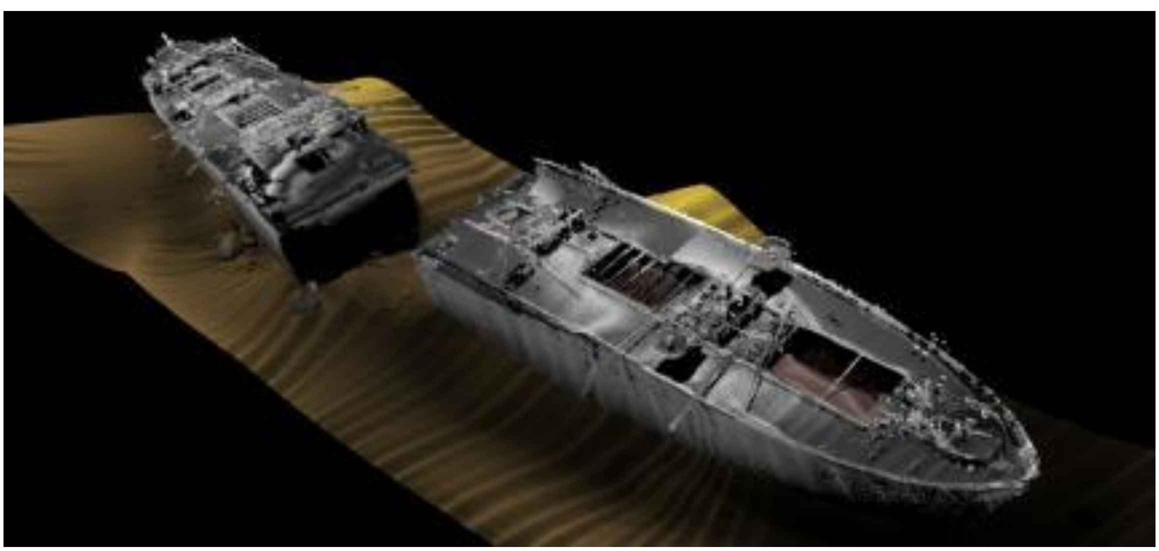

Fig 2. 3D Visualisation of the wreck of SS Richard Montgomery using occlusion objects and locoramps. Copyright C Rowland/ADUS.

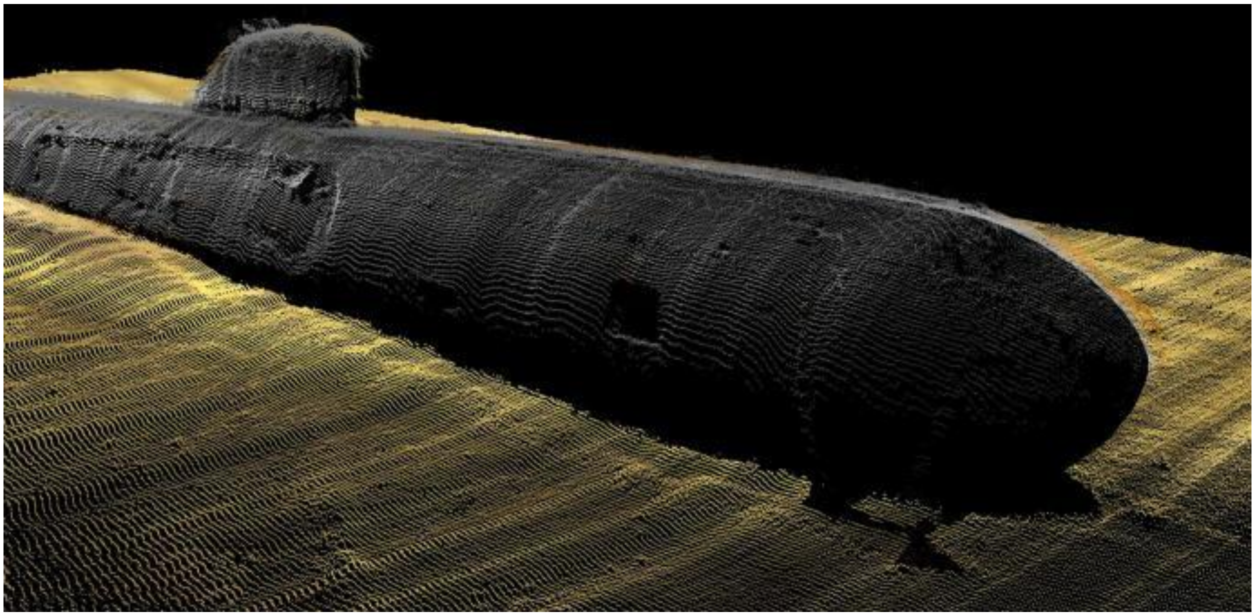

Fig 3. B159 at 250m in the Barents Sea. Copyright C Rowland/ADUS.

Background

There are 62 maritime heritage sites around the UK coast that are designated as historically and environmentally significant under the Protection of Wrecks Act (1973). English Heritage, Cadw and Historic Scotland manage the wrecks on behalf of Her Majesty's Government. The wrecks range from the remains the *Stirling Castle*, a flagship of Samuel Pepys' navy, [1] which sank in 1703 on Goodwin Sands in Kent, to the remains of the WWI German High Seas Fleet scuttled at Scapa Flow, Orkney in 1919. [2]

Designated sites are identified as being likely to contain the remains of a vessel, or its contents, which are of historical, artistic or archaeological importance. Due to the fact that all of these sites are submerged, they are effectively invisible to the general public and the majority of specialist researchers (hydrographers, historians, artists etc). Interest in shipwreck sites is not limited to their cultural or historic significance. Environmental factors are also important.

Marine salvage is carried out when a shipwreck may be a danger to shipping or the environment. When hazardous cargo (e.g. munitions or oil) create an environmental threat, salvage teams are engaged to assess the risk then carry out procedures to minimize the impact. The UK Ministry of Defence is responsible for approximately 20,000 known military wrecks around the world, many of which present such a threat to the environment. [3]

Visualising the Problem

To manage the environmental threat, there is a requirement to monitor the condition of the wrecks as they deteriorate. Surveys of the wrecks are regularly undertaken. Traditionally, maritime archaeologists have used photography, video and drawings to record the condition of important wrecks. However this is time consuming, hazardous (due to the risks inherent in repetitive diving) and limited to shallow sites where visibility is good.

When visibility is bad or the sites too deep for diving operations, the method of choice has become multibeam sonar. This method uses sound to produce high definition 3D images of objects on the seabed much more quickly and accurately than traditional analogue methods. [4] However, multibeam sonar does not collect colour information from the targeted shipwreck, therefore colour has to be added later in order to visualise the data. The resulting dataset takes the form of a point cloud, i.e. millions of xyz co-ordinates representing the shape of the wreck as the beams of sound reflect from its surface back to the sonar device.

Industry Standard Visualisation Methods

The standard methods of visualizing such point clouds include converting them into simplified polygon surfaces. This has the advantage of preventing the viewer from seeing through the gaps between the points. The main problem with this method is the draped polygon surface also hides detail that was otherwise visible in the original data. This method is fine when visualizing large areas of seabed e.g. prior to laying sub-sea pipelines. However, when surveying environmentally hazardous shipwrecks, important information is often visible in the fine detail. For example, a polygon mesh will hide cracks in the ship's hull or holes in the deck structure, which may indicate how the wreck is deteriorating.

The Ubiquitous Rainbow Ramp

The lack of colour in the point cloud data is most often resolved by the application of a colour ramp that ranges from dark blue to red. In maritime archaeology and sub-sea salvage the colour is used to indicate depth, i.e. blue is applied to the deepest part of the wreck and red to the shallowest. Figure1. However there is no accepted standard use of colour, it can vary considerably from wreck to wreck. The use of "rainbow" colour ramps is not contained to this type of survey data. Aesthetic considerations in the presentation of scientific data are mainly found in the field of visual analytics where large abstract datasets need to be presented in visual form to promote visual interpretation and pattern detection. As Eduard Tufte describes in The Visual Display of Quantative Information: [5]

"Colour often generates graphical puzzles. Despite our experiences with the spectrum in science textbooks and rainbows, the mind's eye does not readily give a visual ordering to colours, except possibly for red to reflect higher values than other colours."

Theory of Data Graphics, p. 154.

Tufte goes on to describe a method for colouring data as used by L. L. Vauthier, [6] called the mountain-to-the-sea method. White is used to represent greater intensity since it was the colour of snow on a mountain, next came green, representing forests farther down the slopes, yellow for the grain in the fields then minimum values were coloured blue, the colour of the sea.

Examples of the ubiquitous rainbow ramp approach repeatedly appear in the visualisation of a wide range of scientific data. A simple web image search will bring page after page of rainbow coloured scientific images whether it's geospatial visualisation from geological survey data, Golevka asteroid explosion simulations, telemetry from the McClaren Formula one racing team or isosurface normals from the Visual Human Project (to name but a few).

We are presented with these coloured scientific images repeatedly to the point where we don't really question them. Maybe the rainbow colours convince us that they are scientifically generated and therefore are likely to be true? We simply accept their validity. Unfortunately, this method of colouring data has limited benefit when visualising hazardous shipwrecks on the seabed.

An Aesthetic Approach

Working in collaboration with maritime archaeologists Martin Dean and Mark Lawrence at the University of St Andrews, it became clear to the author that the aesthetics of presenting shipwreck data followed a standard approach that did little to reveal the details necessary to understand the condition of the wrecks. Dean and Lawrence had carried out extensive research trials in gathering ultra-high resolution multibeam data from important shipwrecks around the UK. [7] In doing so the team realised that the standard methods where not sufficient and a novel visualisation approach was needed to display the level of detail that could now be gathered from shipwrecks.

The first step in attaining this was to stick with the original point cloud data and reject any form of converting the data into polygon surfaces. If data was incomplete, then it should be portrayed as such and not disguised by any meshing technique. Therefore a new method was required to prevent the viewer from seeing through the gaps between the points. An alternative to the use of rainbow colour ramps, which applied arbitrary colours to data defined by depth, could also be investigated. Finally, the use of digital cinematography offered opportunities to explore how visual depth cues could be enhanced by moving virtual cameras around the shipwreck visualisation.

Occlusion objects were developed as an alternative method to the use of polygon draping and locally oriented colour ramps (Locoramps) were created to replace the use of rainbow colour ramps. Both of these methods are described in detail in prior publications, [8] so will simply be summarized here: Occlusion objects are a solution to the gaps between points problem. They consist of 3D polygon shapes modelled to follow the topology of the wreck data. The occlusion object acts as a mask to prevent the viewer from seeing points on the opposite side of the wreck dataset by its placement in the interior of the point cloud shape.

Locoramps are used to highlight fine detail in the data by the placement of locally considered colour (or greyscale) ramps which are aligned to specific details on the wreck. Structural details are often difficult to see with the use of brightly coloured rainbow ramps often used in data visualisation; locoramps offer an alternative method for adding local colour that can be oriented in different directions.

When both of these methods are used in conjunction, the resulting 3D visualisation reveals the high detail level of the original data by applying aesthetically considered and sensitively positioned colour that emphasizes important details of the wreck's structure.

Case Study Examples

The most effective way to demonstrate the novel visualisation methods is to describe how they how have been deployed in real world situations. Figure 3 shows both methods employed in the 3D visualisation of the wreck of the *SS Richard Montgomery*, which lies in the Thames estuary. The wreck still contains 1.4 megatons of unexploded munitions approximately 400 metres from the main shipping lane and is considered to be a significant hazard to the local environment. As one of the UK designated shipwrecks mentioned earlier, the wreck is the responsibility of the UK Government and is regularly surveyed to monitor its deteriorating condition.

The tidal water around the wreck is very low visibility due to silt deposits therefore multibeam surveys and 3D visualisation are the only reliable and accurate methods of managing the site. The 3D visualisation that we produced clearly showed the damage to the wreck caused by long term submersion. Cracks along the decks and the sides of the hull were able to be measured due to the centimetric accuracy of the data. By using locoramps, it was possible to reveal high levels of detail on the decks and differentiate between seabed and debris. The wreck's proximity to the local power station, oil and gas terminal and residential housing suggest that careful monitoring of its deterioration in the long term is of significant interest.

Following the *SS Richard Montgomery* project, NATO commissioned the team to survey and visualisation of a sunken nuclear submarine in the Barents Sea near Murmansk. The *B159* was a November Class Russian submarine that foundered and sank when under tow for decommissioning in the Arctic Circle. Of the ten crewmen on board, only one survived the sinking and two bodies were recovered. The remaining seven bodies are thought to be still on board the wreck alongside 800 kilograms of spent nuclear fuel with a radioactivity level of 750 curies per kilo [9] at 250 metres below sea level. The survey successfully gathered multibeam sonar data from the submarine wreck. The resulting 3D visualisation showed the submarine sitting upright on the seabed with a six metre section of its stern missing. Figure 3.

The final 3D visualisation shows the wreck on a pitted seabed with two of the floatation pontoons nearby. Damage to the hull of the vessel is clearly visible along the sides of the hull, suggesting considerable impact from the floats as the submarine sank. In the wider area it is possible to see crater like deformations in the seabed. These were initially considered to be damage from cold war depth charges. However, these features can also be found in areas of UK waters where there is no history of depth charge use. It is therefore most likely that they are caused by gas emissions through the seabed sediment. The survey and subsequent visualisation allowed some conclusions to be drawn which otherwise would have been difficult to surmise, bearing in mind that the depth of the site is 250m and beyond safe diving limits, optical methods of examining the area would be extremely difficult.

"Towards the stern of the wreck, raised sediment ridges are apparent on both sides of the hull. This is evidence that the submarine impacted the seabed stern first then rotated forwards along the keel line, possibly breaking of the stern section under the sediment. The survey data shows no discernable major distortion of the hull although specific damage to parts of the outer casing is evident. This implies that the internal pressure hull will be in reasonably sound condition. If further surveys prove to be the case, it is possible that the vessel could be lifted in one piece."

Martin Dean, B159 Survey report for the Ministry for Defence.

Accurate and easily understandable representation of the data is important to inform site management and potential recovery of the radioactive elements. These steps forward in visualising the data hope to enhance this understanding.

Real World Applications

Other applications of our visualisation methods have been commissioned by commercial salvage companies (e.g. Titan, Mammoet) to examine recently sunken wrecks in shipping routes around the world. The team surveyed and visualised the sunken wreck of the oil rig *Deepwater Horizon* in the Gulf of Mexico in March 2011 following the explosion and sinking that caused the biggest oil spill in USA history. The resulting 3D images are being used to help identify potential causes of the disaster as well as the rig's current condition on the seabed at a depth of 1,500 metres.

The visualisation methods are also in use in heritage applications: twenty wrecks off the coast of North Carolina, USA have been surveyed and visualised for the National Oceanic and Atmospheric Administration (NOAA see: http://desne.ws/nj0qwR). The intention is to produce 3D images of ships that were involved in the Battle of the Atlantic in WWII that will be accessable to a public audience who otherwise have no access to these sites.

Summary

Our approach to visualising sonar data of hazardous or historically important shipwrecks is differentiated from traditional methods through the aesthetic approach that we have taken. The industry standard rainbow ramp approach is useful to show threshold values in some forms of data but in this field it can distract the viewer from understanding what they are seeing. Approaching the problem from a design perspective, and constantly asking the question: *"How can this image be improved?"*, we open up the opportunity for alternative visual thinking. Artists and designers can offer an alternate approach to visual communication, tacit knowledge gained through creative practice is the starting point.

Images of the *B159* survey and other projects mentioned can be viewed at
http://www.adusdeepocean.com/

References and Notes:

1. *J. Curtis, Shipwreck of the Stirling Castle (Whitefish, MT: Kessinger Publishing, 2006).*
2. *D. Van der Vat, The Grand Scuttle: Sinking of the German Fleet at Scapa Flow 1919 (Edinburgh: Birlinn, 2007).*
3. *Sarah Dromgoole, "Military Remains Around the Coast of the UK: Statutory Mechanisms of Protection," in International Journal of Marine and Coastal Law 11, no. 1 (2006).*
4. *Martin Dean, Mark Lawrence, Richard Bates et al., "RASSE Report (Project Number 3837)," English Heritage, January 17, 2007, http://www.st-andrews.ac.uk/rasse/library/pdfs/rassefinal.pdf (accessed July 3, 2011).*
5. *Eduard Tufte, The Visual Display of Quantitative Information (Cheshire, CT: Graphics Press, 1996), 54.*
6. *H. G. Funkhauser, Historical Development of Graphical Representation of Statistical Data (London: St Catherine Press, 1937).*
7. *Martin Dean, Mark Lawrence and Richard Bates, "Factors that Influence the Quality of Archaeological Multibeam Sonar Surveys" (paper presented at the conference on Historical and Underwater Archaeology, Sacramento, CA, January 11-15, 2006).*
8. *Chris Rowland and John Anderson, "WreckSight: Revealing our Submerged Maritime Heritage," in VAST 2010: The 11th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage, eds. Alessandro Artussi et al. (Paris: Eurographics, 2010).*
9. *Bellona, "Northern Fleet Accidents and Incidents," Bellona's official Web Site, http://www.bellona.org/subjects/1140451820.2 (accessed July 3, 2011).*