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WreckSight: Revealing our Submerged Maritime Heritage

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Abstract

This paper describes WreckSight, an interactive application for viewing aesthetically considered, accurate, 3D visualisations of historic shipwrecks on the seabed. Maritime heritage sites around the world, especially historic shipwrecks, are typically difficult to access by the general public. In many cases they are beyond the reach of traditional maritime archaeological investigation due to depth and low visibility. Historically significant wrecks have been successfully raised to the surface for research and public exposition in recent years. The Mary Rose raised in 1982 from Portsmouth harbour (UK) and the wreck of the US Civil War submarine Hunley recovered in 2000 from Charleston Bay, are on public display along with many artefacts recovered from the wrecks. However, the majority of historic shipwrecks lie at the site of their sinking, on the seabed, hidden from the public view. Recent improvements in multibeam sonar technologies have resulted in new opportunities to gather very high definition, 3D point cloud data from submerged historic shipwreck sites, therefore offering the potential to create highly accurate 3D images for public exposition. Traditional maritime archaeological methods for displaying this data can be improved by addressing a number of known problems. These are:

- *Gaps between points allow data to show through from the other side of the wreck, potentially misrepresenting the structure of the wreck.*
- *Point cloud data contains no inherent colour information. Traditional display methods apply arbitrary colour ramps to the data which often does not enhance the viewer's interpretation of the wreck.*
- *Points are rendered at the same size regardless of their distance from the viewer*

The WreckSight application resolves these problems by utilising occlusion objects, locally oriented colour ramps (Locoramps) and digital cinematography. This 3D visualisation tool also has applications beyond heritage, e.g. in the marine salvage industry, recreational dive planning and environmental management.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Color, shading, shadowing and texture I.3.8 [Computer Graphics]: Applications—

1. Introduction

Maritime archaeologists investigating submerged historic shipwrecks can employ a range of techniques in the field to record, analyse and represent such sites. Traditional methods such as drawing and photography are often the tools of choice when a site is accessible to divers and visibility is not a problem. In such cases, artifacts recovered from the site can be displayed alongside the scale drawings, photographs and video recordings in a museum environment. In cases such as the Mary Rose, [Fri04] the remains of the wreck itself have been recovered and placed on public display alongside many artifacts at the Historic Dockyard, Portsmouth, UK. However, the high cost implications of recovering, preserving and displaying historic shipwrecks is prohibitive and therefore rarely attempted.

In locations where conditions prevent the use of optical methods, e.g. in depths beyond safe diving limits or where visibility is significantly reduced due to particulate matter in the water column, other methods have to be employed. One effective method for recording submerged sites when these conditions are present is the use of multibeam sonar. Improved methods for deploying this technology [BDL*07]

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have led to the possibility of gathering very high resolution data that accurately represents the sonar target as a 3D image. This can be compared to LIDAR imaging of land based targets [CS08] and laser scanning of individual artifacts. The challenge for the museums is how to display this 3D data to effectively engage the public with what are otherwise invisible maritime heritage sites.

Using the WreckSight application, viewers can interact with high definition point cloud datasets that represent historic shipwrecks. The application could be utilised in museum environments to reconnect accurate 3D images of the original shipwreck sites with artifacts recovered from them.

2. Gathering the data

Multibeam sonar deployed effectively produces high density point cloud data. Dean and Lawrence identified a range of factors that significantly affect the data quality and resolution [DLB06]. They subsequently developed the ISHAP system (Independent Sonar Head Attitude and Positioning) to counteract many of these factors. In particular, the system allows deployment of the sonar head closer to the target resulting in higher data density which in turn produces greater accuracy. For these reasons, the ISHAP deployment system was used to gather the shipwreck data for implementation in WreckSight.

3. Gaps between the points

Point cloud data consists of collections of many individual points located in 3D space. Each point is defined by XYZ Cartesian co-ordinates and represents a position on the target object where sound is returned to the sonar head. A dataset containing one wreck and local seabed can contain millions of points. Resolution is defined by the density of points i.e. small distance between points = higher density= higher resolution. Higher resolution provides more detail of the wreck's structure. Higher density also equates to larger file sizes and therefore an increased demand on computer hardware to display the data.

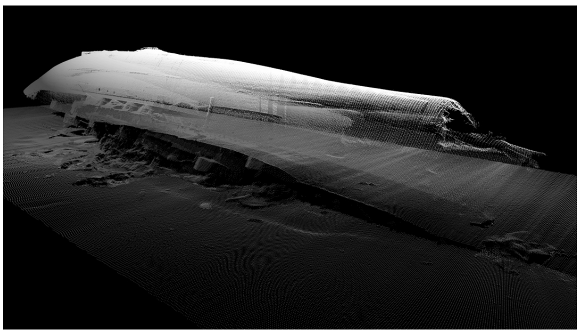

Figure 1: *HMS Royal Oak data point cloud. Distant points are clearly visible through the gaps.*

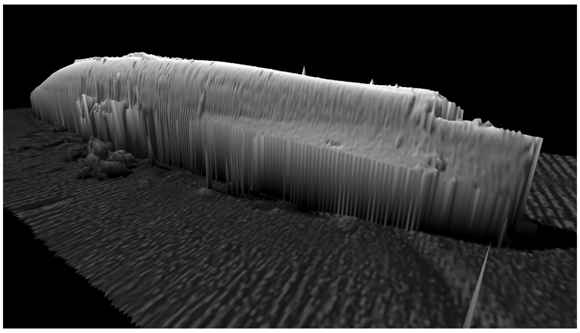

Figure 2: *HMS Royal Oak data with draped polygon mesh. Detail becomes obscured.*

When the data is less dense, gaps between the points allow data from the opposite side of the wreck to show through. Since points are rendered at the same size irrespective of their distance from the camera this creates depth cueing problems for the viewer (fig 1). In maritime archaeology, a common solution to this problem is to drape or wrap a polygon mesh around the point cloud data (fig 2). This has the effect of blocking the gaps between points by connecting a sub-sample of the data with polygon faces. In addition, this process simplifies the dataset thus allowing smoother interaction. However, the draping method also hides details that were visible in the original point cloud, effectively defeating the purpose of gathering high resolution data in the first instance.

4. The occlusion object

In WreckSight the "gaps between points" problem is addressed by the addition of an occlusion object to the dataset. The occlusion object is a simple polygon object constructed to emulate the shape of the point cloud and placed just within the outer shape of the wreck ensuring that it did not cover any of the exterior points in the dataset. Detail is added where necessary using 3D extrusion and subdivision tools. The resulting polygon object is contained entirely within the 3D space of the point cloud data and effectively prevents points on the far side of the wreck from being displayed in the foreground. A non-diffuse black shader is applied to the occlusion object to hide it from the viewer.

The image sequence shows the Royal Oak data as a point cloud (fig 3), with the occlusion object in place (fig 4) coloured blue for illustration purposes) and finally with a black shader applied (fig 5).

The use of the occlusion object resolves the problem of seeing background data through the gaps between foreground data. The object acts as a traveling matte, masking the background data when viewed from any angle while preserving the detail of the original point cloud. Figures 6 and 7 show the occlusion object method applied to data from the

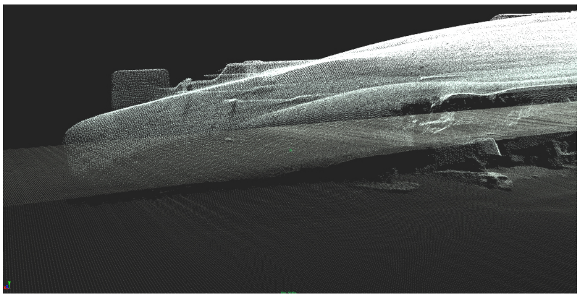

Figure 3: *Royal Oak point cloud*

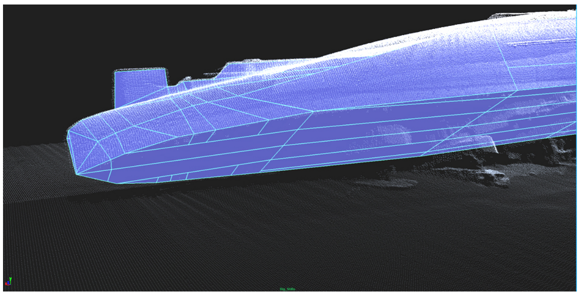

Figure 4: *Occlusion object in place*

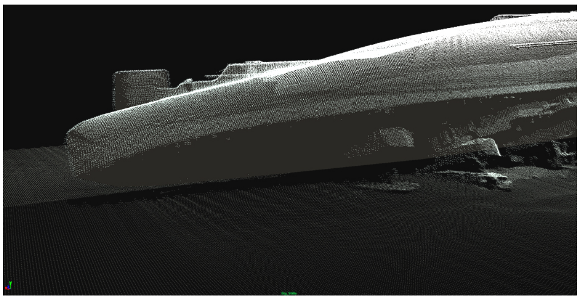

Figure 5: *Point cloud combined with occlusion object*

wreck of a WWII liberty ship SS Richard Montgomery, in the Thames estuary, London.

4.1. Limitations of occlusion objects

The occlusion object needs to be carefully constructed with a good understanding of the wreck data i.e. knowledge of the ship's structure will inform the shaping of the object. Placement of the object within the dataset has to be very precise to avoid unintentional occlusion of finer details. Polygon construction methods are restricted to straight edges; therefore any curved surfaces require a higher density of polygons to create the illusion of curves. A balance has to be achieved between the accuracy of the occlusion object and the number of polygons displayed to retain smooth interaction for the viewer.

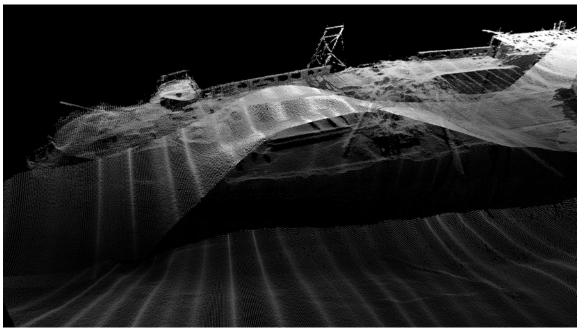

Figure 6: *SS Richard Montgomery point cloud*

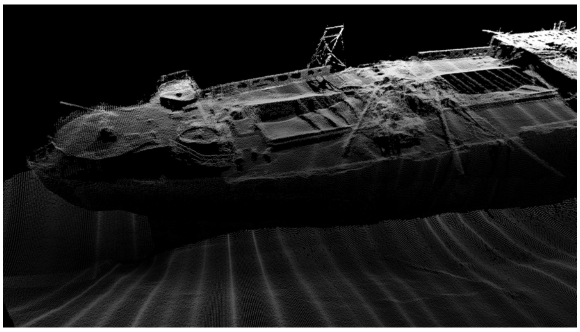

Figure 7: *Point cloud combined with occlusion object*

5. Point cloud colour

Point cloud data from multibeam sonar contains no inherent colour information. In order to display the data, colour therefore has to be added. The standard method in maritime archaeology for applying colour is to use a simple grey ramp or a multi-coloured stepped ramp that aligns with depth measurements in the data. Figure 8 shows data from the wreck of SS Richard Montgomery in the Thames estuary displayed using this method. Dark blue represents the data at the greatest depth ranging through to red at the shallowest points. The stepped scale clearly identifies the relative depths of various features on the wreck but does little to enhance the detail in the dataset. The large blocks of intense colour can appear to obscure detail where small changes in the wreck's surface are rendered. Conversely, abrupt colour changes across flat deck planes appear to signify surface detail where none may be apparent.

5.1. Locally oriented colour ramps (Locoramps)

In WreckSight, colour is applied selectively to different parts of the data using locally oriented colour ramps (Locoramps)

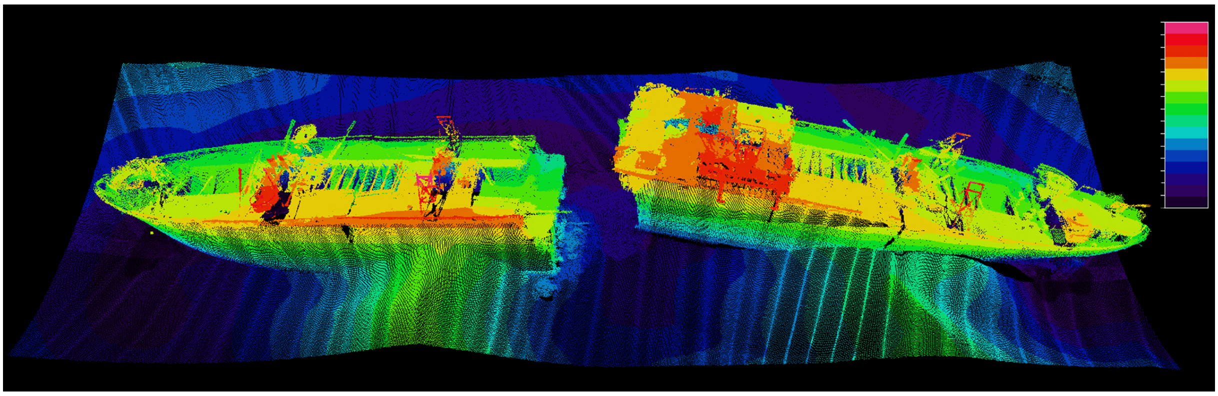

Figure 8: *SS Richard Montgomery rendered with stepped colour ramp aligned to depth.*

as a method to distinguish finer detailed features on the shipwreck data. Since we are working in a 3D environment where the X axis represents Eastings (East to West values), the Y axis represents Northings, for our purposes the Z axis represents depth below the sea surface. In figure 9 the greyscale ramp assigned to the wreck data makes the features that are close to the seabed appear darker than those nearer the surface. This occurs in a linear manner where black is assigned to the deepest points (lowest Z value) and white is applied to the shallowest (highest Z value). Any point that lies exactly half way between the maximum and minimum Z value will be assigned a fifty percent grey shade from the ramp.

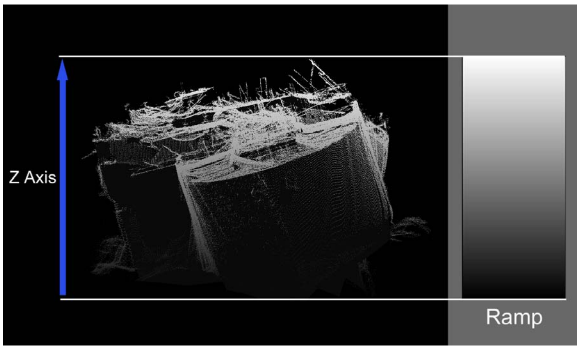

Figure 9: *Greyscale ramp applied to wreck data along the Z axis.*

Viewed from the south the wreck lies on an angle of approximately twenty degrees from horizontal (figure 9). Traditionally in survey software, greyscale or colour ramps are applied along the vertical Z axis. When the wreck data is not perpendicular to the seabed, as in this case, this can result in features found at the edges of the deck (e.g. the gunwales) being assigned different shades of grey (or colour). Similar features are not represented by consistent colours. By carefully rotating the ramp to align with the prevailing angle of the wreck, similar features across the wreck can be assigned the same shade of grey. This produces a more coherent overall image with similar features on each side of the wreck being assigned similar shades from the ramp.

By inserting additional colour values at strategic points of the ramp it is possible to differentiate between details across the dataset. In the example (figure 10) the ramp has been modified with red, white and green bands where it aligns with features on the main deck. The ramp is shown in the top right corner of the image. The bright colours are used here to simply to emphasise the effect of modifying the ramp at strategic points. Using bright contrasting colours makes the task of aligning the ramps much easier. After the ramp is correctly aligned it is a simple task to change the primary colours to more subtle alternatives. In the final version of the SS Richard Montgomery 3D visualisation only grey scale values were used in the ramps.

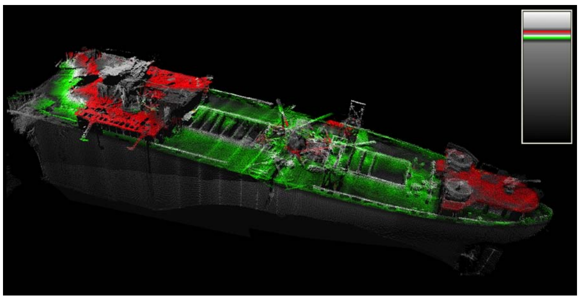

Figure 10: *Modified ramp rotated to align with deck features.*

When the changes in the colour ramp are placed closely together it is possible to pick out levels of fine detail. This idea was further developed using a small section of deck that appeared to be littered with debris. The ramp used in figure 10 was modified further by adding thin stripes of varying shades of grey above the red line. In the example, figure 11 shows how this process emphasises the definition of detail on the deck section.

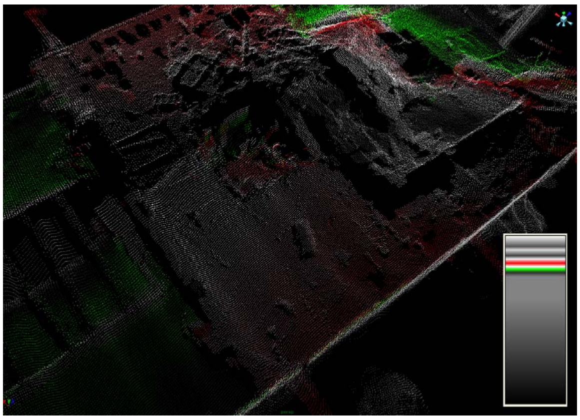

Figure 11: *Detail on the deck*

The wreck is broken into stern and bow sections which are oriented differently to each other on the seabed. Therefore, a colour ramp rotated to align with the stern section will not be appropriate to assign colour values to the bow section. Views of the whole wreck, from the west and above (figure 12), illustrate this problem. The stern section shows the closely aligned ramp colours whereas the bow section is predominantly grey with only the top of the lifeboat frame picking up the colour green. The two wreck sections are located on seabed that slopes in different directions. Evidently, a single oriented colour ramp is not sufficient to assign appropriate colour to both sections of the wreck.

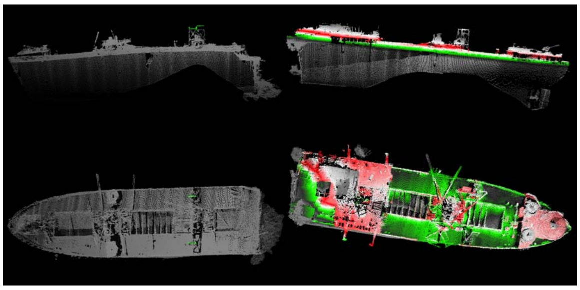

Figure 12: *Side and top views of the wreck sections with a single colour ramp.*

The immediate solution would be to separate the wreck data into two point clouds and apply a separate colour ramp with appropriate local rotation to each section. However, a greater level of control can be attained by taking this method a step further. Significant features can be identified, separated from the original point cloud and assigned an individual colour ramp. Each resulting colour ramp can be oriented locally to its wreck feature without affecting any other part of the point cloud. Also, by assigning multiple ramps with rotational independence, features that are perpendicular to each other can be appropriately managed.

For example, the cross section of hull visible where the ship broke in half, can be assigned a colour ramp that is oriented at almost 90 degrees to the deck. Figures 13 and 14 show the cross section feature with a stepped colour ramp assigned. The green locator cross indicates the local orientation angle of the ramp. Each ramp is linked to a locator and when the locator is rotated the associated ramp also rotates. Once again, the bright ramp colours are useful to correctly rotate the ramp and are replaced with a modified grey scale for the final visualisation.

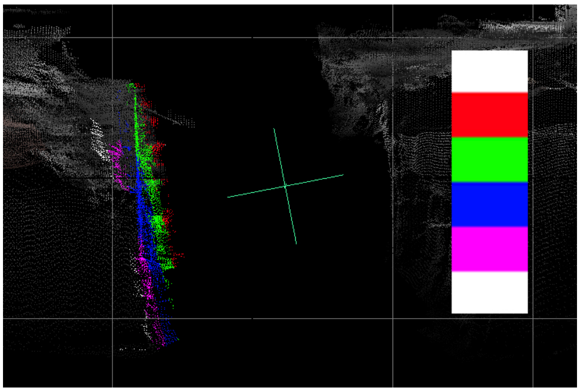

Figure 13: *Cross section showing locally oriented stepped colour ramp. Side view.*

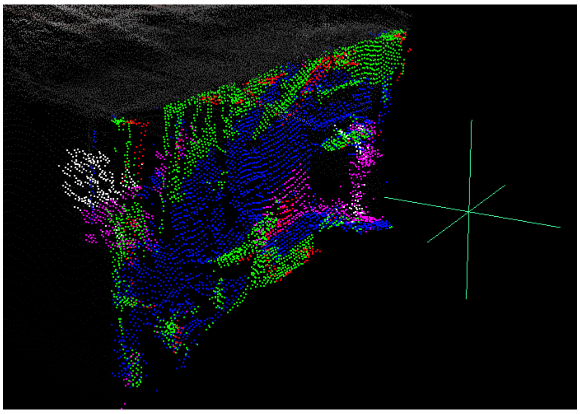

Figure 14: *Cross section seen in 3D view*

The SS Richard Montgomery point cloud data was separated into 22 key features from the seabed, bow and stern sections. Each separate section was assigned an individual stepped colour ramp which was oriented to maximise the display of details on the wreck. The stepped primary colours in the ramps were replaced with edited greyscales. The seabed ramps were edited to resemble the sand/silt found

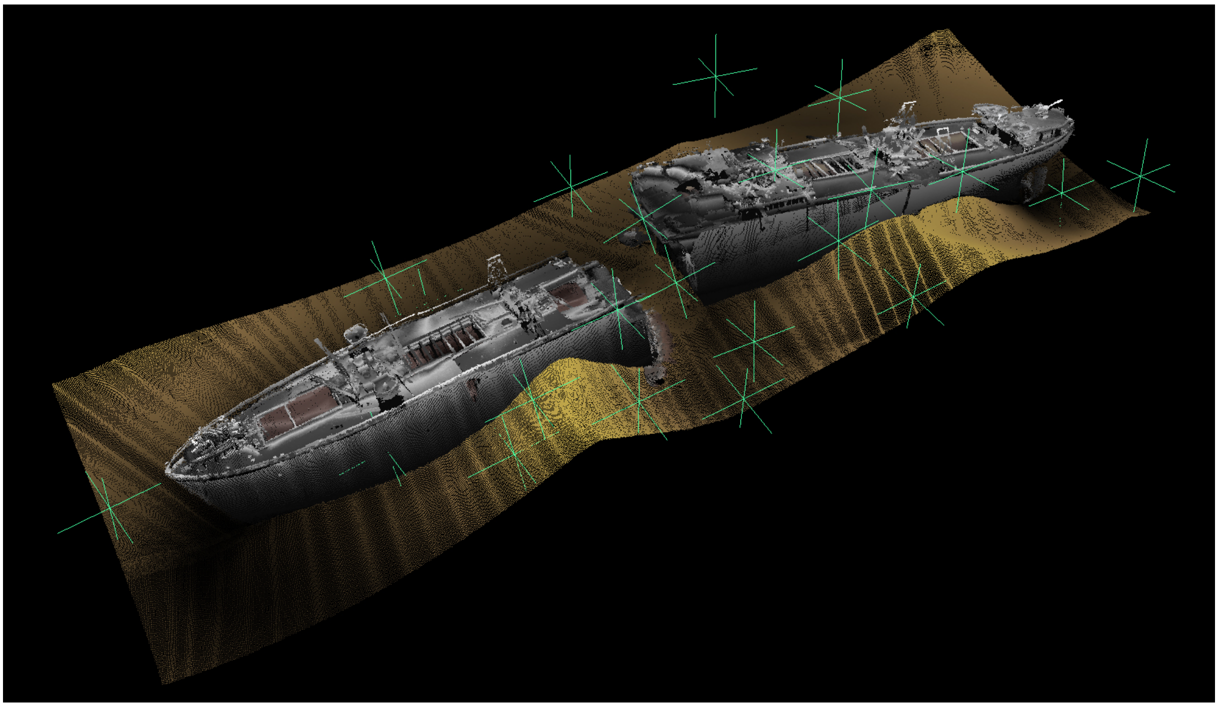

Figure 15: *SS Richard Montgomery with final edited Locoramps and position of locators.*

at the wreck location in order to clearly define where the seabed ends and the wreck begins. The locators associated with each section of wreck are shown in figure 15 and are placed close to the point cloud data to which they are assigned.

6. WreckSight implementation

The development of Occlusion objects and Locoramps to improve the 3D visualisation of historic shipwrecks was initially applied to high resolution rendered movies [Row07] that focussed on distinctive features where deterioration or damage was evident e.g. cracks in the hull. As the project developed it became apparent that it would be useful for the viewer to interactively explore the shipwreck data in a more independent manner. The SS Richard Montgomery contains 1.4 megatons of unexploded munitions and any sign of deterioration could affect the local environment. By implementing the data in an interactive application, the environmental managers are able to analyse the data more thoroughly. WreckSight is a self contained application written in C. It is custom built for each shipwreck (or collection of wrecks) and displays the cleaned, edited point cloud with a section of surrounding seabed. Occlusion objects, Locoramps and digital cinematography techniques are implemented in WreckSight.

7. Applications

We have identified a range of applications for WreckSight. The international salvage industry uses the application to plan the recovery of hazardous wrecks. e.g. The B159 nuclear submarine in the Barents Sea and the wreck of the New Flame off Europa Point, Gibraltar. For this application we have added measurement tools and retained the global positioning information of each point in the data.

The recreational diving industry use WreckSight for dive planning. A version containing the eight historic WWI wrecks at Scapa Flow, Orkney, allows divers to plot a route around each wreck showing the entry and exit points from the surface (figure 16). Previously, divers relied on artist's impressions and illustrations for pre-dive planning. WreckSight provides 3D images of the wrecks with significantly greater accuracy.

In the heritage sector we have developed a version that displays the wreck RMS Campania, a protected wreck which lies off the Firth of Forth near Edinburgh. The Campania was a Blue Riband winning Cunard liner which was converted by the MoD for use as an early aircraft carrier before sinking in 1918. WreckSight is used by local maritime archaeologists to help map the wreck and mark locations were artefacts have been recovered and are on display in the local museum at Burntisland.

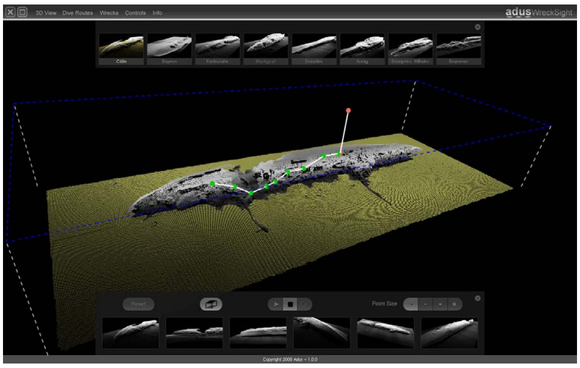

Figure 16: *Screen shot from WreckSight: Scapa Flow*

8. Conclusions and further work

The development of Occlusion Objects and Locoramps to improve the 3D visualisation of historic shipwrecks from multibeam sonar data provides the heritage community and museum sector with an opportunity to bring these important landmarks directly to the public. Using WreckSight, previously invisible and inaccessible remnants of history could be explored alongside artifacts in museum collections that have been recovered from these wrecks. Raising public awareness of our wider cultural heritage is paramount if we are to preserve important sites for future generations.

There is further work to be done in combining rich media with the point cloud data, co-locating underwater photographs, video, ship's drawings etc with the 3D visualisation would enhance the end user experience. A method to automate the creation of the occlusion objects would improve the efficiency of the workflow. Re-tasking cloth simulation techniques is one avenue that we are exploring to achieve this.

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