Niabara - the Western Solomon Islands War Canoe at the British Museum

3D documentation, virtual reconstruction and digital repatriation

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***Abstract*—This paper describes the 3D digital documentation of a highly significant cultural heritage object from the Melanesian Southwest Pacific, held in the ethnographic collections of the British Museum. The object, which dates from about 1910, is a large plank-built war canoe from the island of Vella Lavella in New Georgia, Solomon Islands. 3D laser scanning is paired with anthropological research, which aims to deliver a holistic virtual 3D reconstruction and multimedia interactive delivery of the boat for the digital repatriation to the source community.**

Keywords; 3D laser scanning, museum documentation, virtual reconstruction, digital heritage, digital repatriation

I. INTRODUCTION

The largest water craft in the British Museum's collections, a war canoe from Vella Lavella, New Georgia in the Solomon Islands, can now be experienced again for the first time in 30 years – in virtual space as digital object.

One of the admired highlights in the Ethnography galleries of the British Museum (BM) for 40 years, the plank-built single-hull war canoe was brought to the Ethnography store in East London in the seventies, when the Ethnography department moved its galleries to the Museum of Mankind. To properly transport and store the canoe, the tall, ornamented prow and stern were cut off, and precious details like the *nguzunguzu*, a doglike face attached low on the canoe's prow signifying its specific origins in the island of Vella Lavella, were removed and stored.

Even in storage, hidden among other vessels, the war canoe still attracts significant scientific interest from visitors, researchers and Pacific Islanders, including in 2005 the Rev. Ikan Rove KBE of New Georgia and the Hon Milner Tozaka MP of Vella Lavella, because it is unique in its kind and dimension.

Therefore the need for a three-dimensional digital documentation of the canoe was recognized and initiated by anthropologists Dr Graeme Were and Professor Edvard Hviding with the aim to digitally restore a holistic impression of the BM War Canoe, including decoration and colour.

Through the combination of metric survey technology with anthropological considerations the documentation is not only seen as a "scanning and modelling" problem, but also considers the object as a real cultural heritage masterpiece of a living culture with specific and unique features. The goal was to produce a high resolution 3D image which can be taken back to the source community, for study use, so as to encourage technological and ancestral knowledge restitution to the inhabitants in the western Solomon Islands, where this type of canoe remains a core symbol of culture and history.

After the two-week documentation campaign in the BM East London storage in November 2008 – with an interdisciplinary team of anthropologists, conservators, curators and 3D heritage documentation specialists – this magnificent seagoing vessel is now once again accessible, for researchers in the virtual realm, and for descendents of its originators in New Georgia with its successful digital repatriation.

This is a preliminary status report of our ongoing project. Further multimedia outcomes and 3D images and research results about the reception of the digital images in Solomon Islands will be presented in 2010.

Figure 1. War Canoe in the Western Solomon Islands in front of canoe houses, ca. 1910. Oc.B36.4 British Museum Pictorial Collection Images, © The Trustees of the British Museum.

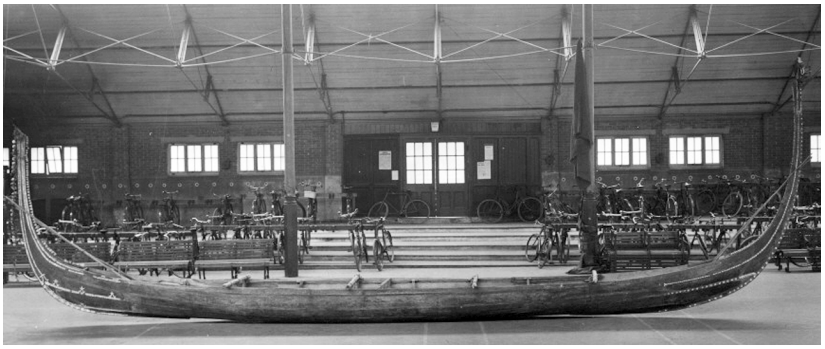

Figure 2. The Vella Lavella war canoe ca. 1920 inside a bicycle shed , Lady Lever Gallery, Liverpool, UK. Oc.B35.5 British Museum Pictorial Collection Images, © The Trustees of the British Museum.

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II. PROJECT MOTIVATION

A. Interdisciplinary collaboration

The digitizing of the BM war canoe takes place under the international collaborative project *"Pacific Alternatives, Cultural Heritage and Political Innovation in Oceania"* funded by the Research Council of Norway and led by the Bergen Pacific Studies Group, a major European centre of anthropological research in Oceania. Within the research agenda of *Pacific Alternatives* there is a major focus on the Solomon Islands and the BM war canoe project is one of several activities [1]. The Solomon Islands National Museum and its Director are central partners in the project.

The war canoe in the possession of the British Museum lends itself as an optimal case study; also as the British Museum itself is engaged in a major research project on Melanesian artefacts [2].

UCL provides a high expertise in digital documentation of museum artefacts and remote sensing. A previous research project *"E-Curator: 3D colour scans for remote object identification and assessment"* [3] produced high-resolution 3D images with up-to-date colour laser scanning technology and explored the remote dissemination over an interactive website. The BM war canoe project gives the UCL team the opportunity to apply their expertise in the production and visualization of high-quality 3D colour images of a significantly larger object than those used for *E-Curator*.

B. Preliminary anthropological investigations

Photographs of the war canoe in the British Museum in the seventies stirred a significant reaction with the people of New Georgia. Although this specific canoe is from Vella Lavella, the type it represents is anchored in collective memory. Information about such canoes remains known, a century after war canoes were banned and in many cases destroyed by British colonial power bent on "pacifying" the head hunters of New Georgia who used such canoes on their overseas expeditions of warfare. During the 1970s and 1980s several true plank-built replicas of war canoes were built in Vella Lavella, Roviana, Marovo and other locations throughout New Georgia. Recently, the Christian Fellowship Church, a social movement in New Georgia that is led by the Rev. Ikan Rove KBE (who examined the war canoe at the British Museum in 2005), has built a fleet of 15 war canoe replicas which is in demand for official celebrations and other major events in the Western Solomons.

Solomon Islanders are actively interested in new technologies, such as the internet and the virtual realm. In recent years, a number of Solomon Islands schools, including many in the New Georgia area, have had satellite-based broadband connections installed, and a programme of "distance education" with digital content is being developed by the Solomon Islands government. This gives us an indication that digital 3D objects are indeed a desirable and suitable medium for the digital repatriation of the war canoe.

The direction and use of digital repatriation of tangible and intangible cultural heritage is being actively explored from an international perspective by museums and scholars. Further research on digital heritage technologies intends to explore widespread dissemination and replication of cultural objects and associated knowledge. 3D documentation of the object was, thus, triggered by these critical, and largely unexplored debates.

C. Research goals

3D scanning can provide both a detailed metric survey of the canoe and digital documentation towards a museum and conservation point of view. The process of 3D handheld laser scanning captures the geometry at sub-millimetre resolution. The construction technology, like the overall tectonic of the boat, joints of planks, as well as construction details and elements, can be recorded.

Research with the 3D image of the BM war canoe should help to answer some of the following questions. Can we find out more about the history, use and significance around the war canoe at the time when it was built, for example was it ever launched and used? Can we complement the known indigenous vocabularies pertaining to New Georgian war canoes with new findings regarding canoe parts by showing 3D images of the whole canoe or its elements of construction? The war canoe project wishes to reinvigorate the local knowledge about canoe building in source communities.

The project will first and foremost benefit the people of New Georgia. It will give them, particularly the canoe's source community, access to the data, the images and the results. One of the outcomes should be a multimedia exhibition, about the canoe, its Solomon Islands context and its 3D documentation. This exhibition is planned in close cooperation with the Solomon Islands National Museum, the Solomon Islands Ministry of Education, and representatives of the people of the BM war canoe's island of origin. The exhibition will be "travelling" in New Georgia and elsewhere in Solomon Islands also through integration in the nation's new network of rural "Distance Learning Centres" where there is internet access through VSAT broadband.

III. THE BRITISH MUSEUM WAR CANOE

A. Ethnographic Background

The type of New Georgian war canoe represented in the collection of the BM was called *niabara* (in Vella Lavella), and was used for overseas raiding for the purpose of taking human heads and slaves. This practice was put down with a strong hand after a British Protectorate was declared over the islands in 1893, followed by the influence of Christian missions [4]. The reason for this interdiction was not only the bloodshed between the different tribes and the obstruction of colonial trade, but certainly also the superior speed and manoeuvrability of these war canoes that could outrun the steam-driven British naval ships of the time.

The Western Solomon war canoe shows a high prow and stern post, both richly ornamented, and in some views thought to protect the up to 30 men in it from arrows (figure 1). The hull of the New Georgian war canoe consists of a standard assemblage of finely shaped planks bent over a set of ribs, lashed together along the seams and attached to the ribs by means of the vine of a creeping fern (*Lygodium* sp.). From grated nuts of the *tita* tree (*Parinari glaberrima*), a putty was made for sealing the seams of the planks in order to make the canoe watertight. The finished hull was blackened with mixtures made from certain types of charcoal and the sap of

aroid climbers. The inside of the boat remained uncoloured. The BM war canoe shows well how the black-stained outside was contrasted with an intricate pearlshell inlay on the sides of the bow and extending upwards on prow and stern. A string of white egg cowries (*Ovula ovum*) was suspended by a lattice framework attached to the tall prow, and their shape and colour were contrasted by alternating sticks of red twill tipped with white cockatoo feathers [5].

Directly above the waterline on the prow a wood-carving of an anthropomorphic head was lashed onto the prow of the war canoe for each passage. The so-called *nguzunguzu* (Roviana language) had a protective function to dispel the malevolent spirits of the water by always open eyes, so that water and wind would not harm men and boat [6]. Just below the *nguzunguzu* a wood tablet was fixed which would deflect the sea spray and create a rainbow in front of the travelling canoe. The construction of the canoe with all its technical stages would take up to two years with steel tools, and six to seven years using only stone and shell implements.

B. *Description of the BM war canoe*

The most enlightening, precise and technical description of the BM war canoe is given by Haddon [7]: *The keel and the six strakes on each side have a median ridge with cleats at intervals for the attachment of the inserted ribs and frames [..]. There are two or three ribs at each end and elsewhere; the inserted frames have varied forms. The ends of the second rib at the bow are united by a bar of wood which is notched at the ends to clamp the rib and pegged to make all secure; this bar has a central hole for a mast, and a corresponding shoe is pegged on to the middle or the rib. The planks are thinned down at their edges, the edges are lashed together, and the groove thus formed is filled in with Parinarium putty. The whole exterior surface is also coated with this black putty. Both ends are alike and rise into a high peak which is ornamented with Ovulum shells along its outer edge and along the inner edge with triangular toothed pieces of shell. The sides are decorated with inlay. A bunch of feathers is on the tip of each peak.*

The canoe is 11.3 metres long. Its shape is maintained by eleven ribs, each cut from a single piece of wood, one of which is in the form of a frigate bird (figure 5). There is no decking; the paddlers would sit on planks supported by the longitudinal braces that run from prow to stern. A steersman would sit at the stern with a particularly large paddle. The *nguzunguzu* of this war canoe is made of light wood, stained black and elaborately inlaid with nautilus shell (figure 3). We are sure that the *nguzunguzu* belongs to the boat, since it appears in historical photographs from the Solomon Islands (figure 1). The shell inlay follows the general designs of the area as described by Somerville [8].

C. *Provenance of the British Museum War Canoe*

It is known that Mr Jiosi Angele of southern Vella Lavella built the canoe around 1910. However, in light of the ban on building war canoes and the interdiction of headhunting, it is intriguing that this canoe seems to have been commissioned by a junior employee of the British colonial government, Mr Broadhurst-Hill. He shares very dear memories of the canoe in a letter to the British Museum dated April 1965, and argues that its commissioned construction was a measure to lighten up the depressed spirits of the islanders *" ... because joy had been taken out from their lives by the prohibition of murder"* [9].

In 1913 William Lever bought the war canoe and brought it to the United Kingdom, to the Lady Lever Gallery in Port Sunlight. It was photographed at the time in a bicycle shed with its decorations attached, albeit idiosyncratically: The *nguzunguzu* was mounted in the wrong position, on top of the stern (figure 2).

The war canoe was then given to the BM which displayed the canoe in its Pacific gallery from 1927 to the 1970s [9]. When the Ethnographic Department moved out of the BM, the war canoe's prows were carefully cut off for better transport. Decoration and small parts were collected in cases or mounted onto wooden boards. The entire canoe, its structural elements as well as the associated dismounted parts and complete decoration, have been kept in the BM's East London store ever since. The condition of conservation of the war canoe in storage is very good.

The war canoe proves to be of high significance and a unique ethnographic object, not only because it shows a gapless provenance, but also because it is the only preserved war canoe of its size. It is a representative of both a Vella Lavella *niabara*, and of other plank-built war canoes of New Georgia.

IV. 3D Documentation of the War Canoe

A. *3D documentation goals: the object in the virtual realm*

Whilst the direct encounter with the material object will always have value for conservators and curators and includes an important learning process, museum specialists have traditionally used a combination of photography and text to prepare illustrated catalogues and reports. Conventional imaging and documentation techniques have always been strictly two-dimensional and as such very selective and insufficient to record nuanced information about the complete shape, colour and texture of an object.

The goal of the 3D documentation is a detailed metric survey of the canoe in the round, producing an archival record that will widen the knowledge about the object. The virtual reconstruction will show methods of construction and details

Figure 3 The *nguzunguzu* figure head was lashed to the bow for the scanning campaign.

Figure 4 Solomon Islands war canoe in the storage of the British Museum, moved from rack to open floor space.

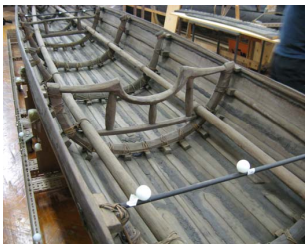

Figure 5 Detail of the inside of the canoe: one of the ribs shaped like a frigate bird, and longitudinal poles.

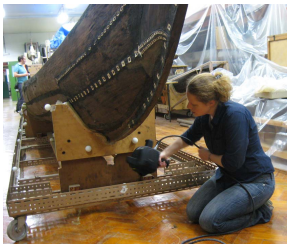

Figure 6 Scanning of a control sphere at the stern with Metris Handheld K-Scan.

of decoration. Specifications for the model are aimed at the delivery for the digital repatriation.

Up-to-date scanning technology, in connection with photographic documentation and digital reconstruction, offer the possibility to interactively encounter and analyze the canoe in a new light. The use of 3D scanning is considered by us as a non-invasive, non-tactile documentation method; furthermore it is a conservation examination method that brings the war canoe into the Virtual Heritage realm fit for digital repatriation with the source community.

B. Scanning - November 2008 in the British Museum Store

The 3D laser scanning equipment was brought on-site by car. The storage space was re-arranged according to our specifications (figure 4) giving us an additional work space of about six meters along the length and four meters at the ends of the boat. Since the canoe is stored within a mobile 'slotted-angle' chassis, we were able to easily move it into optimal positions that enabled us to set-up our equipment at optimal locations to capture both the inside and outside of the canoe.

C. 3D scanning with Metris K-Scan

The equipment used for the digitizing was a Metris K-Scan handheld laser scanner designed for portable metrology applications. The optically tracked scanning system is ideal for on-site 3D digitizing in indoor environments.

The system consists of a handheld scan head (LC50 probe) and a mobile Coordinate Measuring Machine - Krypton K610 (K-CMM) with three synchronised linear camera units. A number of infrared LEDs built into the handheld scan head housing are imaged and accurately tracked by the Metris Optical CMM via triangulation. Tracking of the scanner head delivers scan head position and orientation in real time enabling the operator to freely walk around and efficiently acquire surface scans of the measurement object. The practical tracking volume of the K-CMM camera is approximately 5 x 5 x 3 metres.

The scan head is a laser triangulation system that emits a laser line. The system measures the two-dimensional projection of the laser line (class IIIa) on an object, using a CCD camera with an angle of 30 degrees to the laser plane to calculate the 3D position. The CCD camera in the scan head registers the reflection of the projected laser line on the object's surface. The width and depth of field is 50mm, the accuracy (best fit sphere) is 15 microns RMS, at a stand-off (distance to the object) of about 100mm. The scan head outputs up to 19,200 points per second. By slowly moving the scan head parallel to the object surface, scan stripes with a point density of 0.4 x ca 1 mm can be recorded. The quality of the data depends on the object's surface and can be adapted by varying laser brightness and software filtering parameters according to the object properties [10].

The large volume accuracy of the measurement system is ensured by including calibrated length bars within the scan volume. In our case this is carried out using a modified Metris K-Reference Bar.

D. Method: 3D scanning process

The on-site scanning time took eight working days. The illumination levels and the temperature in the storage space did not alter over this period which proved to be an ideal surrounding for the Metris K-Scan system which includes temperature sensors to ensure that the system maintains its operating stability.

An independent control system was set up for later alignment of single scans and evaluation of accuracy. 48 white control spheres (table tennis balls with a diameter of 20mm) were fixed to the canoe supporting structure at different levels and planes all around the canoe. We recorded at least three spheres per scan, and - where needed - we introduced a mobile bar with three control spheres on top for scans of the inside the boat.

The practice of scanning involves the slow passing of the scan head over the surface of the object. The scan head is optically tracked by a static K-CMM tracking camera on one side and connected to a computer on the other side that receives and visualizes the collected data in real-time. Each scan position produces a conglomeration of hundreds of scan segments from the single 'strokes' of the scan head (figure 6).

To digitize the different surface type's different laser intensities were chosen. For the dark wood of the canoe a high intensity, and for the pearl shell inlay, a lower intensity was employed. Data from different scan settings were stored on independent layers in the point cloud database (figure 7).

The scanner was set up in 19 different positions around the canoe. Since the position and setup height of the K-CMM camera tripod is flexible, it enabled us to digitize both the exterior and interior. With each scanning position ca. 5 m² were captured with between 3 and 9 million points. The high-resolution 3D scanning method produces a dense point cloud.

An interesting parallel can be observed between the construction process of the real and the digital object. The plank construction is achieved by an additive method. The scanning process acts like the additive construction of the digital image of the real object; a series of points is acquired pass by pass and stored into different scan sets, which are then assembled to create the new digital surrogate.

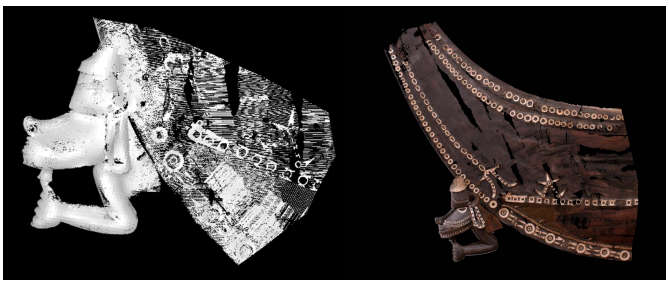

Figure 7 Pointcloud detail of *nguzunguzu.*

Figure 8. Preliminary test of texture mapping by VMS before holefilling.

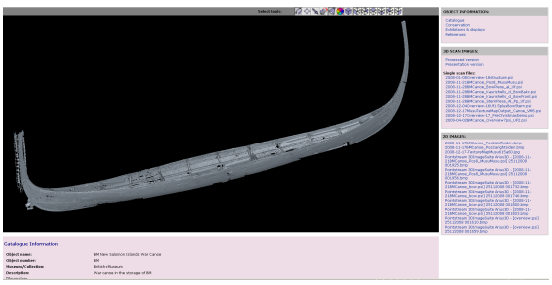

Figure 9: Reconstructed canoe uploaded to the E-Curator prototype. The 3D model can be interactively explored on this web-based 3D archive [3].

E. Post-processing of the collected 3D data sets

The post-processing time of the different scans takes about five times longer than the actual recording on-site.

The collected point cloud data were imported into Pointstream 3D Image Suite [11], a capable software tool for handling colour point clouds of up to 15 million points. The point clouds were filtered to 1mm distance and then all scans were algorithmically aligned. Subsequent filtering produced a complete model of the status-quo condition in the BM Storage of ca 8 million points (figure 10a).

Independent measurements of 17 distant points on the control system of spheres had taped on-site in the BM. When compared with the separation between fitted control spheres in the reconstructed model an agreement of to 2-3 mm was found.

Since the recording time had been limited by the accessibility of the BM stores, we had defined primary areas for scanning. And so, in a next step any small holes in the dataset were closed with a grid-fit to deliver points at 1mm spacing. This interpolated data is on a separate layer to allow its removal should this be required for future analysis.

Additionally to the canoe we had also scanned the detached decoration. In a next step the prow and stern as well as their cowrie and wood decorations were virtually put back into place. By bringing all these parts together we were able to show a complete digital version of the canoe that had not been seen in reality for the past 40 years (figure 9 and 10b).

F. Difficulties encountered in the scanning process

The quality of the data not only depends on the successful calibration of the system, but also the capability of the operator handling the scan head. A calm and steady slow hand movement maintaining a set distance from the object is required. A technical introduction to the best scanning tactics and the software needs to be ensured for every operator. Since the war canoe is a very big object the turns to scan the object were swapped about every 30 - 45 minutes.

Since the war canoe was very heavy, it could not be lifted from its support. Thus it was impractical for us to scan the complete underside of the boat except at the stern and bow.

For the finer decorations, such as the cane binding, photography is our preferred method of documentation.

G. Results of 3D documentation

The 3D laser scanning produced a high-resolution point cloud and an excellent documentation of the geometry of the war canoe as a whole. Surface details and plank joints as well as the shell decoration are visible on the scan, and for the first time the inside and the outside of the boat can be correlated. It is now possible to produce a true to scale representation of the canoe, its planks and ribs.

The final product was uploaded to the E-Curator prototype application to remotely share the 3D image of the war canoe [3]. Single scans from sequential stages of the data acquisition and processing workflow were also uploaded to guarantee a traceable production chain to the final version (figure 9).

The dataset provides archival condition documentation in a specific point of time. The resulting 3D image can be put to different uses: analysis and monitoring for conservators and anthropologists, display, replica, education. The isolation of individual structural elements could enable a systematic comparison with other canoes and their schematic drawings. This documentation should also benefit the BM in providing up-to-date imagery of the object.

H. Additional research during the scanning campaign

Colour information was acquired with a high-resolution photogrammetrically calibrated Nikon D100 camera (28mm lens) to image the complete canoe hull. These photographs provide a detailed documentation and will be used for texture mapping to produce a coloured point cloud [11].

The technician's scanning and photography work was observed by several anthropologists in order to follow the "life cycle" from the scan, to the digital surrogate 3D image. A first step was to understand engagement with the canoe and the digitizing of the object. The scanning process was seen as an ocular method; the technician is establishing a bodily exchange and corporal relationship to the scanner and the canoe. The reception of the digital image in Solomon Islands will be closely observed and documented.

The scanning process in the BM was accompanied by professional film recording in preparation for a documentary film about the whole project.

V. Outlook for further work

The first phase of the project completed the 3D survey and partial reconstruction of the BM war canoe. The second phase will be dominated by a more detailed reconstruction of geometry and colour to form a new 3D image of the boat to resemble the as-built appearance.

A. Virtual reconstruction of the BM War Canoe

For the visually correct reconstruction we can resort to Woodford's plates and drawings of canoes [4], and to the

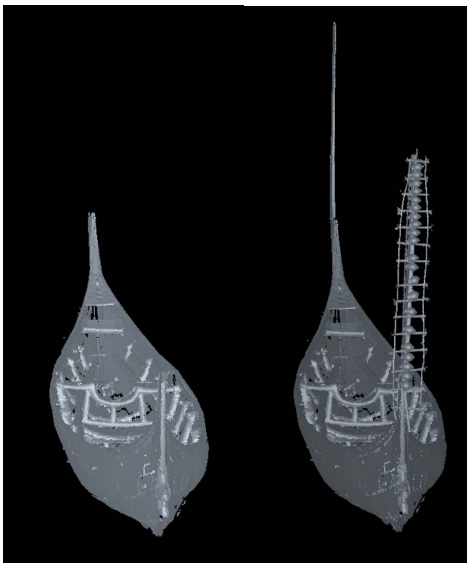

Figure 10 First result of 3D documentation: a) right –scan without decoration, b) left – fully recostructed with decoration, bow and stern.

ethnographic expertise of the University of Bergen team. The 3D reconstruction will complement missing pieces, like the un-captured underside of the canoe. Constructive elements like ribs and planks will be modelled. Not only will prow and stern be put back to their original locations, but their decorative details will also be completed virtually. Missing shells in the prow's white cowrie grid will be replaced, now faded colours of the decoration will be dark red again and flanked by white cockatoo feathers.

Finally a texture mapping of photographs onto the point cloud with VMS software on the outside will complete reconstruction of the canoe (figure 8). Without triangulating the pointcloud, the greyscale geometry information will be coloured by common features of photograph and scan. This will be executed with the software *Vision Measurement System* (VMS version 8.2) which uses a self calibrating photogrammetric bundle adjustment to solve for the registration of arbitrarily taken digital images and the scanned model [12]. A photogrammetric reconstruction is then used to associate imaged pixel values with the scan point cloud automatically utilising the optimal images (viewpoint to surface normal and image magnification) in the reconstruction at each scan point. There is currently no estimate of intrinsic reflectance within the reconstruction process.

B. Digital repatriation to the Solomon Islands

A central anthropological question to this project is to investigate what kind of associations (technical and symbolic) are carried through from the real object into the digital domain? In the case of the BM war canoe we would like to explore how indigenous communities engage with virtual reproductions of their cultural objects and the kind of perceptual, sensory and experiential relations this raises [13]. Furthermore, what are the social, political and ethical implications of the digitisation process and what local discourses surround this?

In the next phase of the project the scans and multimedia outputs will be brought to Vella Lavella in late 2009. The digital repatriation hopes to connect the intangible values of the object with the digital representation. Some of these questions were taken up already during the scanning itself in November 2008 when a representative from the source community in Vella Lavella, now resident in London, was invited to follow the scanning process and discuss the experience as she saw it. An interview documents how she envisages the digital canoe to be received at home.

The 3D image will be presented to the Solomon Islanders as part of poster exhibition and through a documentary film of the scanning process. It is hoped that the film as a medium will be a mediation technique in showing the scanning process. An interactive engagement with the 3D image of the war canoe will also be offered to the Solomon Islanders.

The reception of the digital object and the 3D replica of the *nguzunguzu* will be observed by anthropologists who have worked in this island, notably by Bergen Pacific Studies scholar Dr Cato Berg.

It is envisaged that the presentation of the digital object may trigger discourse about this unique and hitherto inaccessible artefact, and that local reproduction or reconstruction may even eventuate. This is in line with a current revival of war canoe building in many parts of New Georgia.

VI. CONCLUSION

The 3D image and additional reconstruction now allows holistic, if remote, experience and digital repatriation of the Solomon Islands war canoe at the British Museum.

The cutting-edge boat building technology of the islanders makes an interesting comparison to the state of the art technology used for 3D documentation.

One of the greatest values of this project has been the combination of anthropologically and technologically informed approaches, both to engage with cultural objects languishing in Western museums and to involve source communities in the restitution of their past.

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