RESEARCH ARTICLE

Creating a 3D database of Svalbard's historical sites: 3D inventory and virtual reconstruction of a mining building at Camp Asbestos, Wedel Jarlsberg Land, Svalbard

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ABSTRACT

Most of the historical sites of the Svalbard Archipelago comprise remains of whaling stations, trappers' huts and mining activities. Although most parts of Svalbard lie within the boundaries of national parks, not all cultural remains have been thoroughly documented and catalogued. The rapid development of modelling software allows for (re-)creating the shapes of some of these historical objects in three-dimensional (3D) computer space, for use in research, education and cultural heritage conservation. Ideally, a database of 3D vector shapes representing various historical sites would be made available as an open-access resource. This article shows how such a database could be started. During the summer of 2015, a 3D inventory of the remains at some historical sites in north-western Wedel Jarlsberg Land, Svalbard, was performed with the use of a Leica C10 laser scanner. One was a mining building at a site known as Camp Asbestos, in Asbestodden, in inner Recherchefjorden. Later, data on its history were gathered and a 3D digital reconstruction was done. The end result consists of: (1) a model of the building in its current ruined state; (2) a model of the assumed shape around the time of asbestos mining activities in 1921; and (3) documented changes in its shape between those time periods. We plan to perform similar documentation for other scanned objects and make all the data available via an open-access web server.

Introduction

North-west Wedel Jarlsberg Land, in Svalbard, is known for its numerous historical sites (Jasinski & Zagórski 2013). They can be divided into three distinct groups: remains of whale-hunting stations, remains of trappers' huts and remains of mining activities. Although nearly the entire Svalbard Archipelago is a national park still, not all remains have been firmly documented and catalogued (Krawczyk & Reder 1989; Avango et al. 2010; Kruse 2013). The rapid progress of three-dimensional (3D) modelling software allows for creating or recreating the shape of some of those objects in 3D computer space (Dawson et al. 2013). Although this is not the same as proper maintenance of historical objects, it can provide backup information on an object's geometry that could be used for educational and reconstruction purposes. Also, having a 3D vector shape allows for 3D printing. It would be ideal to create an open-access web server consisting of vector shapes representing various historical sites (Yastikli 2007; Pauwels 2008). This article proposes how such a database could be started.

A staff/technical building near the A/S Kulspids' mine at Asbestodden, Wedel Jarlsberg Land, was chosen to be modelled and virtually reconstructed (Fig. 1). Excavation of serpentitite, the rock from which asbestos is extracted, in the area of south of the fjord Recherchefjorden and Asbestodden was carried out by two rival companies: the Northern Exploration Company Ltd (Roll 1993; Arlov & Reymert 2001; Avango et al. 2010), which was British, and A/S Kulspids, which was Norwegian. The Norwegian company A/S Kulspids occupied parts of Asbestodden in 1907. The Northern Exploration Company erected Camp Asbestos nearby, starting a long-lasting conflict over mining rights. The area was finally deserted in 1921 and since then all facilities have fallen into decay. Today the remains of the house of A/S Kulspids are still there, but in a condition that does not allow for restoration (Roll 1993). There are almost no remains of the Northern Exploration Company activities.

Available historical information on Camp Asbestos

The asbestos mine was in operation between 1917 or 1918 and 1921. The exact dates are hard to establish since there are few records documenting the excavation process and settlement establishment. Four photographs by Anders Orvin (source: Norwegian Polar Institute), taken in about 1920 or 1921, show the original shape of the settlement (Kruse 2013; Reymert & Moen 2015). It

Figure 1. Study area (image courtesy of the US Geological Survey, Department of the Interior). The location of Wedel Jarlsberg Land (WJL) in Svalbard is shown on the inset.

consisted of two buildings. One building was placed on a flat area at the edge of a small cliff a few metres from the seashore (Fig. 2). It was constructed of horizontal beams, which were attached to support corner beams, with a pitched roof and no apparent foundation. This building had four windows, two at each side, and one entrance. It was probably used as a storage facility. No trace of this construction remains. Besides Orvin's pictures there are no records of its existence, so it was probably demolished around the time the mine was closed (Fig. 2).

Another building was placed closer to the mine's adit (or quarry), near the seashore, on a shale cliff 5 m in height (Fig. 2). The walls and roof were built of wooden boards. Its foundation was 11.50 m × 4.75 m, made of rock without masonry. The building had a gabled roof constructed of horizontal boards (wooden lining) attached to corner vertical column beams and other support column beams. From the south it was protected by another cliff, about 6 m in height. The building was placed at about 1.5 m from each cliff (Kruse 2013; Reymert & Moen 2015).
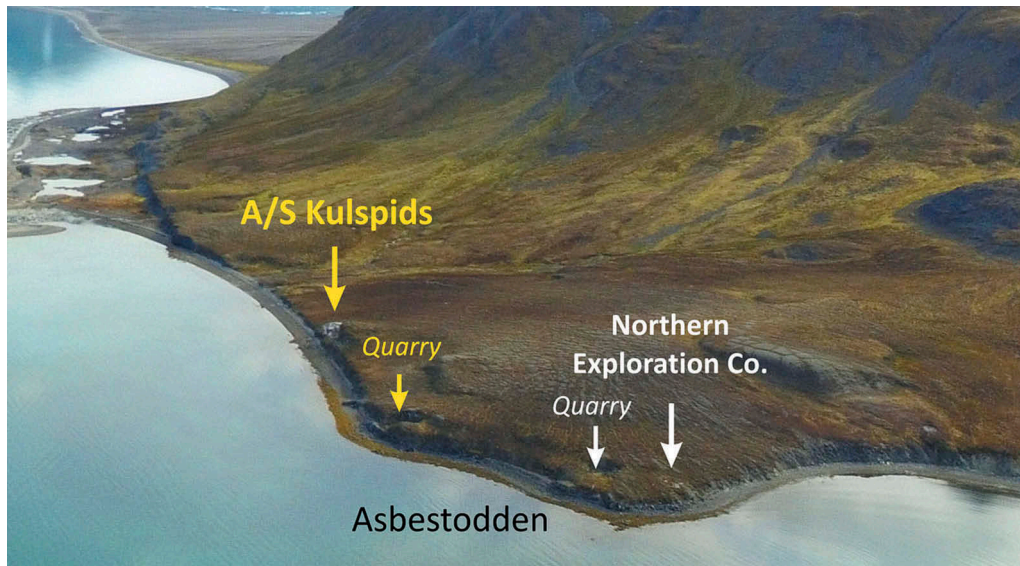
The building was divided into two parts, with two separate entrances on the south side. The western, bigger part consisted of three rooms. Upon entering, the biggest room, probably a dining area (mess), was visible. Single doors led to a smaller chamber,

probably the kitchen in which the TMU Trolla Brug No 246 oven was placed. Doors from the kitchen led to the smallest chamber, possibly a sleeping room. The second, eastern part of the building was about one-fifth the size of the western one (Krawczyk 1996). It had a small hallway and a main chamber. It could have been used as a storage room. Orvin's picture shows construction beams coming out of the building's walls (in the area of the smaller part) that could have supported a double floor or a reinforced shelf supporting a heavy load. Since no written documentation from this period is available the primary function of this chamber is questionable.

There were probably a total of seven windows at the time of construction. Orvin's photographs show one window on the north side, two on the south side and two on the east side (one locked and covered with vertical wooden beams – possibly not a window but a trap door for unloading material). Pictures of the west side were not found but later accounts show two extra windows (Krawczyk 1996).

The settlement was most likely used only during the A/S Kulspids excavation. After 1921 or 1922 the adit was buried and the buildings deserted. Records show that by 1936, windows and doors were gone and the first holes in walls and ceiling had appeared (Roll 1993; Kruse 2013; Reymert & Moen 2015). In 1970, Svein Magne Olsen and Jan Erik Bakkerud inspected the construction and "fixed up the remaining room to document" (Reymert & Moen 2015: 367–368). This might mean that by this time the smaller, eastern part had at least partially collapsed. It was in a broken-down state by 1988 and 1989 (Krawczyk 1996). One of the early records suggest that a part of building was anchored by metal beams or strings to the north cliff or surrounding rock. This support system might have failed at some point, causing the eastern part of the building to collapse.

Accounts from a visit to the site in 1989 provide some information on the shape of the building at that time (Krawczyk 1996). There were three windows on the south wall – Orvin's photographs had shown just two – and the window to the "kitchen" had been blocked with wooden beams. This could indicate that the building was used at some point after the closure of the mine, but no record of that exists. The other possibility is that during construction in about 1917 the south wall had three windows, one of which was later covered with wooden lining (arranged in panels) and was photographed this way by Orvin in about 1920 or 1921. Unfortunately, this wall is currently in terrible shape and would require extensive research in order to establish what exactly happened. By 1989 the roof of the building was missing, only the support beams were left. The north wall was missing almost all of its lining (Fig. 3). By the early 2000s the building had fully collapsed. First the smaller, eastern

Figure 2. Location of Camp Asbestos, including the facilities of A/S Kulspids and the Northern Exploration Co. (Photo Ł. Pawłowski 2016).

part had fallen. Then the eastern wall collapsed, dragging the rest of the construction down with it. Fortunately, the wall stayed mostly intact on the ground. The north wall was misshapen but support beams stayed connected, while the south wall was destroyed completely. Later, the larger part of the building collapsed. It was almost completely destroyed, and only the support beams of the north wall still lay intact on the ground. The reason for this is uncertain, but since the nearby mine adit is a spot where polar bears were frequently seen it is possible that they contributed to the current state of the structure (Fig. 4). The only elements that have remained almost untouched are the rock foundation, the floor lining and the oven. This makes it possible to confirm that the size of the building from the early records is correct. Where the panels of floor lining meet indicates the position of the building's inner support beams.
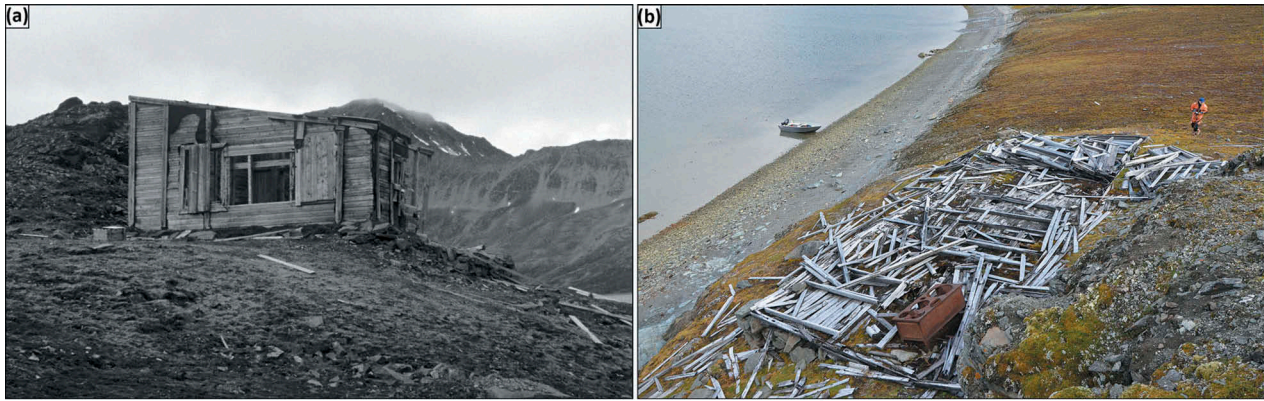
Methods

3D inventory of the structure

During the summer season of 2015 a 3D survey of the building ruins at Camp Asbestos was performed, using a Leica C10 terrestrial laser scanner (Kociuba et al. 2014; Arif & Essa 2017). Terrestrial laser provides a point cloud, which consists of a large number of points measured on the surface of the object. The survey consisted of eight scan stations that were registered with the use of high-definition surveying Leica targets and spheres.

The scanning survey took about 6 hours and included laser scanning, taking photographs with the laser scanner and photographically documenting the current state of the structure. The building itself, the surroundings and the mine entrance were surveyed. Also, three black and white

Figure 3. Anders Orvin's photographs: (a) the view of two buildings at Asbestodden; (b) south wall of the main building, with dates from 1917 until 1921 painted on the side. (Source: Norwegian Polar Institute).

Figure 4. Remains of the A/S Kulspids house in (a) 1999 and (b) 2015. (Photo P. Zagórski).

chessboard targets were placed around the construction and their locations measured with the use of a GPS receiver (Dawson et al. 2013).

Later, scans were registered with the use of Leica Cyclone software. First they were connected in local coordinates system. The average error of registration was about 6 mm, with a maximum of 12 mm. The maximum error appeared in the scan of the adit. This was due to the large distance between this scan and scans of the building. Scans were then registered into a global coordinate system with the use of measured chessboard targets. The accuracy of point cloud transformation into global coordinates was within about 37 mm. Taking into account the accuracy of GPS (assessed using corrections from the reference point known as CALY point, located at the research station in Calypsobyen, Svalbard) measurements, this result a is deemed satisfactory. The accuracy of the GPS measurements was within an average of about 30 mm for XYZ coordinates.

The final product was a point cloud: a text file that consists of a discrete model of the Asbestodden building (Guidi 2011). The coordinates of multiple points on the surface of the structure were measured and stored. During laser scanning a series of pictures were taken with the instrument that allowed us to obtain other data (RGB columns in the point cloud file): the colour of the object at each measured point. Additionally, the scanner measures the strength of the laser signal coming back to the instrument. This information is also stored in the file. Every material has slightly different reflective capabilities, so if two materials have the same colour they can sometimes be distinguished only by intensity. In this case, the distance between measured points was less than 5 mm in at least 70% of the point cloud – covering most of the building.

Producing the 3D model of the building

Point cloud preparation

After a point cloud was registered it was converted to a POD format from the default E57 or TXT formats provided by the Leica Cyclone software. POD is a default format for point clouds for all of Bentley software. It was first devised for Pointools, a cloud editing and cleaning software, and later implemented more widely in Bentley products. In the POD format points are written into a smaller file, making it easier for the hardware to deal with. This is important when working with large point clouds that represent complicated shapes. This format easily converts into all standard formats.

These prepared data were then imported into Pointools. The initial step of the virtual reconstruction was separation of the point cloud into layers that represented ruins of the building, entrance to the mine and the surrounding terrain (Fig. 5). In total, it was decided that eight major layers were needed. One layer represented the building's rock foundation. Another layer comprised the support beams – only those that could be distinguished with certainty – as well as windows, door frames and roof supports. The wall lining – all wooden elements that could be associated with the internal or external wood covering of the building – was represented in another layer. This layer included the roof and inner walls. The next two layers contained, separately, the wooden elements of the floor and the oven. All elements not associated with the building were in another layer, labelled "terrain." A final layer – "other"– included wooden elements that could not be assigned to one of the other groups. This process had to be done manually. The observer looked through the point cloud and, examining the shape of the elements as well as their colour and intensity, the observer assigned the elements to the layers described above. There are some semi-automatic ways to perform this action; however, those algorithms are usually developed for pipelines or large groups of buildings, which

makes them ill-suited to cases of small but complicated structures.

After converting the point cloud into layers, it was possible to see how each part of the material looked on its own. The "other" layer turned out to contain mostly elements that were used for building maintenance, for example, beams that were attached to the window frames to close them. Other elements may have been shelves or parts of bunk beds.

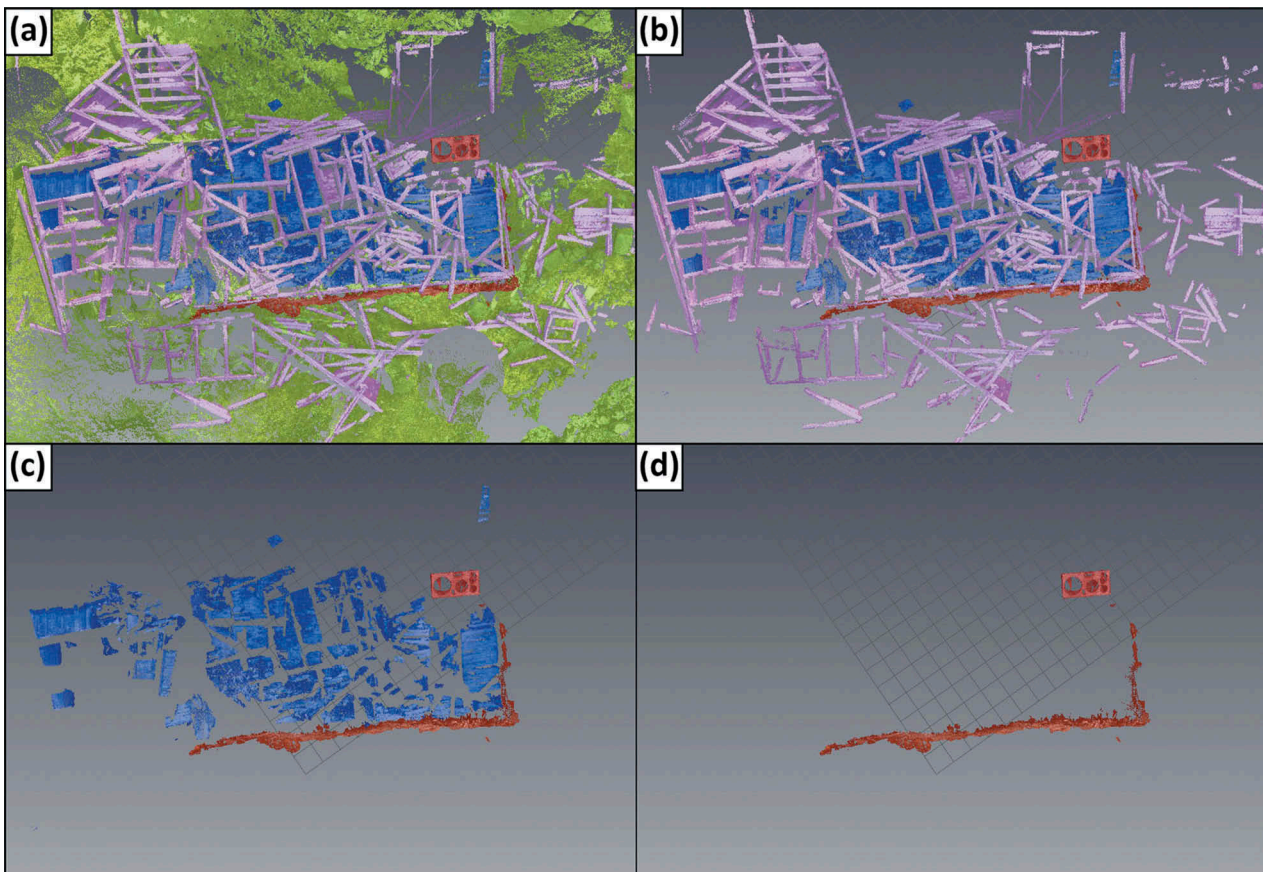The last step was creating an animation showing separate layers of the project.

Point cloud modelling

Modelling was done in Bentley MicroStation, computer-aided design software that allows for attaching point cloud as reference files and creating 3D shapes and solids (Cheng 2006; Cardaci 2011). Modelling usually consists of a few steps. First an element to be visualized needs to be recognized in the point cloud and its general shape determined by the person performing the modelling (Guidi 2011). To avoid confusion with other elements, the appropriate layer of the point cloud is opened. Still, single layers consist of too many elements to make drawing quick. The clip tool allows the user to cover the unnecessary part of a point cloud.

In order to create a vector 3D model, which is much smaller and more mobile than a discrete model, the shape of the object must be mirrored in the software's 3D space. This is done by using basic tools: draw lines, curves and surfaces. They define structures that are later converted into more complex shapes and solids. It is important to remember the topological aspect of the task. In order to use an edge shared by two objects to create two separate solids, two edges are needed. In some cases predefined solids can be used for drawing. However, since they are defined as ideal shapes (perfect cube, square, etc.), they rarely represent the actual shape of a modelled object (Ahmon 2004; Al-Kheder et al. 2009).

In the case of Camp Asbestos, the drawing was done layer-by-layer. The least time-consuming was the floor. Since all of the lining was made of boards of almost identical shape and size, it was enough to draw just one of them and then copy and edit or rotate to the shape that they achieved with years.

Since the support beams were scattered around the area and also often broken or twisted it was necessary to draw each of them separately. This allowed for better identification of the original usage of elements visible on the scan. We decided to draw only elements that kept some form of shape or structure after

Figure 5. Point cloud separated into layers: (a) the terrain (green), floor (blue), support beams (pink) and foundation (red) layers; (b) three of the layers; (c) two of the layers; and (d) the foundation layer.

they collapsed. Four elements fulfilled these requirements. Support beams of the eastern part's east wall were one of them. This included window frames, some part of the lining (close to the roof) and extra boards that were used to cover the windows. The other element was about two-thirds of the north wall of the western part (not including the doors, but including parts of the window frames). Also, some part of a west wall was found. The last element had been assumed to be a part of the roof or of the south wall but later it was discovered that its shape did not fit the necessary dimensions. This element was left out of further processing since no apparent connection to the rest of the structure was discovered (Fig. 6).

The last task consisted of creating a model of the building's foundation. Modelling each rock would be time-consuming and unnecessary, so a different visualization method was used. Thirty percent of the foundation layer was imported to MicroStation as a group of points (not a point cloud). Later those points were connected into a triangle model that represented the object. Not all points were imported on account of the hardware capabilities of the computer.

The accuracy of the model can be estimated from two factors. Accuracy of the point cloud (including survey error and registration error) and the average distance between point cloud (of each modelled object) and the model. The latter never exceeded ±4 cm and the point cloud accuracy was 3.7 cm. It can be estimated that the average error was ±4 cm.
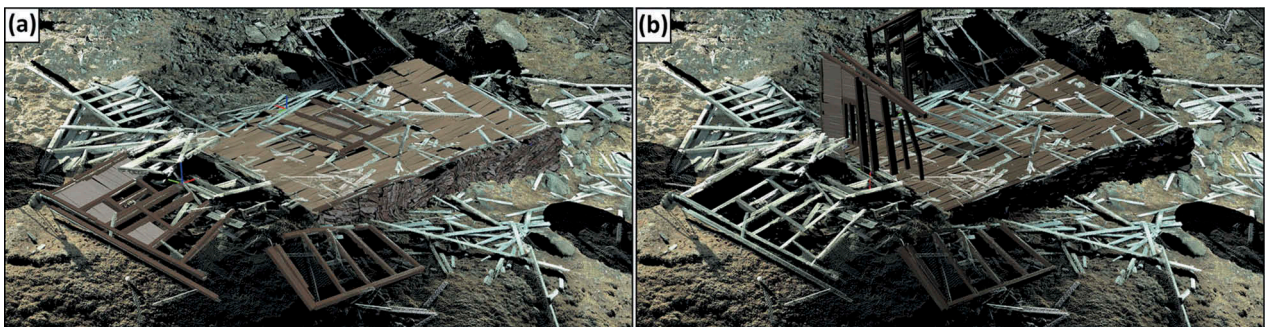
3D virtual reconstruction of the structure

After creating a 3D model of the structure's existing elements, virtual reconstruction was attempted. First, modelled parts of the building's walls were placed in their proper place. Those elements were lifted and rotated but were not straightened. The virtual reconstruction was treated as a real reconstruction so no
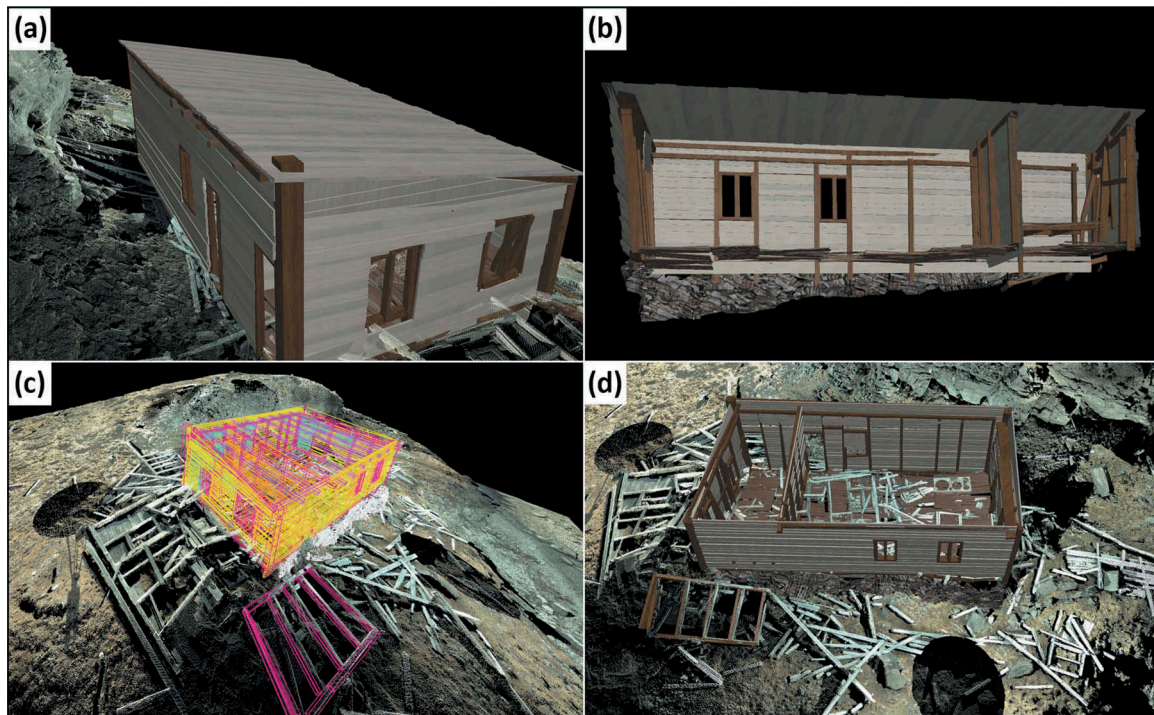
unnecessary modification to the shape of the remaining elements was done (Fig. 5).

The rest of the elements needed to be estimated from historical data. According to photographs dating from 1921 and 1989, the support beams of the north and south wall should be placed where panels of floor lining connect (Krawczyk 1993). This theory was supported by modelling part of the north wall, where the distance between the middle of vertical support beams was roughly the same as the length of floor lining board. This way, the vertical beams on the north and south walls were placed. On the east wall, after placing the modelled element, there was only enough space to place one more support at the edge of the building. This wall was later copied and edited into the west and middle walls. Information on placement of the middle wall was taken from Krawczyk (1993), and was also consistent with the idea that the middle wall would have stood where the two panels of floor linings met. The height of all of those structures was taken from model elements and checked (Reymert & Moen 2015).

The next step was to reconstruct the shape and placement of the windows. Large parts of the east and west windows were modelled from the point cloud. Also, one window on the north side was almost entirely modelled, providing the basis for all north and south windows. Since there was no modelled part of the south wall, the windows were placed in accordance with the few available photographs of this area of the building. These photographs were not good quality, so the position and shape of these windows on the south wall may not be as accurate as the modelled windows for which there are better photographs and an appropriate number of scanned elements. As for doors, none of them could be modelled, but a big part of one support beam with readily identifiable parts of doorway was found on the point cloud. It was too decayed to be modelled but in good enough shape

Figure 6. 3D model of the A/S Kulspids building remains at Camp Asbestos: (a) in their position in 2015 and (b) modelled elements in their estimated original position.

Figure 7. The reconstruction of the A/S Kulspids building: (a) full model with textures; (b) a cross-section (east–west) through the inside of the building; (c) wireframe model; (d) inside of the building with the roof taken off.

to measure the dimensions of the frame, and the width and height of its placement in relation to the support beam. This information allowed for a rough reconstruction of the shape and placement of this doorway. The doors to the bigger part of the building were copied from this and placed in accordance with a rough sketch made by Krawczyk during his visit in 1989 (Krawczyk 1993). There was no point cloud information that allowed us to determine with certainty the size of the roof support system. Photographs from 1921 and 1989 show the number of support beams and since records state that all the building's elements were prefabricated elsewhere and then brought to Camp Asbestos it can be safely estimated that their size should be similar to those of the walls. Taking this into consideration, the appropriate beams were placed (number and dimensions) into the structure. The shape and the size of the wall lining was estimated from the laser scan and later confirmed with Orvin's photographs. Those elements were reconstructed separately and placed on the model's support beams. There is little information on the cover of the roof so wooden boards were placed onto it.

Results

A 3D model of the estimated shape of the A/S Kulspids building was produced. This model can be edited, so if new data appear it can be incorporated to make the model more accurate. It is worth mentioning that the project aimed at recreating the building as it was in 1921. However, our research revealed that the building's shape had been modified during the years that it was in use, for example, the number of windows had changed. Therefore, a second, slightly edited, model was created. Figure 7 shows the final 3D model of the building's shape in 1921.

Visualization and animation

After creating a wireframe or a solid model it was important to present it in a more realistic form. MicroStation allows users to cover drawn shapes with textures – bitmaps that consist of information on the colour of elements and their physical features (shine, reflectiveness, grain, etc.) so as to make final product more photo-realistic (Ahmon 2004; Al-Kheder et al. 2009). In the case of the A/S Kulspids building, only a few textures were used. Four kinds of wood were chosen, one for support beams and the others for the lining. Also, a rock texture was chosen for the foundation (Fig. 7). During the visualization stage multiple light and environment options ware used in order to better visualize the building's overall appearance and its features. This allowed for better utilization of the different render types (Fig. 8).

Animations were done in a few versions. A wireframe model was animated in order to show the number of modelled and reconstructed wooden elements. Then a cross-section of the textured model was animated to show the inside of the building. The

last animation consisted of complete model placed on the point cloud representing the surrounding terrain (Fig. 7, 8). This animation can be viewed here: https://www.youtube.com/watch?v=Y1KFyW96QJA

Raster-textured 3D model

After creating a 3D wireframe model, an attempt was made to create a raster-textured model. In order to achieve that, a very general 3D model of the structure was needed. It consisted of four outside walls, roof support beams, roof, corner support beams and foundation. Textures were created using the 1921 photographs.

The Descartes module of Bentley's Microstation software allows for converting photographs and raster images into textures. In order to perform this action at least four corresponding points on a model and on the photograph/raster must be pointed. The software needs to be informed that a particular point on the model (usually vertex of a vector model) corresponds with particular pixel on a raster. Orvin's photographs were done from a large angle (the target axis of the camera was far from perpendicular to the wall) but with a good quality camera. This allowed the software to cover the model with pictures with a surprisingly good visual result. In this case, the transformed rasters were saved as image files and used to create proper textures (visible from all points of view and including features like shine or bump).

Since those photographs were taken almost 100 years ago and the building is a ruin, it is hard to estimate the accuracy of this model. However the placement of modelled and textured windows line up with an average accuracy of 17 cm. This model provides better information on the position of signs and graffiti on the building's south wall (Fig. 8), stating the building's company name and possibly the years of excavation: 1917 until 1921.
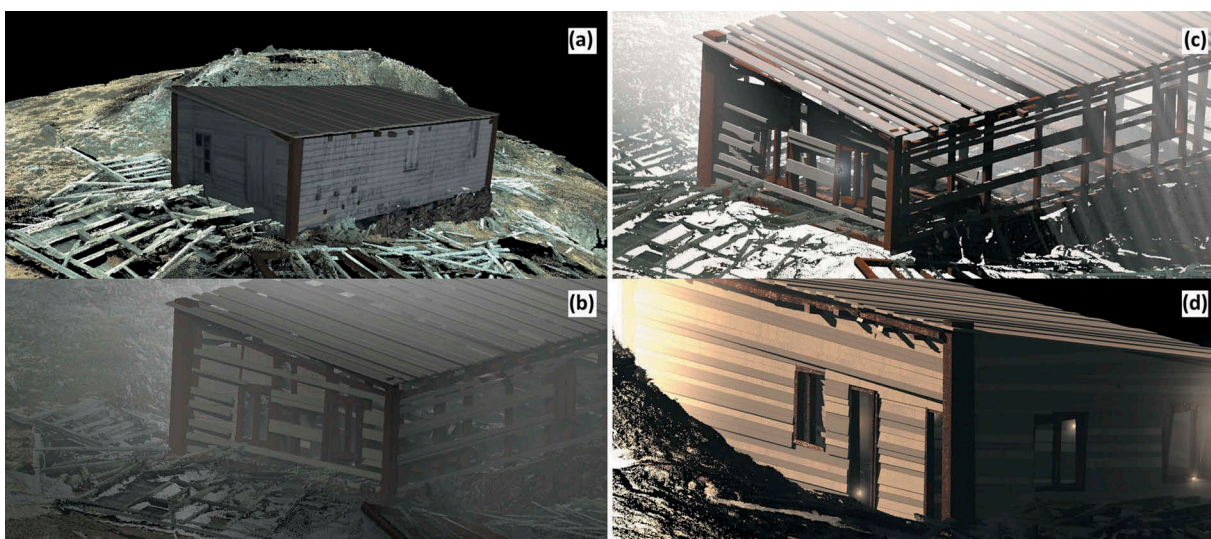
Conclusion

A 3D inventory and virtual reconstruction can prove to be very useful as a means of storing spatial information on vulnerable or fragile cultural heritage objects (Cheng 2006; Napolitano 2017). It could be even more important in remote places like Svalbard that do not allow for constant observation and maintenance of historical sites (Yastikli 2007; Rüther 2009). Such objects could be stored in a 3D database and, if needed, destroyed parts could be physically reconstructed using these data. A 3D print would also be available, which would be useful for a physical reconstruction project. Smaller 3D prints can be produced for museums and interactive exhibitions (Pauwels 2008).

Another benefit of such a programme would be easy access of the public to historical data (via an open-access web server). It could be used for educational purposes, in connection with learning about the exploration and settlement of Svalbard. A 3D model can be used not only as a basis for animation but also a 3D tour, educational computer games, etc. Field trips are expensive and have a negative impact on the natural environment and on historical sites.

The biggest benefit is the fact that 3D models can be edited at any time and implemented in many kinds of 3D software. If new information comes to light the model can be updated. Nowadays most computers are fully capable of working with such data, making such virtual reconstructions universal and relatively inexpensive.

Acknowledgements

Figure 8. (a) Raster-textured 3D model of the south wall in 1921 of the A/S Kulspids building; (b, c) stages of decomposition of the building in various visualization/light/environment options, south wall; (d) full 3D textured building south wall.

Fjeldstad (University Centre in Svalbard Library) for all the help with gathering historical data and translation.

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References

Ahmon J. 2004. The application of short-range 3D laser scanning for archaeological replica production: the Egyptian tomb of Seti I. *The Photogrammetric Record 19*, 111–127.

Al-Kheder S., Al-Shawabkeh Y. & Haala N. 2009. Developing a documentation system for desert palaces in Jordan using 3D laser scanning and digital photogrammetry. *Journal of Archaeological Science 36*, 537–546.

Arif R. & Essa R. 2017. Evolving techniques of documentation of a world heritage site in Lahore. In J. Hayes et al. (eds.): *The international archives of the photogrammetry, remote sensing and spatial information sciences. Vol. XLII-2/W5.* Pp. 33–40. Hannover: International Society for Photogrammetry and Remote Sensing.

Arlov T.B. & Reymert P.K. 2001. *Svalbard: en ferd i fortidens farvann. (Svalbard: a journey into the past.)* Trondheim: Tapir Akademisk Forlag.

Avango D., Haas H.R. De & Kruse F. 2008. *LASHIPA 3: archaelogical expedition on Spitsbergen August 7-24, 2006.* Groningen: Arctic Centre, University of Groningen.

Cardaci A., Mirabella Roberti G. & Versaci A. 2011. From the continuous to the discrete model: a laser scanning application to conservation projects. In F. Remondino & S. El-Hakim (eds.): *International archives of the photogrammetry, remote sensing and spatial information sciences. Vol. XXXVIII-5/W16.* Pp. 437–444. Hannover: International Society for Photogrammetry and Remote Sensing.

Cheng X.J. & Jin W. 2006. Study on reverse engineering of historical architecture based on 3D laser scanner. *Journal of Physics: Conference Series 48*, 843–849.

Dawson P.C., Bertulli M., Levy R., Tucker C., Dick L. & Cousins P. 2013. Application of 3D laser scanning to the preservation of Fort Conger, a historic polar research base on northern Ellesmere Island, Arctic Canada. *Arctic 66*, 147–158.

Guidi G., Remondino F., Russo M., Menna F., Rizzi A. & Ercoli S. 2009. A multiresolution methodology for the 3D modeling of large and complex archeological areas. *International Journal of Architectural Computing 7*, 39–55.

Jasinski A.M. & Zagórski P. 2013. Human activity. In P. Zagórski et al. (eds.): *Geographical environment of NW part of Wedel Jarlsberg Land (Spitsbergen, Svalbard).* Pp. 316–359. Lublin: Maria Curie Skłodowska University Press.

Kociuba W., Kubisz W. & Zagórski P. 2014. Use of terrestrial laser scanning (TLS) for monitoring and modelling of geomorphic processes and phenomena at a small and medium spatial scale in polar environment (Scott River – Spitsbergen). *Geomorphology 212*, 84–96.

Krawczyk A. 1993. Remains of seasonal settlement in Wedel Jarlsbeg Land, Spitsbergen, Zeszyty Naukowe Uniwersytetu Jagiellońskiego. *Prace Geograficzne 1993*, 131–170.

Krawczyk A. 1996. Remains of human activity in north-eastern Wedel Jarlsberg Land, Sptsbergen. In J. Repelowska-Pękalowa & K. Pękala (eds.): *Wyprawy geograficzne na Spitsbergen. (Geographic expeditions to Spitsbergen.)* Vol. 7. Pp. 55–71. Lublin: Maria Curie Skłodowska University Press.

Krawczyk A. & Reder J. 1989. Remains of seasonal settlement in the north-west part of Wedel Jarlsberg Land. In J. Repelowska-Pękalowa & K. Pękala (eds.): *Wyprawy Geograficzne na Spitsbergen. (Geographic expeditions to Spitsbergen.)* Vol. 2. Pp. 131–146. Lublin: Maria Curie Skłodowska University Press.

Kruse F. 2013. *Frozen assets: British mining, exploration, and geopolitics on Spitsbergen, 1904-53. Circumpolar studies 9.* Groningen: Arctic Centre, University of Groningen.

Napolitano R.K., Scherer G. & Glisic B. 2017. Virtual tours and informational modeling for conservation of cultural heritage sites. *Journal of Cultural Heritage 29*, 123–129.

Pauwels P., Verstaeten R., De Meyer R. & Van Campenhout J. 2008. Architectural information modelling for virtual heritage application. In M. Ioannides (ed.): *Digital heritage. Proceedings of the 14th International Conference on Virtual Systems and Multimedia.* Pp. 18–23. Budapest: Archaeolingua.

Reymert P.K. & Moen O. 2015. *Fangsthytter på Svalbard 1794-2015. (Hunting cabins in Svalbard, 1794-2015.)* Longyearbyen: Stiftelsen Svalbard Museum.

Roll L. 1993. The remains of the early industrialization of Svalbard as cultural heritage. In J. Repelewska-Pękalowa & K. Pękala (eds.): *XX Polar Symposium. Man impact on polar environment.* Pp. 47–54. Lublin: Maria Curie-Skłodowska University.

Rüther H., Schroeder C.R., Neeser R., Held C., Walker S.J., Matmon A. & Kolska Horwitz L. 2009. Laser scanning for conservation and research of African cultural heritage sites: the case study of Wonderwerk Cave, South Africa. *Journal of Archaeological Science 36*, 1847–1856.

Yastikli N. 2007. Documentation of cultural heritage using digital photogrammetry and laser scanning. *Journal of Cultural Heritage 8*, 423–427.