

Using 3D Digitization in the Preservation of Industrial and Agricultural Heritage

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Abstract

The project titled 'Diving into the Machine' explores the use of existing 3D technology for the preservation and dissemination of industrial and agricultural heritage objects. The project runs a series of case studies purposely identifying best practices for the use of 3D models in collection management and presentation. The digitization technologies used vary in quality, efficiency and cost. Each case study researches the sustainability of the 3D files produced and the feasibility of applying them in collection management practice. The project advocates the sustainable use of 3D technology by heritage organizations and raises awareness among 3D service providers about the use of archival standards and guidelines for producing sustainable 3D documents.

Introduction

The 'Diving into the Machine' project was set up by different partners in the Flemish heritage industry, more specifically the museums Texture and MIAT, the project institutions CO, and zuidwest and the centers of expertise CAG, PACKED, ETWIE, CVAA and VIAA, because a need for in-depth digital preservation of the industrial and agricultural (I&A) objects was felt. The project is largely financed by the Flemish Government.

This project is unique in its kind since it tackles a wide range of preservation questions, offering different digital solution strategies. That is why we find it important that the project results are widely dispersed. In this manuscript we will share our experiences with some of the case studies thus far, while explaining the basics of 3D data. We want to inspire and encourage museums and institutions to get to work with 3D technology in order to achieve collections management goals in new and refreshing ways.

Industrial and Agricultural Objects

The industrial and agricultural heritage covers a broad range of not only tools, machines, places and buildings, but also knowledge, practices and stories that illustrate the industrial and agricultural/agrarian history of a region. As physical evidence of the industrial (r)evolutions that shaped the 19th and 20th century, museums and institutions consider it their task to collect and preserve this heritage. To involve the public, it's necessary to do research on the objects in order to understand its functioning and its historical background.

Challenges

In practice, the preservation of these objects is a considerable challenge because of their proportion and specific build. It is important to not only preserve, but also understand how the tools and machines functioned. This knowledge allows historians and sociologists to put these evolutions in a wider historical and social frame.

As opposed to smaller, historical objects that are put under perfect conditions in depots or museums, I&A heritage consists mainly of massive machines that are stored in their 'natural'

environment like sheds or shelters. While forces of nature have easy access to these places and the objects in it, the public has not. Losing these objects means that in time the knowledge of certain techniques gets lost and leads to a poorer understanding of industrial and agricultural evolutions, and linked to this a poorer understanding of mankind in his economical and sociological environment.

While most historical objects are preserved because of the characteristics in the object itself, industrial and agricultural machines are mainly important because of their functioning. This is not always visible from the outside. Most historical objects in the I&A field are massive metal or wooden structures with the technology on the inside. Without historical documents or living witnesses it's difficult to understand how the machine functioned. Taking the machines apart is a risk for the historical object itself, and because of that is rarely pursued. Restoration towards a working object (for educational and public disclosure) is difficult because older parts are no longer available.

Solution

A digital representation of the I&A objects opens a door to accessible knowledge sharing and alternative means of preservation. Looking at the technology that is used nowadays to define and demonstrate newly developed I&A objects, we found that 3D digitization is most suitable to apply to these heritage objects. 3D models form a comprehensible digital presentation of an object besides being the perfect starting point for (interactive) storytelling.

Goal 1: Making the Perfect Copy

In modern day industry, a machine is fully created in a digital environment. Every component is designed using a CAD (Computer Aided Design) software. By digitally assembling the components one can easily notice and correct design errors before ever spending money on resources, personnel and prototyping methods. If we would like such a detailed CAD model of an I&A object we would have to move the process backwards and 'Reverse Engineer' the I&A object. This can be done on a more detailed or less detailed level.

The Flax Scutching Turbine

The Vansteenkiste Flax Scutching Turbine of project applicant Texture, museum of flax and river Lys, is a top collection piece. Unfortunately a demonstration of the Turbine to the audience is impossible due to safety hazards and ecological reasons. Even if a demonstration of the machine was possible, it would still be difficult for the audience to see the impact of the scutching knives on the flax. Texture decided to test various 3D digitizing techniques on the Turbine in order to determine in what extend the machine can be preserved and disclosed digitally.

Check the Archive

First things first: check whatever information you can find on the collection object. Some information is priceless when it comes to digitization. If you happen to own technical drawings of the

machine you have already solved half of the puzzle. Although some very useful drawings of the machine were found, there were no detailed technical drawings in the museum archive. In the course of the full project it would become clear that complete technical drawings of collection pieces are a rarity. They can be found in company archives, but because of intellectual property issues the companies are not keen on sharing this information.

Reverse Engineering

A straightforward method of reverse engineering is to measure and sketch the machine (components) by hand. The technical sketches then become your CAD-modeling guidelines. It is easy, but time consuming and therefore a nice way of digitizing the machine making use of museum staff, volunteers or students. An extra drawback: hard to reach components might not be measured and modeled correctly.

These days 3D scanning is a commonly used technique for measuring an object. The scutching turbine was submitted to the technology of '3D laser scanning' in order to CAD model with an accurate point cloud reference. Since the point cloud is used as a reference, the CAD model will be as crooked as the real deal. Although very accurate, it can be a quite disadvantageous model for subsequent digital results since the crookedness does rarely allow alignment to the XYZ-coordinate system.

Using the CAD Model

CAD models are quite detailed and in this regard contain a lot of information. The CAD models of the scutching turbine were perfect for creating technical results such as an exploded view, technical drawing, motion simulation and 3D print. Texture also wanted a virtual reality app of the working machine. Therefore the technical CAD model needed to be converted to a 'low poly model'. The conversion of a CAD model to a polygonal model is not very difficult, reducing the polygon count afterward is. Luckily software developers are working hard on facilitating this process.



Figure 1 Low poly model generated from CAD model in visualization setup – Scutching Turbine

Saving the data

When a CAD model is designed, the CAD software keeps track of 'part history'. You are easily able to adapt an earlier design operation (e.g. changing the diameter or depth of a hole). When doing so, this will affect all following CAD operations which will update automatically. Unfortunately, the abundant CAD-file information can only be saved to the proprietary file format. When the CAD model is exported to an open file format, all design information is lost and only a plain shape remains.

For CAD assemblies, comprising several CAD models, different files are linked. Constraints are imposed on the

components so they would be positioned accurately in the assembly and remain that way if a motion is granted to one of the components. Just like with a single CAD model, one can export the assembly to an open format, but then again all constraint information is lost. When the proprietary files need to be preserved in a different location, the referenced file structure needs to be taken into account. Since specified paths may not likely be found on another location or device, the folder cannot be simply copied. The assembly of the Scutching Turbine was created in Autodesk Inventor, which contains the functionality of copying the files to a bundled 'Pack and Go-folder'. This folder represents a complete archive of copied files needed to load the assembly, despite the moving of file location. Undoubtedly other CAD software offer similar solutions.

Since a CAD software uses NURBS (Non-Uniform Rational B-Splines) to build up models, when exporting the model, you preferably use file formats such as *.IGES or *.STEP. Exporting the file to *.STL will triangulate the model and thus transform it into a polygonal model.

Hop Picking Machine

Every year The Themilco Hop Picking Machine is moved to the Hopmuseum's courtyard to compete against human hop-pickers. The rest of the year the winning hop-picker is not publicly accessible and is stored in a local farmer's barn. To visualize the machine digitally in the museum, an overview of the machine's interior and exterior components needed to be mapped.

X-ray imaging

An option for 3D digitization that we found necessary to explore was the making of a CT-scan. But was there an industrial scanner big enough to contain The Hop Picking Machine? Surprisingly, such a large CT-scanner exist in Fürth, Germany. However, a successful result could not be guaranteed and since the cost of the scan would far exceed budget due to estimated scan time and logistical challenges, we decided to go for the 2D alternative. The Hop Picking Machine was put on a trailer and transported to the Antwerp harbor. At the harbor, container content is checked at customs using X-ray imaging. Since the scan tunnel is built for trucks this technology could easily be used on agricultural machines. The X-ray image is quite revealing. However, because of the occurring distortion, it is difficult to interpret the image on first sight.

Eventually the CT-scanning option was explored on a Singer sewing machine that could be scanned locally. Because of ray deflection between the different layers of metal there was a lot of 'scattering' in the 3D *.STL - file, which made it practically impossible to use.

Point Cloud and Mesh

Furthermore, The Hop Picking Machine was 3D laser scanned using both a handheld scanner (low range) and a tripod scanner (high range). The handheld scanner was able to produce a more detailed point cloud. However, because of its high range, the tripod scanner can facilitate the capturing of areas that are hard to reach. Of both point clouds a mesh was generated using Pointfuse-software. A mesh is generated by connecting different points, building triangles, thus creating a triangulated polygonal model. Because of scattering in the point clouds, the results were not optimal. In the course of the project we saw how quality of mesh generating software is improving for the more complex shapes (such as machines). We expect that 'point cloud to mesh' might become a desirable solution to digitally preserve exterior

representation of I&A in the near future. Currently results are still poor.

The technique of photogrammetry seems more approachable for the I&A heritage sector than 3D scanning, since it seemingly requires no expensive hardware, software or specific expertise. Together with the local photo club a series of high-resolution photos of the machine were shot. The photos were processed into a point cloud and mesh using 'Agisoft Photoscan'. The point cloud and mesh were of a lesser quality than the 3D laser scanned versions. However, the generated texture was much better than the one generated with laser scanning and largely made up for the bumpy point cloud and mesh.



Figure 2 Point cloud made by handheld laser scanner – Hop Picking Machine



Figure 3 Mesh generated from point cloud in figure 2 – Hop Picking Machine

Saving the data

The X-ray image was delivered to us as *.TIFF format. The CT scan data of the sewing machine however was not that accessible. We received 3.143 x-ray images in *.TIFF format, accompanied by a 30GB voxel cloud (*.VOL) and a 260MB *.STL file. We were unable to find software to open the voxel cloud and the *.STL was so large and had so much scattering that it caused a computer hang. Because of all the metal components it is hard to know in advance if the scanning will succeed. Before getting on with CT-scanning I&A heritage we recommend you to perform a test scan. Despite potential failure, CT-scanning is a feasible way of digitizing interior structures and components of I&A objects.

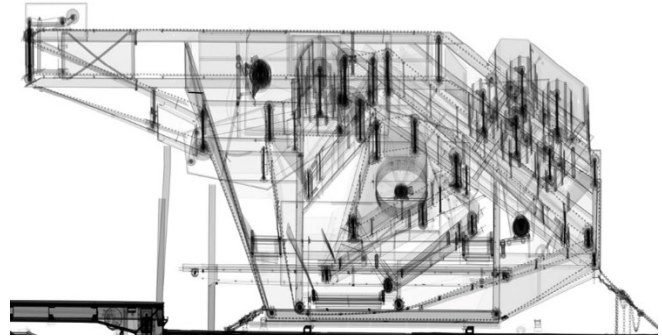


Figure 4 X-ray image – Hop Picking Machine

In the case of photogrammetry, it is more interesting to preserve the photographs than the generated point cloud and mesh. There is yet a lot of knowledge available on the preservation of photographic media and most institutions manage desirable software and expertise to handle the digital photographs. Photogrammetry software can only improve, so in the future better 3D models could be generated.

The point cloud data generated through 3D laser scanning is quite large (millions of points). Yet the data is not complex in itself since each point only needs an XYZ-coordinate and optionally an RGB color code. In the case of photogrammetry the point cloud is scaled and less dense. As collection data, a point cloud made with 3D scanning instead of photogrammetry is more desirable since it contains accurate information on machine dimensions and measurements.

Goal 2: New Opportunities for dissemination

3D polygonal models, or poly models, are often used for visualization purposes. Although the models contain less technical information, a visual representation of a working machine is often a desired type of collection information. As discussed, the CAD model makes for an accurate digital representation of reality. A poly model is only a digital approximation of the wanted 3D shape. Just as the name suggests the polygonal model is built using polygons. This means a curved model is not actually curved, but segmented or faceted. Poly models ask for less computing power in scene built-up and rendering than CAD models do. Nonetheless with the right 'scene, light, material and render settings' a visually impeccable image can be generated. We can distinguish two types of visualizations, namely: the pre-rendered visualizations and the real time applications.

Spinning Mule or Mule Jenny

The Mule Jenny is the name that Lieven Bauwens used for his copy of Samuel Cromptons Spinning Mule. Lieven smuggled the Mule out of England in order to duplicate the machine and deploy its evolutionary spinning technology for the gain of his own enterprise. Ever since, the name 'Mule Jenny' is locally used to refer to the famous semi-automated spinning mules that changed the face of the Flemish textile industry. The exact origin of this Mule Jenny is unknown, but there is no doubt about the rarity of the top collection piece that can be found at MIAT, the museum about industry, labor and textile.

Operating the mule

Since we found that 3D scanning a machine makes for an affordable and applicable information format, we did not refrain to

use it in various case studies. In the case of The Mule Jenny the point cloud was used as a reference to polygonal modeling. Although less accurate than the reverse engineering of the Scutching Turbine, the polygonal model could immediately be used to build an interactive application - there is no need to reduce polygon count.

A last year 'Digital Arts & Entertainment-student' of Howest University developed an application which allows visitors to virtually operate The Mule Jenny. The application makes use of a Kinect which is a motion sensing input device for Xbox. Instead of using a game controller a person's motions are captured in order to launch a game command. With this technology a user can experience firsthand what it is like to control The Mule Jenny since he's required to perform specific operating movements. For some it is more fun than reading about the mule and the experienced knowledge seems to stick better. Disadvantages are that the museum needs to provide enough space to set up and operate the installation. Also the technology is not failsafe yet. MIAT however is keen on having the application further developed so it can be used in the new collection setup.



Figure 5 Test of Kinect-application – Mule Jenny

Saving the data

Game-like applications pose a new challenge when it comes to preservation. Their specific programming only allow launching with the designated operating system. The development of emulators could be helpful.

Retting Factory

A retting factory is an ingenious building that can be regarded as an enormous concrete machine. When flax is retted, the pectin compounds inside the flax stem are being dissolved. This allows for the linen fiber to be separated from the short flaxen fibers. The pectin can only be dissolved by means of a natural decomposition process using water. A retting factory consists of a rooftop water reservoir, a boiler, different sets of pipelines and watertight retting pits. The initially pumped up water is moved throughout the factory using only physics. Since the factory is located several miles West of the museum Texture, a digital presentation of the factory workings is desirable.

Set up scene

A building is much easier to model than a machine. Instead of designing the factory brick by brick, only the basic volume is modeled. Afterward a brick texture can be applied in order to make it look realistic. By using additional texture maps, such as normal maps, the software is told to render (i.e. the generating of a digital image from a 3D model) a certain depth and shading. For the

retting factory there was no desire to create a photorealistic scene, the different volumes are rendered only with a diffuse color.

Creating an animation

Since there are no moving objects or camera viewpoints in the scene, there is no need to render an entire frame by frame animation sequence. With Adobe After Effects the flow of the water is illustrated and animated on the still images.

Saving the data

Multimedia is preferably preserved as standardized formats such as *.MPEG or *.MOV.

Goal 3: Restoration

As discussed, 3D models can be used to derive and communicate technical information, or they can be used for visual and interactive applications. There is yet another museum goal that can be achieved using 3D technology: the one of restoration. It speaks for itself that spare parts for I&A heritage objects are rarely found in the local hardware store or on the internet. Sometimes it is beneficial to reconstruct the spare parts by manual machining, sometimes it is more beneficial to use CNC (Computer Numerical Control) technology. In the first case, a technical drawing derived from a CAD model as mentioned earlier can come in handy. In the latter case you want to use your 3D model to let a CAM (Computer Aided Manufacturing) software program the machining operations.

Mechanical Calculator

The case of the Burroughs Calculator was presented to us by a private collector named Steven. Steven had struck a bargain at an antique market and managed to acquire a mechanical adding machine from around the 1900s. Unfortunately the machine was missing the lever that actuates the calculating mechanism, meaning the old calculator was only good for display. Steven had inquired about the machine with museums and other collectors, wondering if they might have a spare handle to actuate the calculator. Unfortunately the right type of handle is hard to find. Undoubtedly Steven is not the only collector that has to deal with this problem.

3D as open source

How lucky were we when we found out that one of the collectors that Steven contacted had made a CAD model of the functional part of the handle using the open source software 'Designspark Mechanical'. The component was altered in a way that rapid prototyping was a viable solution to create a working handle using a wrench. Sharing the part via an online 3D printing library such as 'Thingiverse' would be a great way to help other collectors restore their own Burroughs Calculator.



Figure 6 Selective Laser Sintered part – Burroughs Calculator

Get calculating

The part was first 3D printed in a plastic material to make sure it fitted the machine. Trying to operate the prototyped handle, we found that the mechanism offered too much resistance. It was very likely that the machine mechanics were blocked due to a too long working pause. At the University of Ghent a ninety year old calculator mechanic volunteers at the campus' Science Museum. He found and fixed the error and together with some colleagues he gave the calculator a full maintenance. A technician that works there turned the functional handle-piece and mounted it to an old crank that served no purpose thus far.

The right amount of skill, time and passion obviously gets the job done. We did not refrain to execute the restoration through 3D printing though, since we want to offer an alternative to private collectors and perhaps museums. The part is printed using a cheaper material and process (aluminum reinforced plastic part through 'Selective Laser Sintering') and a more expensive material and (post)process (solid metal part through 'Selective Laser Melting'). In the 3D print file, 3D printer tolerances were taken into account so any type of print should fit the calculator. The part will be accessible for download in an online 3D print library.

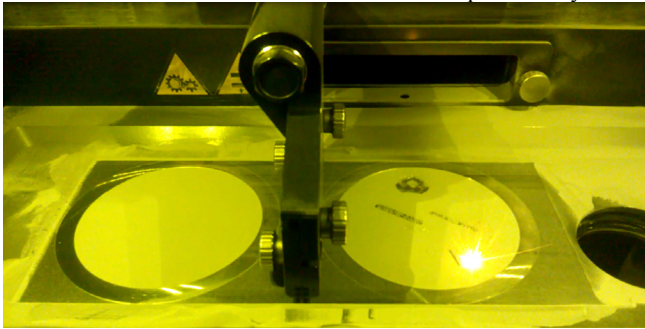


Figure 7 Selective Laser Melting of several parts – burroughs Calculator

Saving the data

When slicing a polygonal model along the Z-axis, the sliced surface will show a polygon profile. Corner Points are connected by straight lines. The path of the profile can be traced from one XY-coordinate to the next. That is why a polygonal file is the perfect type of CAM file. A high poly *.STL of the 3D print file is perfect for print and preservation.

Conclusion

3D technology offers a vast amount of possibilities when it comes to the digital preservation and dissemination of I&A objects. That's why it is important to work goal oriented when applying it. In acquiring 3D data and derivatives, collections managers will quickly find themselves having to deal with an abundance of digital data and limited knowledge on how to access it and keep it accessible for future generations. We recommend that with every consideration of using 3D technology for collections management, sufficient research is done on the different possibilities. The best way to do this is by consulting an expert. When your focus is on restoring an object, or on having a more technical result for archival purposes, you might want to contact someone with an engineering profile. When your focus is on creating a product for exhibition purposes, you want to contact a 3D-artist. When you're not sure, research institutions can help out. Take your time to define your goals and do not solely focus on

getting them solved by using 3D technology. The use of 3D is often only a part of the puzzle.

The 3D source files would be the most interesting files to preserve if it was not for the proprietary format they require. Most of these files are likely to get outdated for the designated software. Besides that, a lot of these files are not made with open source software and regularly updating them would be a costly undertaking. It is recommended to come to terms with the supplier beforehand. Can he help guarantee long term preservation by supplying the source file in an open source format? Can he, depending on what purpose is aspired, make file-exports to open file formats such as *.STL or *.STP? For multimedia results you should instruct the supplier to use a standard file format like *.MPEG. We also recommend to inquire if the files can be shared online using a Creative Commons license, preferably CC-BY-SA, to stimulate creative reuse, data propagation and migration, while managing the traceability of the data. Ultimately it is wise to paraphrase the cause for development of the data, the development process, the acquired data and information on the supplier and the preservation goals and strategies into a collections management policy.

Author Biography

Tine Verroken studied Industrial Product Development at the University College of West Flanders - Howest and is currently working at Texture, Museum of Flax and river Lys. Throughout her studies and previous work experience at the Industrial Design Center in Kortrijk she managed to acquire an extensive knowledge on 3D digitization. Currently she is coordinating the project 'Diving into the Machine' on which this paper proposal is founded.

Bert Lemmens from PACKED, Centre of Expertise in Digital Heritage, provides support for organisations digitizing cultural heritage collections. He is work package leader in the PREFORMA PCP project. For the ArchiAfrika foundation he has researched colonial and post-colonial architecture. Hence he worked on projects for the Dutch Architectural Institute in Rotterdam, Amsab-Institute for Social History in Ghent and the province of East-Flanders. He holds a master's degree both in art history and in conservation.

Renee Mestdagh studied History and preservation of cultural heritage in Ghent and is working as heritage consultant at CO7. This is the inter-communal structure for cooperation regarding archaeology, culture and heritage between the communities of Heuvelland, Ypres, Langemark-Poelkapelle, Mesen, Poperinge, Vleteren and Zonnebeke (Westhoek – Belgium). She is coordinating the digital image bank www.westhoekverbeeldt.be and develops methods for digitization of 2D and audiovisual heritage in a regional structure.