EUROGRAPHICS Workshop on Graphics and Cultural Heritage (2018)
R. Sablatnig and M. Wimmer (Editors)

Short Paper

Granitic recumbent statue reproduction by a seven axes robotic milling machine

Jean-Baptiste Barreau[1], Joëlle Jouneau[2], Johnny Mérelle[3], Loïc Maillard[3], Yann Bernard[4] and Laurent Quesnel[1]

[1]Univ Rennes, CNRS, Ministère de la culture et de la communication, CReAAH - UMR 6566, France
[2]Association des Amis de l'Oeuvre de l'Abbé Fouré, France
[3]Maillard & Maillard company, France
[4]VIRTUAL-ARCHEO company, France

Abstract

Facing the sea, the rocks sculpted by the "Abbé Fouré" at the "Pointe du Christ" and the "Pointe de la Haie" in Rothéneuf (Brittany, France) attract many visitors. Winds, rains and sea spray erode each day a little more the sculptures carved in granite more than a century ago. In order to preserve the heritage, the "Association des Amis de l'Oeuvre de l'Abbé Fouré" tried to start an innovative project: recreate a statue sculpted by the "Ermite of Rothéneuf" at the end of the 19th century thanks to 3D technologies and robotics. With a first 3D scanning of the sculpture of the "Pointe du Christ", a stonecutters' company was approached to reproduce identically this recumbent statue, identified as John IV, Duke of Brittany. Thanks to a robotic milling machine working on seven axes, by cutting layers in the granite at each passage, the company realized 60% of the work in less than a month. Then, a sculptor of the company was responsible, from documents collected by the association, to give the granite block the features of the original recumbent statue. This replica is currently the centerpiece of several French exhibitions dedicated to the general public.

CCS Concepts

•***Applied computing*** → *Arts and humanities;* •***Hardware*** → *Communication hardware, interfaces and storage;* •***Computing methodologies*** → *Computer graphics;*

1. Introduction

Just as Ferdinand Cheval erected Le Palais idéal (the "Ideal Palace") in Drôme (department in southeastern France) [Bru36], the Abbé Fouré is the author of a vast environment made in the Breton village of Rothéneuf, at the end of the nineteenth century. From 1894 until his death in 1910, this hermit, suffering from deafness, undertakes a titanic work with his only tools: a hammer and a chisel. He sculpts for 13 years, day and night, a granite cliff facing the sea on 500 square meters: a total of 300 sculptures came out of the stone. Some evoke the history of Brittany and its heroes, others represent fantastic beings or animals [MC10]. Abbé Fouré can be considered as a precursor of the notion of Outsider Art, which was developed from 1945 by Jean Dubuffet [TD76]. Self-taught, the author does not claim to be an artist. He set to work without any artistic will, but to break his loneliness and idleness. Like Ferdinand Cheval, the abbot considers that the work is already there, in nature; he only completes the work that it has undertaken, revealing the contours of the forms he sees in the rock. Today, this major environment is doubly threatened: on the one hand, because of its popularity and the many visitors constantly treading the site, on the other hand, by the sea and its harmful effects that damage it and make it gradually disappear [DLRP*12]. Slightly separated from the cliff which contains the majority of the sculptures, the "Pointe du Christ" was a favorite place of the Abbé Fouré and it is there that he began to carve the rock. The recumbent figure (cf Figure 1) is 1.80 m long by 80 cm wide and represents John IV, Duke of Brittany, landed at Dinard in the fourteenth century, after an exile in England [Jon70]. Unlike the majority of other sculptures, this one is in free access. The purpose of our work was to produce a copy of this artwork, sculpted mainly by a robot in a granite stone similar to the original one, to expose it to the general public.

2. Method

The methodology used for the reproduction of the recumbent statue was elaborated from the following considerations:

- The replica must not be an exact copy of today's sculpture, but one as close as possible to that of 1910.
- On the 3D digitization and compared to the sculpture of 1910, it lacks some granite material, especially in the legs and the sword.
- The head of an animal, visible on postcards, no longer exists.
- The amount of material that has disappeared is, however, much less than that remaining.

DOI: 10.2312/gch.20181357

Figure 1: *The recumbent statue located on the "Pointe du Christ" in 1910 and 2010*

After consultation with decision-making bodies, the following objectives were defined:

- The goal is to get as close as possible to the work of the "Ermite of Rothéneuf" by completing the missing information with the documentation and the old postcards.
- The head of the animal must be represented and the identification can be left to the general public's discretion, providing them with all the existing documentation.

By replacing the "classic" 3D printing with the CNC milling on a locally extracted material, we have followed the quite democratized digitization-reconstruction-printing process [LBC*15] [Mon15].

2.1. 3d digitization

In 2014 following the request of the "Ille-et-Vilaine" General Council (France), the 3D digitization of the "Pointe du Christ" has been done. The choice of the use of a laser scan was made because we had one at our disposal, but the photogrammetry could also be suitable. During a half-day in mid-January 2015, an engineer and a technician went to the site of the recumbent statue. A Focus3D X330 was placed on 8 stations to perform a scan that focused on the statue, but also concerned the Pointe as a whole. The point cloud resulting from this digitization represents 27 186 559 points. The mesh generated from the cloud with the Poisson Surface Reconstruction algorithm [KH13] has 26 119 291 faces. A first segmentation of the cloud was made in order to focus on the recumbent statue. The resulting cloud has 2 204 008 points and the associated mesh 5 846 040 faces.

2.2. Preparation of the granite block

In order to respect the type of stone used for the statue, a granite ball weighing 2 tons was found in the surrounding countryside of Saint-Pierre-de-Plesguen. This ball has been chosen because it is more than a century old, and closest to the granite located in Rothéneuf. It is the same color and the same era as those of the original. It was then sawed in half and cut into a perfect parallelepiped. The block was next wedged on a base specially created to allow clamping and fixing on the work plan, so that it is blocked during the intervention of the robot. The slightest shift, even a millimeter, can distort the proportions of the replica (cf Figure 2).

Figure 2: *Extraction and rough cutting of the granite ball*

2.3. Preparation of the 3d files

The base mentioned above was first designed with the AutoDesk PowerShape CAD software. In collaboration with the "Association des Amis de l'Oeuvre de l'Abbé Fouré", areas to improve have been reworked with the ZBrush software, including with additions of material. To properly position the statue on the base, this operation was prepared by assembling the two virtual elements with PowerShape (cf Figure 3).

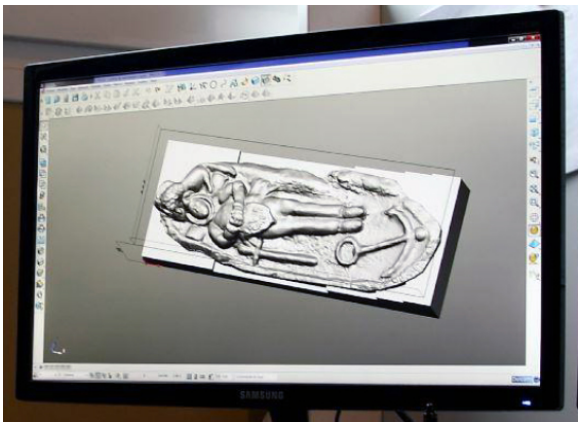

Figure 3: *Design and positioning of the recumbent statue with AutoDesk PowerShape CAD software*

2.4. Machining

In the scientific literature, there are several examples of Computer Numerical Control (CNC) systems, previously scanned in 3D . The number of axes of robots used, when they are mentioned, varies between 3 and 7 [BB]. However, it seems that granite is not a commonly used material for this type of project, even if we can find

simple cuttings in the industry [SUD]. One of the major criteria of feasibility for this operation is, in particular, the ultimate tensile strength [Var]. Because that of granite being between 7 and 25 MPa [Zhu13], a comparison with other materials allowed us to validate the fact that machining was feasible.

Configuration The robot used for our machining is a Kuka with 7 axes, owned by the sculpture company and able to avoid singularities and certain objects [BB]. More specifically in our context we can firstly say that the 7th axis allow to work 5 sides without having to move the working piece. Its action radius is 3100 mm, the maximum loading capacity 210 kg and the weight of machine only is 1120 kg. The ratio between the working space and the volume required for the installation of the machine is also particularly interesting. In France, it is the first robot adapted in the stone field by the French company Thibaut [THI]. The software is the Computer-Aided Manufacturing (CAM) PowerMill® solution. After having sketched in 3D a diamond grinding wheel tool with a diameter of 70 mm, several parameters are defined: increment, cutting and fixed depths, feedrate/rotational speed, connections, reduced speed of entry into the material and height of rapid displacements. The 3D model and the machining strategy are then integrated into the robotic cell so that the configuration of the robot's cell and axes begins. The computation of the course of the robot executes and a visualization of the simulation of this course becomes therefore possible (cf Figure 4). The final step of this machining preparation is the writing of the numerical control program [SH08].

Milling The system offers a high degree of automation for the work process. The robot is indeed able to change the tool itself, thanks to the Tool Center Point Control (TCP), depending on the milling to be done. Once the numerical control program is sent, human visual monitoring is required, at least during the first work phases. The friction of the diamond against the material generates heat, which will be reduced thanks to a system of internal and external watering (cf Figure 4). If necessary, it is possible to manually adjust the external watering and adjust the tool length according to the progress of its wear. With his arm, the robot comes to chisel the stone with the diamond, by abrasion, to draw the contours. Under these conditions, the robot was able to work for 120 hours (cf Figure 5).

Manual intervention of the human sculptor After passing the last tool, the robot leaves streaks that need to be erased manually. The machine allows a stone thickness so that the character's features can be sculpted by hand. For this purpose and with the help of old postcards, a human sculptor began by bush hammering the granite, and made sure that the replica is as close as possible to that of 1910 (cf Figure 6). This duration of the work is 80 hours, 40% of the total production time.

3. Results and future works

First of all, with regard to digitization and according to sources, we know that the recumbent statue was painted. However, the constant humidity, the infiltrations and the air salinity leach out the possible traces of polychromy remaining and promote the development of foams and lichens on the surface, which make the work lose

Figure 4: *Machining tools, door with a security system, 3d simulation and watering system whose parameters must be configured for the milling process*

Figure 5: *Different steps of milling by the robot*

in readability. We tried a few tests of colorful 3d models with 3ds Max software [BLC], but historians' critical feedback on our arbitrary color choices led us to abandon this attempt. The final granite replica is the same size as the original, i.e. 1.80 m, and weighs 700 kg, i.e. 35% of the mass of the initial block. The digitization has a good quality and was a good starting point for the sculptor's work. Parameters and tools have evolved during machining to optimize the work of the robot without damaging it, while preserving the workpiece. Without going into the calculation of added material quantity, even if that can be done in the future, we privileged the possibility of visual comparison easily accessible to everyone (cf Figure 7).

Regarding the funding, it was obtained 60% thanks to the Region

Figure 6: *Human sculptor's work*

Figure 7: *Images allowing comparison, on 3D meshes and real sculptures, between the original statue (images 1 and 3 / 46 726 faces / 2.22MB) and its replica (images 2 and 4 / 277 816 faces / 13.2MB)*

of Brittany, as part of a call for projects on the theme of coastal heritage. The departmental council of Ille-et-Vilaine, the city of Saint-Malo, a deputy's parliamentary reservation, and some private patronage operations [BM] have helped to complete the financing. The total cost of producing the statue was 16,879€ excluding taxes, including 10.59% for digitization and 89.41% for the acquisition of granite ball, the milling process and the sculptor's work. The first feedback from the institutional stakeholders of the project first mentioned a way to save the works located in a protected natural site difficult to access, to preserve the memory, especially for future generations, and alert the other agencies responsible for the Breton coastline. Thus, a mediation process has begun, particularly with school children as part of the arts and cultural education program. In addition to local press coverage [Cha17] [Sau17], two first exhibitions of the replica were held in autumn 2017 during the European Heritage Days in Rennes (France) [LC], and the semaphore of the "Pointe du Grouin" near Cancale [SG17] (cf Figure 8), located not far from the original statue. Finally, a teaser video has also been produced [Ole].

Figure 8: *Presentation of 3d digitization and granite replica to the general public*

At this time, the replica of the statue is currently presented to visitors permanently within the space including museum owned by the "Association des Amis de l'Oeuvre de l'Abbé Fouré". It is accompanied by panels explaining the reproduction process. The follow-up of the project will concern the digitization of the cliff which contains the majority of the other sculptures. To reduce the cost of their reproduction, we work on three tracks:

- The use of UAVs also gives us hope to make photogrammetric recordings, by taking advantage of brief favorable weather windows, thus reducing significantly the cost of digitization.
- The choice of a softer stone that would reduce the machining time and the wear of the cutting tools. Possible gains can be 30%.
- The reduction of the manual carving time, by a finer indentation of the machining, in the areas where the sculpture is very detailed. It is also possible, for a second time, to completely replace the manual sculpture by a mechanical / pneumatic process, which would give an appearance close to the "handmade" sculptures. The financial gains are not quantifiable at this stage, because this process has to be defined more precisely and a prototype machine will have to be created to carry out tests.

References

[BB] BÉLANGER-BARRETTE M.: How many axes should my robot have? URL: https://blog.robotiq.com/how-many-axis-my-robot-should-have. 2, 3

[BLC] BARREAU J.-B., LE CLERC J.-Y.: Numérisation gisant rotheneuf. URL: https://www.youtube.com/watch?v=MrteH8btuQY. 3

[BM] BRETAGNE-MECENAT B.: Fiche d'identité pour projet recherchant du mécénat - valorisation de la pointe du christ de rothéneuf à saint-malo : Prototype de sauvetage des sculptures granit. URL: http://www.bretagne-mecenat.fr/public/AbbeFoure/Projet-AbbeFoure.pdf. 4

[Bru36] BRUNIUS J.: Palais idéal. *Architectural Review 80* (1936). 1

[Cha17] CHASSEVANT E.: Pour sauver une statue, ils la reproduisent en 3d. *Ouest-France Bretagne* (23/01/2017). 4

[DLRP*12] DAIRE M.-Y., LOPEZ-ROMERO E., PROUST J.-N., REGNAULD H., PIAN S., SHI B.: Coastal changes and cultural heritage (1): Assessment of the vulnerability of the coastal heritage in western france. *The Journal of Island and Coastal Archaeology 7*, 2 (2012), 168–182. 1

[Jon70] JONES M. C.: *Ducal Brittany, 1364-1399: relations with England and France during the reign of Duke John IV.* Oxford UP, 1970. 1

[KH13] KAZHDAN M., HOPPE H.: Screened poisson surface reconstruction. *ACM Transactions on Graphics (TOG) 32*, 3 (2013), 29. 2

[LBC*15] LAYCOCK S. D., BELL G. D., CORPS N., MORTIMORE D. B., COX G., MAY S., FINKEL I.: Using a combination of micro–computed tomography, cad and 3d printing techniques to reconstruct incomplete 19th-century cantonese chess pieces. *Journal on Computing and Cultural Heritage (JOCCH) 7*, 4 (2015), 25. 2

[LC] LE CLERC J.-Y.: Teaser jep 2008-2017 archives ille-et-vilaine (7:35-7:45). URL: https://www.youtube.com/watch?v=33FV4OsbLvs. 4

[MC10] MAURICE J.-F., CHESNÉ J.-M.: Les inspirés en soutane, art religieux, art populaire, les sources occultées de l'art brut. *Gazogène - La revue de l'Art Brut, des créations singulières, de l'art populaire et des expressions marginales ou bizarres*, 31 (2010). 1

[Mon15] MONGEON B.: *3D Technology in Fine Art and Craft: Exploring 3D Printing, Scanning, Sculpting and Milling*. Focal Press, 2015. 2

[Ole] OLERON A.: Teaser "les amis de l'œuvre de l'abbé fouré". URL: https://vimeo.com/286542039. 4

[Sau17] SAUSSIER B.: Le gisant de rothéneuf a été cloné. *Nous Vous Ille*, 117 (2017), 34. 4

[SG17] SAVERAT-GUILLARD B.: Le duc de bretagne de l'abbé fouré s'expose. *Ouest-France Bretagne* (21/10/2017). 4

[SH08] SHE C.-H., HUNG C.-W.: Development of multi-axis numerical control program for mill-turn machine. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 222*, 6 (2008), 741–745. 3

[SUD] SUDIAO R.: Granite milling & carving & engraving heavy stone cnc rouer enhanced machining center dsc 0921. URL: https://www.youtube.com/watch?v=LVtdqh8Iyig. 3

[TD76] THÉVOZ M., DUBUFFET J.: *L'art brut*. Rizzoli New York, 1976. 1

[THI] THIBAUT S.: Transformer - robot thibaut 6/7/8 axes. URL: https://www.youtube.com/watch?v=l6P2ucVUE50. 3

[Var] VAROTSIS A. B.: Selecting the right cnc material. URL: https://www.3dhubs.com/knowledge-base/selecting-right-cnc-material. 3

[Zhu13] ZHU T.: Some useful numbers on the engineering properties of materials (geologic and otherwise). *accessed Jan 9* (2013), 2013. 3