Cost Analyse of 3D Digitisation Techniques

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Abstract. In the framework of the Belgian BELSPO AGORA 3D and DIGIT03 programs, we have evaluated 3D digitising technologies with regards to the quality of the acquisition, the capacities and limitations of each technique and also the direct cost of the different 3D digitisation processes. It is on this latest topic that the paper is focused.
In order to evaluate the cost of 3D digitisation, we considered the time for the digitisation, cost of the equipment and cost of the staff.
Our preliminary results show that the real cost by specimen depends on the amount of specimens to digitise. Techniques that appear to be low-cost can be the most expensive in the framework of massive digitization programs, whilst more expensive equipment can be more efficient in the long term. Therefore low-cost equipment is mainly recommended for occasional digitisation or small series of digitisations.

Keywords: Cost, 3D digitisation, Laser Scanner, Photogrammetry, Structured light, CT, µ-CT.

1 Introduction

3D is currently used everywhere and cultural heritage is not the exception. Interest in large scale 3D scanning of collections has grown and many museums, institutes or researchers now use it widely[1] [2]. Many 3D digitisation techniques exist and they are useful to digitise collections for scientific and conservation purposes [3]. 3D digitisation reduces the need for physical manipulation, provides back-up in case of loss or destruction and can determine the state of the object before it is loaned or sampled. It enables the digitised specimens to be shared with other scientists around the world and facilitates comparison between specimens. 3D also offers the possibility to a create virtual museum or to display small objects on a large screen which provide a more detailed view to the visitor.

Reviews of some existing technologies have already been made [2] [4], but as technology has evolved, new reviews are needed. The digitisation methods and equipment are highly variable in terms of quality, limitation, time, price and results.

Depending on the purpose, different choices have to be made, in order to have the most cost-effective ratio.

2 Methods

We can divide 3D digitization aims into three main categories: external shape, external texture and internal structures. The selected technologies can reach one or two aims but none of them are able to fulfill 3 purposes at the same time.

The group of technologies capable of capturing internal structures is mainly derived from the medical domain such as computed tomography, micro-computed tomography and MRI [5] [6]. The surface is reconstructed based on 2D cross-section images. These approaches are relatively expensive and require expert knowledge for the segmentation. The object to be scanned also needs to be physically moved to the equipment.

Techniques capturing external structures are more diverse: laser scanners, white light scanners, photogrammetry and depth sensors. Some of these can capture colour texture, others are highly portable and can be used on the field even without an external power supply [7]. The price for those different technologies can vary from 1000 € for open source photogrammetry software with entry level DSLR camera to 100 000 € for high end equipment.

In the following analyses, we only selected a sets of equipment for which we had enough experience, having produced a large number of models with them, in order to have a good dataset about the average time necessary to scan a medium sized specimen and a small specimen. A medium sized specimen has a diameter of 10 to 40 cm, while a small sized one is less than 10 cm. In this paper, we considered 4 technologies: photogrammetry, X-ray based (Computed tomography and micro computed tomography), structured light scanner and laser scanner.

The equipment used for photogrammetry is Agisoft Photoscan [8] using a Canon EOS 600D 18 MPx. The lens is a Canon 50 mm macro for medium specimens or a Canon 100 mm macro for smaller specimens.

Regarding structured light, we use the HDI Advanced R3x (LMI) [9] for middle size specimens and the MechScan [10] for smaller specimens. Both scanners use the Flexscan software and an automated turntable.

Considering the laser technology, we choose the low-cost NextEngine [11] which is used in many museums. The NextEngine scanner works with the ScanStudio software and an automated turntable as well.

Finally, regarding X-ray based technologies, we based our numbers on the Siemens medical CT equipment for middle range specimens, while we used Skyscan μ-CT for smaller specimens [12]. For CT, we use the prices based on a renting service, instead of buying an equipment, but we still process the images ourselves which requires a graphic workstation and a dedicated software. For μ-CT, we indicated the price of a SkyScan 1173, which includes computer and software licence.

3 Analyse and Results

3.1 Examples

In order to give a short review of what each technique can produce as a result, we selected a small sample of test cases.

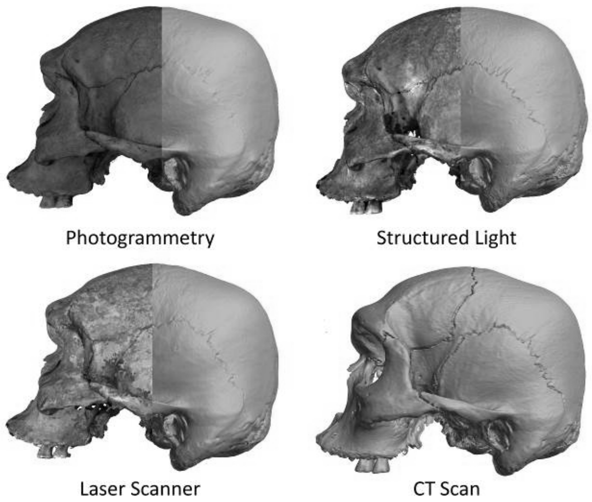

Fig. 1. Example of a medium size specimen captured with the four techniques. a**) Photogrammetry** (Agisoft Photoscan). Staff time: approx. 40 min. Computer process: approx. 3 hours. b) **Structured light** (HDI Advance R3 X, 60 mm field of view). The left half is with texture: the texture has been captured from the camera of the scanner and is not colour accurate since the white balance of the scanner is not correct. The right half shows the aspect of the mesh. You can see clearly the parietal structure. Acquisition: 20 minute. Process: 10 minutes. c) **Laser scanner** (NextEngine, macro settings). The left half shows the texture: the texture is not colour accurate; it is generally too yellow with blue/purple spots. The right half show the mesh, you can see the parietal structure as well. Acquisition: 90 min Computer process: 30 min. d) **CT scan** (Siemens, processed with Avizo). The acquisition took 1 minute, copying the images and processing the model took 20-30 minutes. © RBINS Image Copyright 2014.

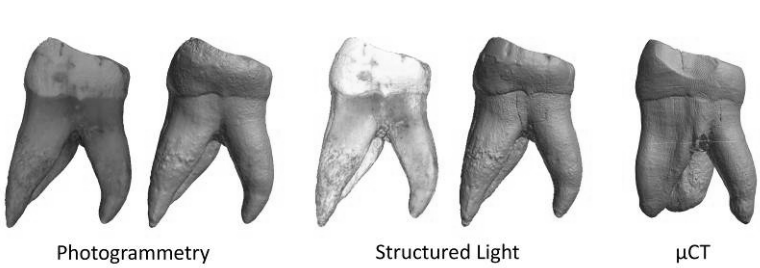

Fig. 2. Example **of small specimen with photogrammetry** (Agisoft Photoscan) **on the left, structured light** (MechScan) **on the middle and μ-CT** (SkyScan InVivo) **on the right.** Neanderthal molar from Spy (Belgium), RBINS collections. It took approximately 20-30 minutes of acquisition for both, but the process of the teeth took several hours of computer work. The level of detail is better with structured light, photogrammetry has more trouble with the enamel creating extra noise. The photogrammetric texture is more colour accurate than the one captured by the scanner which is overexposed and with saturated colours. © RBINS Image Copyright 2014.

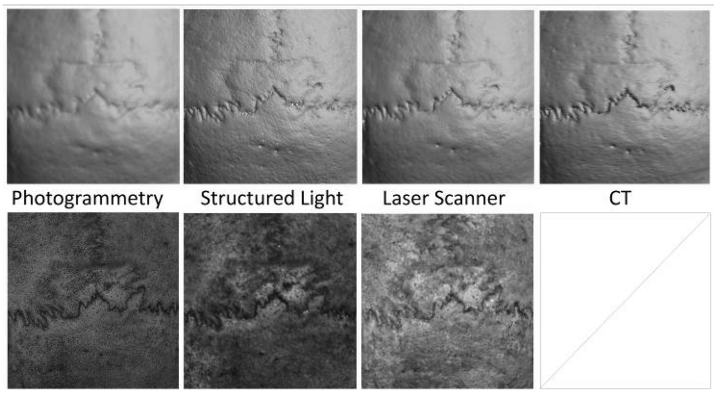

Fig. 3. Part of a skull scanned with the 4 techniques mentioned: From left to right: photogrammetry (Agisoft), structured light (LMI), laser scanner (NextEngine) and finally CT scan (Siemens). With on the top the mesh and on the bottom the textured model. © RBINS Image Copyright 2014.

3.2 Quality of the Results

The examples show that you can get a relatively similar degree of detail between the different technologies (fig. 1 & 3).

Regarding texture (visualisation purposes), photogrammetry (fig. 1) being a photographic technique give the best result. The disadvantage of photogrammetry is that the model has to be manually scaled which gives a small place to imprecision.

Regarding preciseness, our previous studies [13] show that structured light give overall the best results since it give an accurate shape and is the technique the more apt to deal with different materials (as you can see in fig. 1 & 2, photogrammetry and laser cannot cope with enamel because of its shiny translucent aspect). The models are automatically scaled.

The laser scanner has also automatic scaling, good precision, but has more difficulty to cope with some materials (such as enamel).

CT and μCT are the only ones recording internal structure which facilitate the studies of many objects (no need to cut in the specimens), they are automatically scaled but do not record texture. CT and μ-CT allow to deal with materials that other techniques don't record well like translucent/transparent material (glass, beetle, etc.), but struggle with metal or mixed materials (inclusion of metal, etc.).

Table 1. Table of the cost in function of the quantity of specimens to be digitised. The prices include 1 or 2 workstations of approx. 1000-1500 € in order to have a good graphic card and enough RAM (12-16Gb advised). In the case of photogrammetry, you can make 10 acquisition a day and prepare the process file, but you need approx. 3 hours of processing for each model in order to have a decent quality. You will need 30 hours to process the 10 daily aquisitions. That is 150 hours for one week of capture, plus the 38 hours were you are actually working with the computer (taking picture, preparing the photogrammetry mask and batch file), and you only have 168 hours in a week considering week-ends. You will need 2 workstation to keep up.

	Medium size				Small size			
	Photogrammetry	Structured light (HDI Advance)	Low cost laser scanner (NextEngine)	CT Siemens	Photogrammetry	Structured light (MechScan)	Low cost laser scanner (NextEngine)	µCT Skyscan
Portability	+++	+	++	-	+++	+	++	-
Specimens / week	50	75	25	84	50	75	25	50
Cost of equipment	3 500	22 000	3 500	250/h + 1 500	4 000	45 000	3 500	240 000
Staff salary / week	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000
100 specimens								
Time (weeks)	2.0	1.3	4.0	1.2	2.0	1.3	4.0	2.0
Total cost (€)	5 500	23 333	7 500	9 574	6 000	46 333	7 500	242 000
Price / specimen (€)	55	233	75	96	60	463	75	2420
1000 specimens								
Time (weeks)	20.0	13.3	40.0	11.9	20.0	13.3	40.0	20.0
Total cost (€)	23 500	35 333	43 500	39 038	24 000	58 333	43 500	260 000
Price / specimen (€)	24	35	44	39	24	58	44	260
10000 specimens								
Time (weeks)	200	133	400	119	200	133	400	200
Total cost (€)	203 500	155 333	403 500	333 681	204 000	178 333	403 500	440 000
Price / specimen (€)	20	16	40	33	20	18	40	44

3.3 Cost Analysis

We considered the average number of objects of the same size (this imply we are using the same settings. If you have very different sized objects, you will have to redo every setting each time, extending considerably the amount of time required) that we can scan on a 38h week. We considered we don't do extra processing on the texture (as could be required in some cases to have better texture), but just the time to produce the full 3D shape. We didn't either considered the time to do manual segmentation of CT and µ-CT images.

Medium size specimens.

The cost table presented shows that for a small quantity of specimens (like 100) the structured light equipment is three to four times more expensive than the other technologies proposed here (table 1). The low cost laser scanner, even though is the same price for the equipment as photogrammetry, is more expensive by specimen because of the longer acquisition time. For a small serie of specimens, if texture is not an issue, a CT renting service is a reasonable price (but you have to bring the specimens to the equipment).

To digitise 1000 specimens, even if photogrammetry remains the cheapest option, all techniques mentioned for medium size specimens have more or less equivalent prices. To digitise 10 000 specimens and more, structured light is the cheapest option as it is the more efficient technique, while the low-cost laser scanner will be definitely the more expensive. Although you have to consider what you are aiming for: if you are making models for visualisation purposes with great importance on the texture, photogrammetry might be the best option because it produces the best texture and doesn't need any post processing of the texture while structured light or laser scanner might need some adjustments which will extend the time required to produce the model and that implies cost as well.

Small specimens.

For small specimens, digitising specimens with structured light is advantageous if you digitise around 10 000. μ-Ct is the most expensive technique, but is the only technique that allows a good digitization of small specimens made of reflecting or transparent material.

4 Conclusion

The equipments which are evaluated here have very different prices. If the results are relatively similar in terms of precision, the time ratio is very different for generation of models and thus an increase in staff cost (table 1).

If low-cost technologies (like Next-Engine or photogrammetry) seem at first to be a more affordable process, it should remain dedicated to small scale digitisations or the occasional digitisation. If you plan to digitise large collections of similar sized specimens, investing in a structured light scanner could be more advantageous, especially if you are also interested in taking measurements. If the aim of the digitisation is more for visualisation where texture is important, then it might be better to orient yourself towards photogrammetry as prices are similar or combine photogrammetry with surface scanning.

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