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2ème année du Cycle des Ingénieurs diplômés de l'ENSG

COMPARISON OF 3D DIGITIZING AND IMAGE CORRELATION SYSTEMS: ACCURACY TEST AND USABILITY







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RESUME

On assiste de nos jours à une diffusion importante de nombreux logiciels dont les outils permettent de numériser simplement des objets à partir d'une série d'images photographiques prises sous certains critères. Le stage propose de comparer différents logiciels de numérisation 3D et de corrélation d'images, en effectuant pour cela plusieurs tests sur différents objets et projets en cours au sein du laboratoire.

A travers ce rapport, le lecteur découvre la méthodologie que j'ai suivie pour répondre aux besoins et aux exigences des membres du laboratoire. Ces derniers avaient besoin de connaître le potentiel de ces logiciels ainsi que les limites de leur application à des cas réels de documentation des biens culturels. Les étapes suivent une démarche linéaire : de la phase d'analyse des données et des outils à tester, à la phase d'évaluation et de mise en production des logiciels, en passant par les phases de test et de comparaison des résultats. Des illustrations, des schémas et surtout des photos sont là pour appuyer le raisonnement et faciliter ainsi la lecture et la compréhension.

Mots-clés : Architecture, Patrimoine, Relevé, Photogrammétrie, Nuage de points 3D, Logiciel de reconstruction 3D, Corrélation d'images

ABSTRACT

Recently, there has been a significant increase of the softwares the tools of which can easily digitize objects from a set of photos. The internship consists of the comparison of different 3D digitizing and image correlation softwares, by performing several tests on different objects and projects underway in the laboratory.

Through this report, the reader can discover the methodology that I followed to meet the needs of the laboratory members. In fact, they wanted to know the potential of these softwares and the limits of their application to real cases of cultural heritage documentation. The steps follow a linear approach: from the analysis phase of the data and tools to be tested, to the phase of evaluation and implementation of the softwares, through the testing and comparison phases. Illustrations, diagrams and photos are mostly there to support my argument and facilitate the reading and understanding.

Keywords: Architecture, Cultural Heritage, Survey, Photogrammetry, 3D Point Cloud, 3D Reconstruction Software, Digital Image Correlation

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GLOSSAIRE & SIGLES UTILES

DiCEA: Dipartimento di Ingegneria Civile e Ambientale.

DiCR: Dipartimento di Costruzioni e Restauro.

TIFF/TIF: Tagged Image File Format.

XML: Extensible Markup Language.

ICP: Iterative Closest Point. The basic algorithm that automatically precisely aligns a moving mesh M with a fixed one F. The main idea is that we choose a set of (well distributed) points over M and we search on F for the corresponding nearest points. These pairs are used to find the best rigid transformation that brings the points of M onto the corresponding points of F. ICP has a lot of tunable parameters.

INTRODUCTION

This report presents a synthesis of all the works carried out during my internship within the GeCo laboratory (Geomatics for Conservation & Communication of Cultural Heritage) in the University of Florence, Italy.

It describes first the global context of the work with the presentation of the laboratory, the objectives of the internship and the tools used. An in-depth approach is made to the photogrammetric softwares used.

Then, it presents the different data and projects that were used as case studies to compare and evaluate the softwares tested.

Finally, it focuses on the implementation of the two softwares MicMac and CloudCompare within the laboratory.

PRESENTATION OF THE LABORATORY AND THE INTERNSHIP

The GeCo laboratory

Description of the laboratory

The GeCo laboratory started its activity in 2007, together with the introduction of ICAR-06 teaching programmes (Topography and Cartography) within the Faculty of Architecture. In the whole University of Florence, the department is represented only by two specialised professors: a Full Professor at DiCEA (prof. F. Sacerdote) and an Associate Professor at DiCR (prof. G. Tucci). That is why huge efforts (both as far as money and energies are concerned) are made to “maintain” PhDs, research fellows and contract workers. Some initial difficulties have further worsen by the fact that this discipline was new for the University, so Florentine postgraduates had no basic knowledge. Recently, the organisation of workshops, seminars and collaborations with colleagues dealing with similar subjects has helped improve the situation and involve an increasing number of suitably trained people possessing into the laboratory activities.

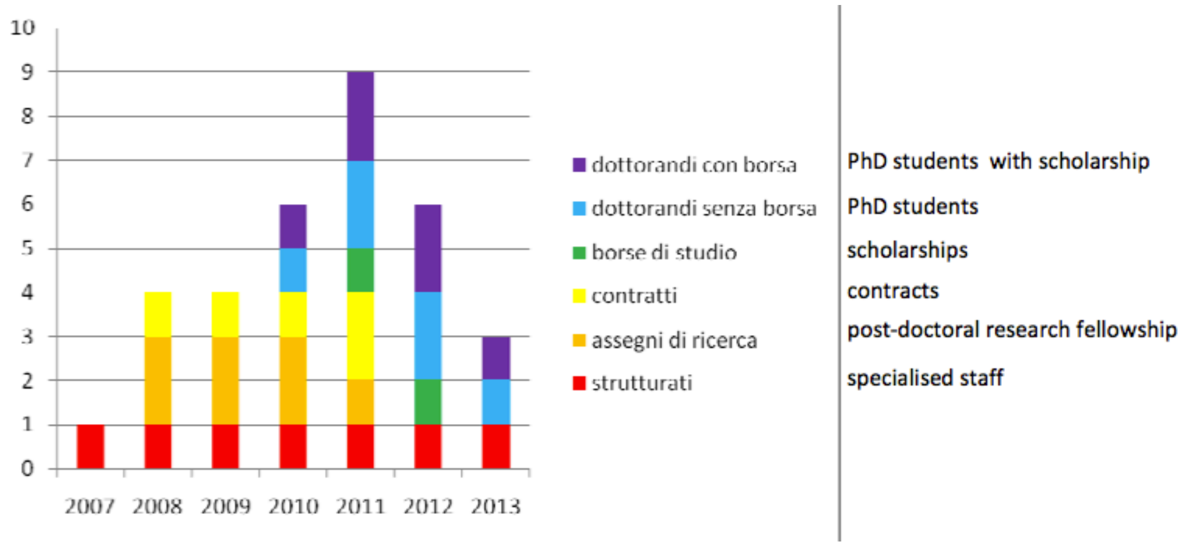


Figure 1: Composition of the GeCo laboratory, source: http://www.geomaticaeconservazione.it/

Projects and activities

The research **activity** of the Geomatics and Communication for Cultural Heritage Laboratory is applied to sectors as varied as architecture, civil engineering, land and environmental engineering and protection, and Cultural Heritage study and preservation. The laboratory’s mission is to develop modern methodologies of integrated survey, testing new hardware and software tools in relevant application fields. It focuses mainly on the study and test of innovative solutions for metric documentation and monitoring of Cultural and Territorial Heritage. Quality measurement (and the relative indicators) represents the essential element for all the studies carried out.

The activity of the laboratory dealt with the survey of some huge monuments in Italy and abroad (The Church of the Holy Sepulchre in Jerusalem, the Basilica della Madonna dell'Umiltà in Pistoia, the Medici Fortress in Arezzo, etc.), as well as the metric documentation of many buildings, environmental contexts, and small or medium-sized objects. The techniques adopted are those of land and satellite topography, digital photogrammetry, and 3D scanning; in general, many measurement systems are applied contextually, in order to carry out an "integrated metric survey". The surveys performed have often been the object of research agreements or contributions made by public or private bodies.

In fact, the laboratory enhances spillovers within the professional world of the activities which have been conducted in the academic circle: the high request for consulting service by public and private organisms proves the efficiency and competitiveness, also in terms of costs, of the submitted assignments. Since 2010 the laboratory's members have entered the Special Group For Geoinformation (SGFG), which consists of researchers and students undertaking multi-disciplinary scientific and academic studies and projects in different sectors of the Geoinformation sciences.

The research **projects** carried out by the laboratory in recent years frequently had a strong interdisciplinary character. Areas of expertise the laboratory has engaged with are, distinctively, the ones covered by restorers, planning architects, archaeologists, art historians, structural engineers, technologists and chemists.

The applications are extensively varied, whether for the investigation scale, or for the dislocation of the interventions. The laboratory has committed to international projects, in collaboration with European and other universities and institutions. At the same time however, the connection with local institutions is regarded as essential (Superintendence of Historical, Artistic and Ethno-anthropological Heritage for the provinces of Florence, Pistoia and Prato, Local Governments, etc.).

The objectives of the internship

The use of 3D information in the field of cultural heritage is increasing year by year. From this field comes a large demand for cheaper and more flexible ways of 3D reconstruction. The possibility to acquire accurate and realistic 3D representations of objects and scenes is highly valued by cultural heritage professionals as it offers possibilities to better document, study, preserve, restore and present sites and artefacts.

For most of the laboratory's projects, data have been acquired with a 3D scanner and then frequently processed with the help of sofwares like Cyclone from Leica Geosystems for instance.

However, researchers from the laboratory are much less familiar with the fact of getting a 3D model, textured or not, only from a set of photos depicting the object of interest.

The proposed internship consists of the comparison of different 3D digitizing and image correlation softwares, by performing several tests on different objects and projects underway in the laboratory.

To this end, the whole project was divided into four main areas:

- Identification of objects of different natures or types.
- Testing several free softwares on these data.
- Comparison and evaluation of the results achieved.
- Conclusions and writing of general guidelines and instructions for the implementation of some of these softwares within the laboratory.

PRESENTATION OF THE TOOLS USED

In this chapter, the different softwares used and tested during this internship are introduced. There is first an explanation of how and why these softwares were chosen in particular. A more abstract approach was brought to the photogrammetric pipeline MicMac, whose operations are less obvious to understand than the two others.

Choice of the different softwares to be tested

Upon my arrival at the laboratory, my supervisor asked me to focus on three specific softwares: the photogrammetric pipeline MicMac, which I already knew a bit from practical and projects carried out during the year, the automatic reconstruction software Arc3D, and the software ArcheOS geared to archaeological projects.

As regards 3D models and their use, the GeCo laboratory is interested in their « communicative » aspect (general public exhibitions, collaborations with museums and cities, communications of cultural heritage via internet, etc.) as much as their « metrological » aspect (scientific application, measurements and achievement of architectural sections or plans, etc.).

On one hand, researchers at the laboratory know pretty well the main acquisition techniques and often use the laser scanner and then processing softwares such as Cyclone from Leica, or also PhotoModeler which recognizes automatically the targets put on the object to compute the orientation. On the other hand, the process which consists in getting a 3D model, textured or not, from a simple set of photos shot in a specific way was quite new to them.

Thus, these three softwares represented interesting cases to be tested, because each of them had a different approach to 3D digitizing and models creation.

The installation and the introduction to Arc3D were extremely quick. In fact, this software is meant to be easy to understand and use. That is why it is entirely automatic, there are very few options to specify.

Nevertheless, the setting up of the pipeline MicMac required more time and reflection in the beginning of the internship, more particularly because I encountered some technical problems and constraints: use of Ubuntu Linux in Virtual Box on a Mac laptop, configuration of the laboratory's proxy, installation and first tests on the examples provided by MicMac in the folder « micmac_data », with and without the interface, etc.

Thereby the installation of ArcheOS was given up in favour of MicMac, because of a lack of time and also because there were neither user documentation nor case study available on the internet. That's why it was decided to set it aside.

Then, I decided to use and test a third software as a replacement for ArcheOS, in order to carry out more tests and compare more results at the end. At some point, I hesitated to choose the photogrammetric tools Bundler/PMVS but their complexity and their lack of ergonomics put me off doing it rather quickly.

Finally, I chose the automatic reconstruction software 123D Catch, developed by Autodesk and comparable to Arc3D. In fact, both Arc3D and 123D Catch are fully-automated, end-to-end 3D modeling systems that take as input digital photographs and produce 3D computer models as output without any user intervention.

123D Catch was first suggested by my school supervisor Ms. Chandelier, and then it was validated by my supervisor at the laboratory Ms. Bonora when I decided to keep it for the tests. She had already used it in the past for the documentation of simple cultural heritage cases. By the way, its installation and introduction took me little time and so I was able to integrate it properly in the ongoing processing.

MicMac

Presentation

« Pastis-Apéro-MicMac » - commonly known as « MicMac » - is a free, open-source *photogrammetric pipeline* or *suite* from the French National Geographic Institute (IGN), developed and released by Marc-Pierrot Deseilligny It carries out all the different steps of a photogrammetric processing line : calculation of tie points, aerotriangulation and generation of 3D point clouds with dense correlation.

A visual interface has also been developed by Isabelle Cléry within the MATIS research laboratory (Photogrammetry, Computer Vision and Remote Sensing Laboratory) to offer external users a better accessibility to the different tools provided by MicMac.

Functioning of the software

This photogrammetric processing pipeline follows three main phases:

- The matching of photos with the module PASTIS:

  PASTIS detects a set of SIFT points for every image and then automatically looks for their homologous points in all the other images.

- The computation of calibration and aerotriangulation with the module APERO:

  APERO calibrates the cameras and determines also their positions and orientations.

- The dense correlation with the module MICMAC:

  MICMAC creates depth maps and 3D point clouds from the project's photos and the data previously computed.

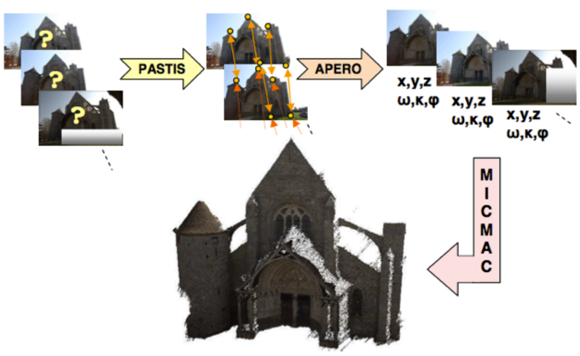


Figure 2: MicMac Operating system

PASTIS

PASTIS is an acronym for **P**rogram using **A**utopano **S**ift for the **T**ie-points in the **I**mage**S**. First, this tool detects local features in the images. Then, it matches them with the SIFT algorithm (Scale Invariant Feature Transform) of the professor David Lowe.

In fact, PASTIS is no more than an interface to the algorithm SIFT++, distribution of SIFT, without any other algorithmic added value. The SIFT method detects and describes local features in images. Its main advantage is to integrate the tie points generation in a compatible way with the global pipeline.

By the way, these features are not sensitive to scale variations, rotations or noise. Thus, there can be homologous points even on the images whose geometry is different.

This search is carried out on monochromatic TIFF files which favours the resolution to the coloured interpolation. PASTIS gets these images via a version of the software DCRAW, adapted by Marc Pierrot-Deseilligny.

APERO

APERO is an acronym for **A**erotriangulation **P**hotogrammetric **E**xperimental **R**elatively **O**perational. With the help of the homologous points previously obtained with PASTIS, this tool computes the calibration and finds the position and orientation of the cameras. It can also compute aerotriangulations « in the air », without any ground control points.

The auto-calibration of the camera is computed first: it rebuilds the real light path by taking into account the distortion, the position of the PPS (Main Symmetry Point), the focal length, etc. The PPS is the intersection between the optical axis and the sensor. The PPA (Autocollimation Main Point) is the orthogonal projection of the optical centre onto the sensor. In reality, these two points are not merged.

Figure 3: Characteristic points of the camera

For most lenses, the distortion is corrected with a radial model. The distance r, separating every pixel from the PPS, is corrected of a distance dr in order to know the position of the theoretical point (as if there were no distortion).

For fisheye lenses (with a small focal length), as the distortion is more considerable, it is corrected with a mesh from a radial model and a polynomial model.

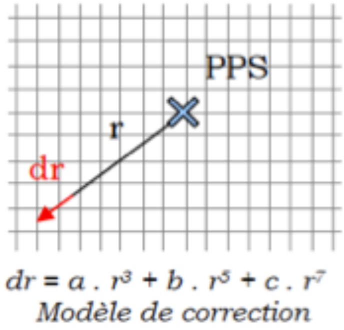


Figure 4: Radial distortion correction

The calibration is made either directly on photos from the object to digitize, or on other photos taken specifically for this process.

Once the lens(es) calibrated, APERO computes the aerotriangulation of the photos in two steps. First, this module finds initial approximate solutions. Then, the solutions are refined by minimization of linearized least squares (Gauss-Newton method). At the end of the computation, if it converged properly, the mean value of the residuals should be around half a pixel.

MICMAC

MICMAC is an acronym for **M**ulti-**I**mages **C**orrespondence **M**ethods **A**utomatic of **C**orrelation. This tool creates depth maps and 3D point clouds from georeferenced photos. Its parameters are contained in a XML file.

MICMAC uses a multistereoscopic approach of the scene under consideration, in order to determine more robustly points in the space. An image called « key image » is chosen from the images of the scene in order to specify the reference geometry in which MICMAC will work. Thus, the depth map created will be exactly in the same geometry as this key image.

The correlation area in which MICMAC works is specified with the help of a mask, captured on the key image. The depth map and the 3D point cloud are thereby contained in a search cone.

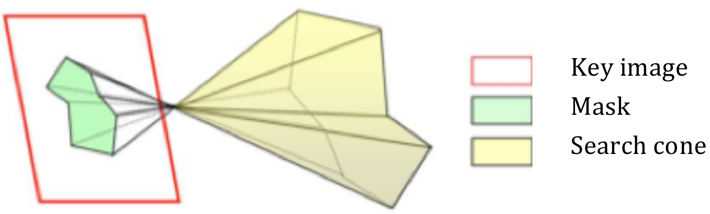


Figure 5: Mask principle in MicMac

Determining the depth of points in the search cone results in the measurement of the parallax in the images. Given a pixel of the key image, the correlation between several images will enable to determine its homologous points and to obtain the parallax.

The correlation is a process which needs many ressources. To accelerate it, MICMAC re-samples a pyramid of seven images and explores all the possible combinations in the more sub-sampled image. It creates a search space for the next image ; in this space, MICMAC finds a smaller search space for the image of the next re-sample step. The operation goes on like this until the full resolution image is reached.

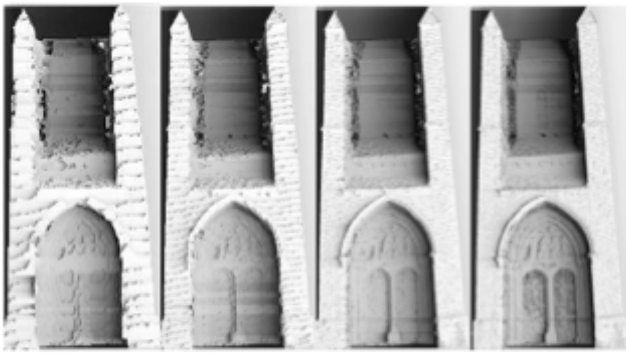


Figure 6: Shade of surface at different levels of the pyramid

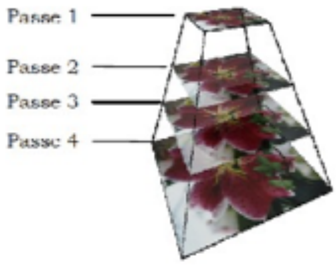


Figure 7: Different levels of the pyramid of sub-sampled images

The result of the dense correlation is saved on a TIFF file whose the pixel value represents the success of the process: The numerical value 0 (black colour) corresponds to the correlation coefficient -1, and the value 255 (white colour) to the coefficient 1.

Once the dense correlation carried out, the tool PORTO can be possibly used then: it starts from the individual rectified images that have been optionally generated by MICMAC and generates a global ortho-photo.

Arc3D

Presentation

Arc3D is a free web-based software of automatic 3D reconstruction from images, developed within the research project EPOCH (European Network of Excellence in Open Cultural Heritage), which brings together a hundred institutions in order to improve the quality and effectiveness of information and communication technologies for cultural heritage.

Software developers are the ESAT-PSI Lab at the Katholieke Universiteit Leuven (Belgium) and the Visual Computing Lab of ISTI-CNR of Pisa, both long active in the field of 3D reconstruction : the first deals with passive reconstruction from images, the second with mesh decimation and integration. The two laboratories decided to join their efforts to develop a low cost tool for 3D reconstruction for use in the field of cultural heritage. The idea is that, to reconstruct 3D scenes, only a digital camera and an internet connection are needed.

Arc3D runs as a service on-line : a *webservice.* It provides a group of tools which allow users to upload digital images to a server where a 3D reconstruction of the scene will be performed. Then, the output will be reported back to the user. Arc3D also provides a tool for producing and visualising the 3D scene using the data computed on the servers.

Functioning of the software

This service consists of a pipeline that starts with the user uploading images of an object or scene(s) he wants to reconstruct in 3D. To use this webservice, a user account is needed. It is almost instantaneous to register on the website : only your name and your e-mail are requested. Then, an e-mail containing username and password will be sent few minutes later.

The automatic reconstruction process, running on a server connected to a cluster of computers, computes the camera calibration, as well as dense depth (or range-) maps for the images. The time a procedure may take depends on the size, the number and the quality of the images that have been uploaded (from 15 minutes to 3 hours according to the website).

Once the data processed and the reconstruction successfully computed by the server, the user is sent an email with a link to the results that he can then display and process (on MeshLab for example). The data received are the following: depth maps, full resolution 3D model (OBJ format) and low resolution model for online viewing (requires a WebGL compatible web browser such as Firefox 4 or Chrome).

The website also provides guidelines to help the user to take « correct » photos in order to get better results.

The idea of Arc3D is that only a digital photo-camera and an Internet connection are necessary for a user to reconstruct scenes in 3D.

Figure 8 shows a schematic overview of the complete pipeline. It consists of three services that are performed on servers, accessible via the Internet and fed by data from the user and two local applications. Images of the object of a scene to be reconstructed are first checked for quality, then uploaded to the first web service which computes dense range maps. A second web service is capable of merging these range maps. The user can also align range maps from different image sequences locally and merge them. The third web service is in charge of mesh creation and simplification.

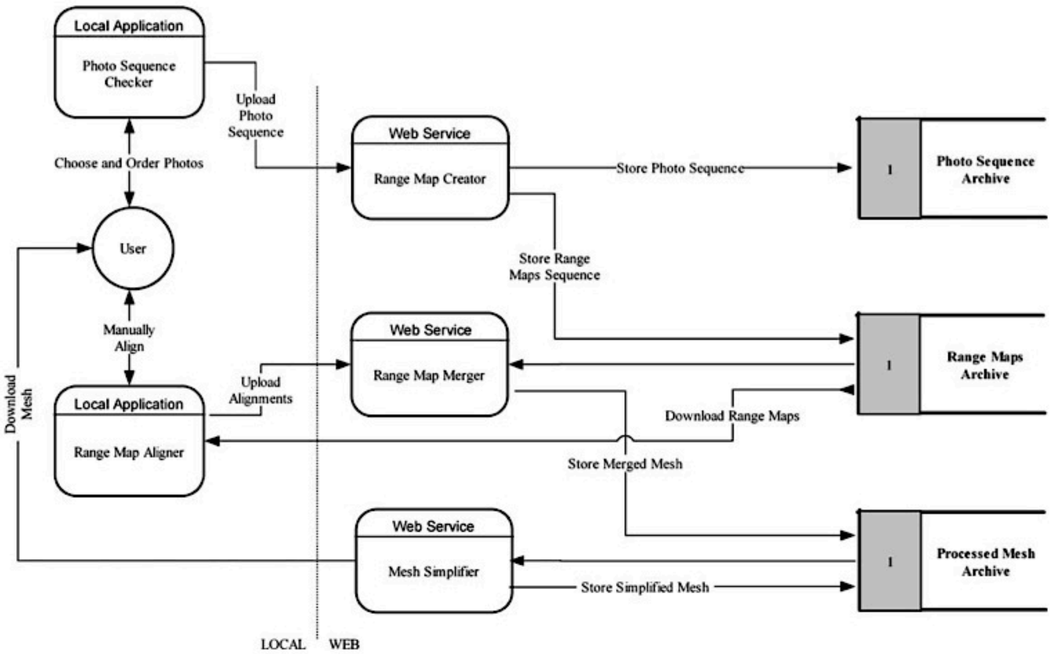


Figure 8: Arc3D Operating system

123D Catch

Presentation

123D Catch (formerly Project Photofly) is a free software developed and released by Autodesk. It is a cloud-based application which creates 3D geometry from photographic data: it takes as input a number of photos of an object – up to 40, the more photos the better – and then finds identical points and distinguishes representative features between them. Finally, it merges them all together to create a relatively accurate, realistically textured modifiable 3D object.

After the creation of a 3D model, it is possible to share it on the internet (social networks) and if a physical representation of the model is needed, it is also possible to inexpensively print it via a number of 3D printing services made for non-professional users, like Shapeways and Ponoko.

Functioning of the software

First and foremost, the creation of a free account at Autodesk is needed to use 123D Catch. Once the images uploaded to the remote services in the cloud, the render will be completed in about 20 minutes to one hour. When complete, the 3D scene is built and opened in a basic 3D editor.

The figure 9 below shows the general workflow for the process and the main functionalities of the software (though labeled for Photofly, it still holds true for 123D Catch).

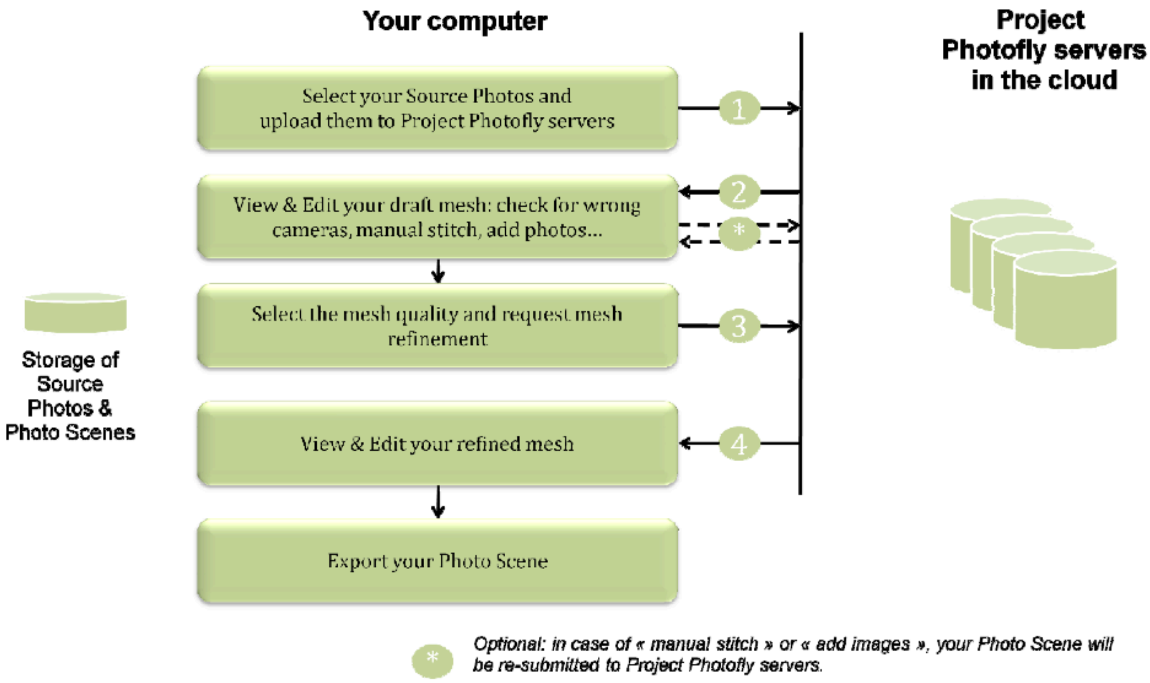


Figure 9: 123D Catch Operating system

TESTING PHASE

Choice of the different data to be processed

My aim during this internship was not only to test several 3D digitizing softwares but also to test them on objects or structures really different from one another, to see how far these softwares were able to reconstruct a 3D model. That is why trying objects and scenes with different characteristics (materials, texture, brightness, cameras position, focal length, etc.) was really important.

Among the three projects used for the tests, I carried out only one of them: the wax bust of Scipione de' Ricci from the Casa Martelli in Florence. Actually, the two others were projects on which the laboratory was working at that time and so they offered me to perform some treatments and tests on them, as the data acquisition had already been done before: these two projects are the frieze of the Ospedale del Ceppo in Pistoia, and the main entrance door of the Castello dell'Imperatore in Prato.

Before starting the treatments on the three projects named before, I tried to process some simple data with few images, taken from the examples provided by MicMac or from my personal data. The results were satisfying as expected, but then it got really interesting (and more difficult too) when I focused on these three specific projects and started to process them.

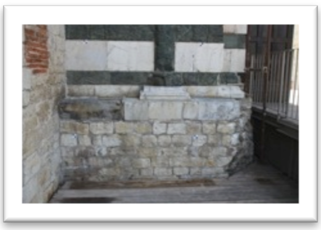
I also tried for a few days to process other data acquired and provided by the laboratory (including a meteorite and the Holy Sepulchre in Jerusalem) but the results either did not come off or were unusable (in particular because the scenes and the photos were inappropriate for 3D reconstruction softwares), so my supervisor and I decided not to use them for the rest.

By the way, three different projects were enough because then I also needed some time to carry out the comparison phase and then the implementation of the softwares used within the laboratory.

Data processing

The main entrance of the Castello dell'Imperatore in Prato

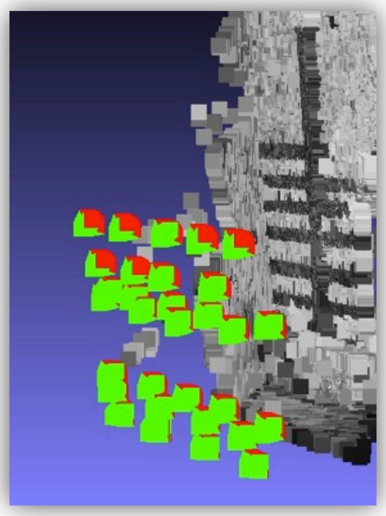
PRESENTATION



This set of data represents the left side of the castle's main entrance, built in the 13th century and made in stone and marble. Dimensions are approximately 400 cm in length, 150 cm in width and 10 cm in depth. The set of data used for the process is made up of 32 photos (JPG format, 5184 × 3456 pixels).

The data were acquired by Menci Software Srl, based in Italy. The shooting was performed around midday on a sunny weather, and the whole door was at that time in the shadow except its upper part.

The camera used was a Canon EOS 600D (18.0 megapixels, 22.3 × 14.9 mm sensor) with a 20 mm focal length (classical lens). The survey type chosen was a parallel shooting, with distances camera – object around 5 m.

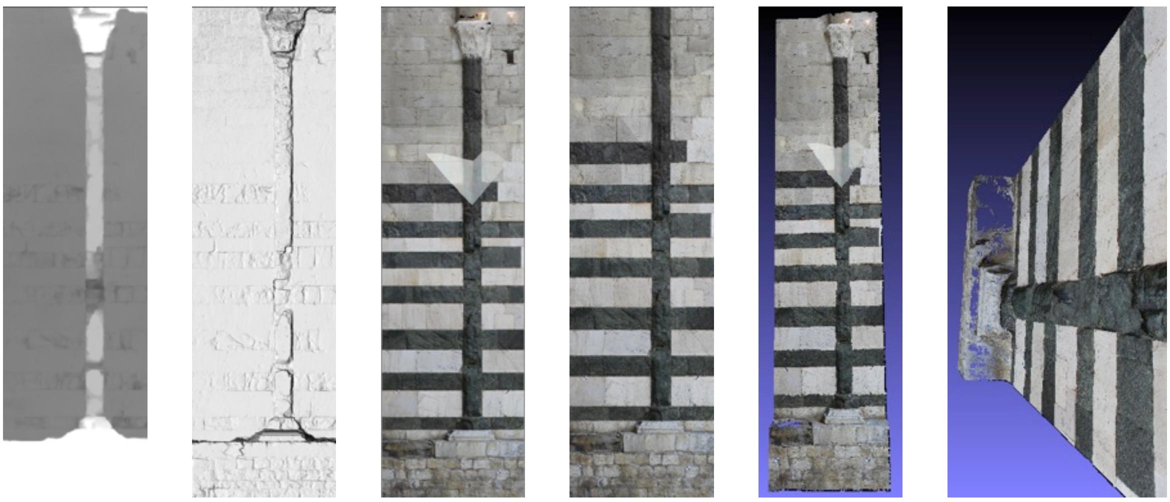


RESULTS

The results obtained were very satisfactory for each one of the three softwares. In fact, this scene was more « classic » than the two other projects, the parallel shooting and the non-reflecting stone were optimum for the computing. Thus there are no issues to report on this project, except maybe a couple of overexposed images in the upper part of the wall which caused the apparition of a luminous shape on the final orthophoto computed and produced by MicMac in ground geometry, so I retouched the orthophoto afterwards with the software Gimp.

The number of vertices of each 3D point cloud obtained is not really significant to evaluate its quality, as automatic 3D reconstruction softwares like Arc3D or 123D Catch choose their own mask for the dense correlation, so the reconstructed scene is not exactly the same as the one chosen and computed on MicMac. What is more interesting is the presence or not of some holes in the mesh for instance, or the global quality of the 3D model (« presentable » or not, aesthetically speaking).

MicMac – Depth & Shade maps, Orthophoto, retouched Orthophoto, 3D Point Cloud



Arc3D – 3D Point Cloud

123D Catch – 3D Point Cloud

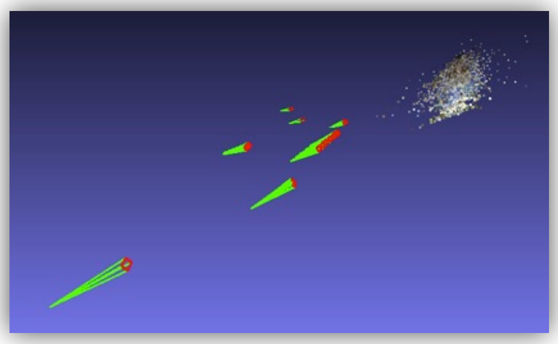
The frieze of the Ospedale del Ceppo in Pistoia

PRESENTATION

This set of data represents a part of the main frieze of the Ospedale del Ceppo in Pistoia which is made in 'terracotta invetriata' (ceramic). Actually, this part of the frieze represents one of the seven Corporal Works of Mercy called « To bury the dead ». Dimensions are approximately 250 cm in length, 100 cm in width and 10 cm in depth. The set of data used for the process is made up of 22 photos (TIF format, 4256 × 2832 pixels).

The data were acquired by two architects and external consultants of the GeCo laboratory, Lidia Fiorini and Alessandro Conti. The shooting was performed on a sunny weather and a high brightness.

The camera used was a Nikon D700 (12.1 megapixels, 36 × 24 mm sensor) with a 200 mm focal length (telephoto lens) The survey type chosen was a convergent shooting, with distances camera – object around 7 to 14 m.



RESULTS

The results obtained were rather different for each software. In fact, this scene is quite specific and posed some problems for me at the beginning of its processing. On one hand it is rich in texture, has distinctive colours and a good brightness, but on the other hand it has little relief, the scene is almost plane and made in a smooth ceramic material. Above all, the focal length used was really long and the consecutive pairs of images were all acquired from quasi similar points of view, this sort of configuration is not so favourable to the aerotriangulation process, especially to find the initial solutions.

Actually, resolving this specific case was quite difficult for the automatic 3D reconstruction softwares Arc3D and 123D Catch. Nevertheless the results were rather satisfactory, particularly the one from Arc3D: it is just a pity that the reconstruction was not performed on the whole frieze (the left side is missing). As for the result from 123D Catch, we can clearly notice that the edge is all blurred and contorted, which is certainly due to the problems listed before.

However, and this is where it is getting interesting, MicMac managed to get round these problems and provided good results and a clean orthophoto of the scene. Before getting there, I had to face many problems and different errors: incompatibility of the TIF format, aerotriangulation not converging because too few homologous points were found, auto-calibration of the camera made on another scene with more 3D relief (the building, a bank, was shot a few days before with the same camera and settings, and then the photos were used to process this auto-calibration before treating the frieze). By the way, I unfortunately did not succeed in putting the texture of the final orthophoto onto the 3D point cloud generated at the end of the process.

Marc Pierrot-Deseilligny helped me a lot on this project, he even provided me the following advice and command lines in order for me to get over the aerotriangulation step:

Under « Edifico_AutoCalibrazione » which has some relief, we process the first calibration:

*Tapioca All ".*NEF" -1* [1]
*Tapas RadialBasic ".*NEF" Out=All* [2]

[1] Because the images are homogeneous, so the maximum of resolution is needed.
[2] A model with few parameters, because of the long focal length used.

Then we copy the calibration results into « Fregio/Ori-CalExterne/ » and we process the frieze:

*Tapioca All ".*TIF" 1500* [3]
Tapas RadialBasic ".[02468].TIF" InCal=CalExterne Out=WithCalE* [4]
*Tapas RadialBasic ".*TIF" InOri=WithCalE Out=All* [5]

[3] This time we don't need the full resolution because there is a lot of texture.
[4] We take the calibration computed previously, and we only use one image out of two to avoid first the problems due to quasi similar points of view.
[5] We adjust now all the images using the existing orientations from « WithCalE ».

MicMac – Depth & Shade maps, Orthophoto & 3D Point Cloud

Arc3D – 3D Point Cloud

123D Catch – 3D Point Cloud

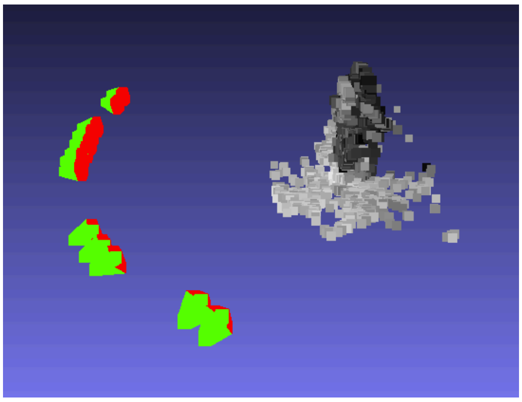
The bust of Scipione de' Ricci in Florence

PRESENTATION

This set of data represents the face side of the bust of Scipione de' Ricci, made by Clemente Susini in the 19th century. Currently located in the Casa Martelli in Florence, it is made up of different materials: the face is in wax and the eyes in glass. Dimensions are approximately 50 cm in length, 30 cm in width and 30 cm in depth. The set of data used for the process is made up of 13 photos (NEF format, 4256 × 2832 pixels)

The data were acquired by Arch. Alessandro Conti and myself. The shooting was performed in a dark room inside the museum, around midday.

The camera used was a Nikon D700 (12.1 megapixels, 36 × 24 mm sensor) with a 50 mm focal length (classical lens) The survey type chosen was a convergent shooting, with distances camera – object around 1.25 m.



The bust was also surveyed with a NextEngine 3D laser scanner by Arch. Lidia Fiorini and Dr. Daniela Cini, in order to try it out on this object made of specific materials like wax, and so that I compare then the results with the models obtained from the 3D digitizing softwares. This will be described in the comparison phase.

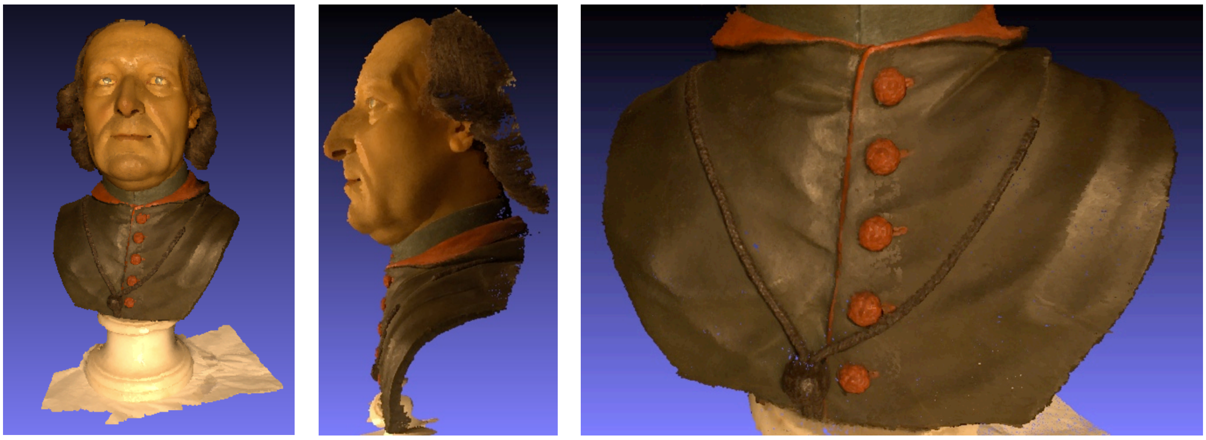
RESULTS

Once again, the results obtained were rather different for each software. The bust was also a specific scene, especially because the shooting conditions were not optimal: dark room, little light and photos not bright enough. The back of the bust, the hair, was way too dark and the computing did not come off, so it was decided to process the 3D reconstruction on the face only.

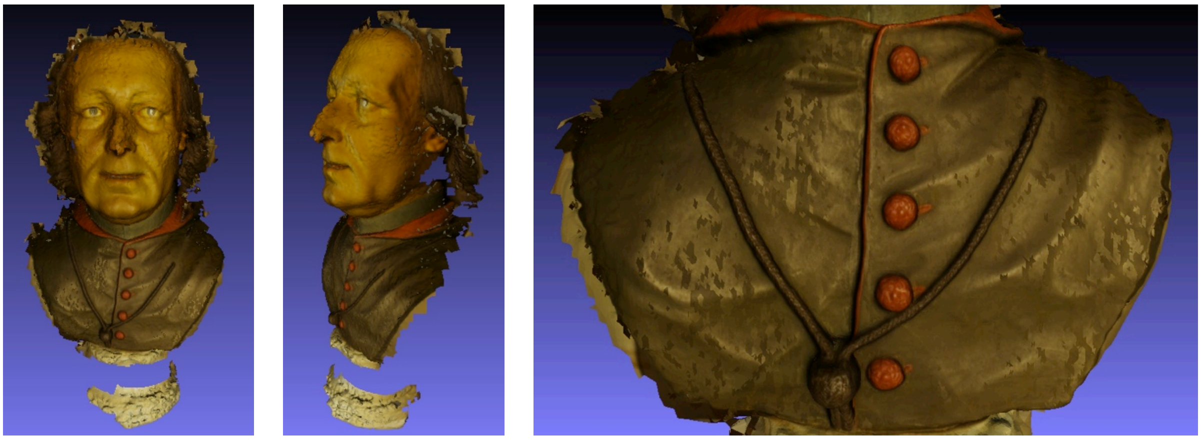
Despite these problems, the results with the two automatic 3D reconstruction softwares were not so bad, but this time on the contrary, the one from 123D Catch seemed better than the one obtained with Arc3D, at least smoother and more presentable. In fact, the latter is too dumpy and noisy, the process did not go very well probably because of the lack of brightness and the presence of wax.

As for MicMac, once more, it turned out to be better in terms of results because actually it is more adapted to specific cases like this one. In this case, I processed with image geometry, defining three different masks around the face and then bringing together the three computed parts in only one; finally, I cleaned the 3D model afterwards on MeshLab and CloudCompare. For the homologous points and aerotriangulation computation, I followed classical protocols like the one provided by Marc Pierrot-Deseilligny and Isabelle Cléry on the processing of the head of Ramses II head (« Acquisition of 3D models of sculpture »). The result was really satisfactory and even better than the model obtained with the NextEngine scanner, smoother but with many holes in it. Still, there is one defect: the slight noise nearby the skin and the chest of the character, certainly due to the wax texture.

MicMac – 3D Point Cloud

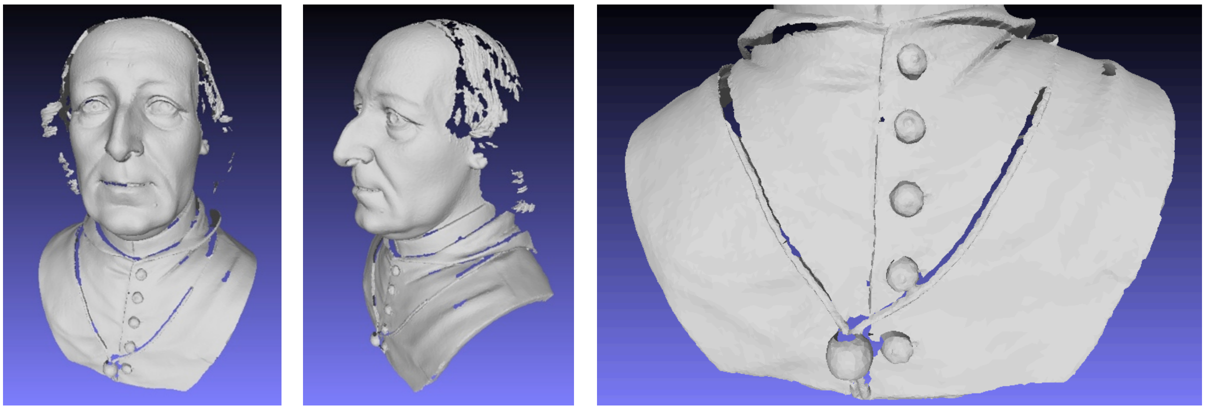


Arc3D – 3D Point Cloud



123D Catch – 3D Point Cloud

NextEngine Scanner – 3D Point Cloud



COMPARISON PHASE

CloudCompare

Presentation

CloudCompare is a dense 3D point cloud processing and matching software (along with triangular meshes to some extent). Its development started from 2004 within the framework of PhD thesis CIFRE funded by EDF R&D and supervised by the Ecole Nationale Supérieure des Télécommunications (ENST – now Telecom ParisTech – TSI laboratory, TII team). It has since continued and is from now on an independent open-source project. CloudCompare is not devoted to a commercial use.

This software has been historically designed to treat dense point clouds (like those from a 3D scanner) so as to compare them in order to extract differences. Thus, it typically allows to:

- calculate local distances between two dense point clouds or between a point cloud and a triangular mesh (figure below left)
- filter the measurement noise from the 3D scanner to highlight the « true » differences (middle figure)
- segment the remaining points into subgroups corresponding to distinct objects (figure right)

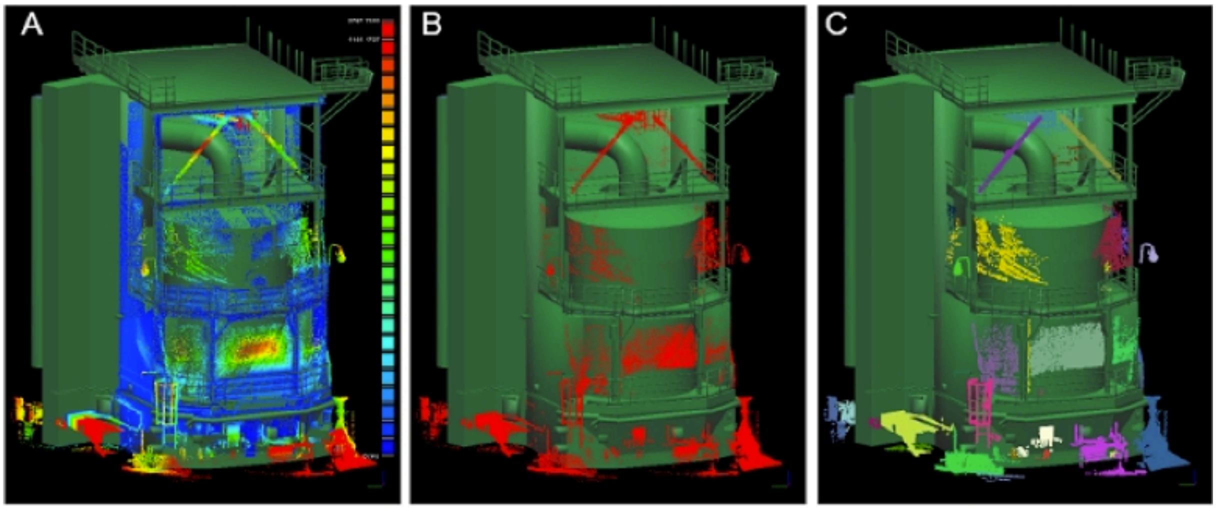


Figure 10: Several examples of use of CloudCompare

CloudCompare has since evolved a lot and offers now many editing functions (interactive rigid transformation, interactive segmentation), automatical adjustment functions (ICP type), modelling functions (computation of Delaunay or Poisson-type surface meshes), reprojection functions (from the point of view of the 3D scanner, a main direction, onto a cylinder or a cone, etc.), morphological calculation functions (roughness, curvature, etc.) and many others. Through a plugins system, the user has also access to external functionalities and libraries (algorithms from the research world – mesh reconstruction by Poisson-type approach, filtering of non-visible points, etc. – acquisition devices such as the Kinect from Microsoft, or some evolved shaders to ease the display of 3D entities – Eye Dome Lighting or SSAO, etc.).

The originality of CloudCompare is based on several factors:

- The data structures used: in particular, a specific « octree » which can process very quickly large point clouds (several millions of 3D points).
- Many choices and methods for the calculation of the distance between point clouds or between a point cloud and a triangular mesh (all based on the notion of nearest neighbour distance); and a fast but less accurate calculation based on a Chanfrein distance;
- The possibility to take the sampling differences between the compared data sets into account;
- The possibility to filter the measurement noise a posteriori;
- The possibility to take the scanner visibility into account for every data set;
- The management of multiple scalar fields associated with the same point cloud (such as distances typically). These scalar fields can be displayed by colouring dynamically the points. They can also allow to modulate the display of the entity (by filtering the points associated with certain values) or to segmentate the associated cloud. More generally, they are used to access numerous algorithms, they can be made up together, etc.

- Lastly, several types of evolved renders (either real-time via some shaders, or offline via a calculation of ShadeVis Ambient Occlusion for instance) enable a significant improvement in 3D data readability on the screen.

It is also important to note that, even though CloudCompare can manage triangular meshes, this type of entity remains first and foremost a point cloud for CloudCompare (the vertices of the mesh), with a specific structure (triangles) and beside many other structures (octree, kd-tree, colours, normals, scalar fields, calibrated photos, etc.). As a user of CloudCompare, it is important to always keep in mind this characteristic and particularly pay attention to the roles of every 3D entity when processing with the software.

Use of the software

I wanted to use a free and simple 3D model comparing software. After carrying out a bibliographic research on the internet, I found several tools developed by some computer vision or photogrammetric laboratories, unfortunately little user documentation was provided and using them did not seem so easy. I talked about it with my school supervisor and she advised me to have a look at CloudCompare.

Actually it turned out to be a very easy and handy software, which crashes much less than MeshLab for instance. The installation went very well and a user documentation is also available, written in french and containing many clear and useful examples.

So this is how and why I chose CloudCompare to process the comparison phase.

Organization of the work

The main tool I used was the « Compute Cloud to Mesh distance » to compute the comparison between two 3D models of the same object. Of course, before getting proper results, many settings and processing were needed. In fact, when the two models we want to compare are loaded in the software, they have not the same scale (because they come from different 3D digitizing systems or softwares), moreover their respective scale don't make sense because they were defined arbitrarily by the software during the process. Thus, I had to scale and register all the models with the help of CloudCompare before starting the comparison phase.

As for the door and the frieze, I chose the result from MicMac as the reference model because it seemed to be better and more accurate than the two others. By the way, the MicMac model is the only one without a mesh already computed, so choosing it as the reference model was imposed by the software itself. As for the bust, I chose the result from the NextEngine scanner, considered to be the most reliable.

Here is a summary of the main steps I performed to compare the surfaces of the different results obtained with all the softwares and presented before:

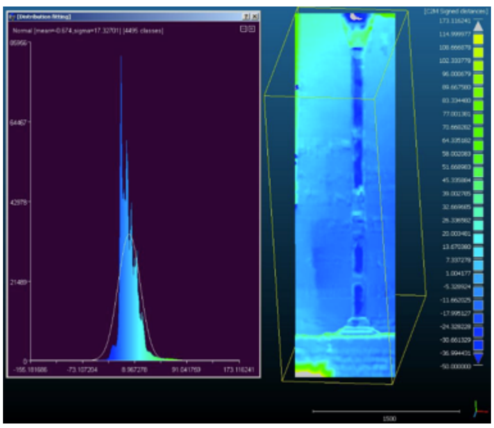
- Scaling the reference model in millimetres.
  To this end, measure the same element on Gimp (millimetres) and on CloudCompare (arbitrary scale of the model), then divide the first value by the second one and apply the corresponding scale factor to the model.
  As for the bust, the reference model is the one from the 3D NextEngine scanner, so its scale is already in millimetres and this step can be skipped.
- Scaling the second model on the first one.
- Roughly and then precisely registering the two models by ICP algorithm (Iterative Closest Point) which minimizes the difference between two point clouds.
- Comparing the surfaces of the two models through automatic measurement of the distance of any point on the surface of the test model from the surface of the reference model.
- Displaying statistics (Gaussian distribution) and results (colour scale and saturation).

Results

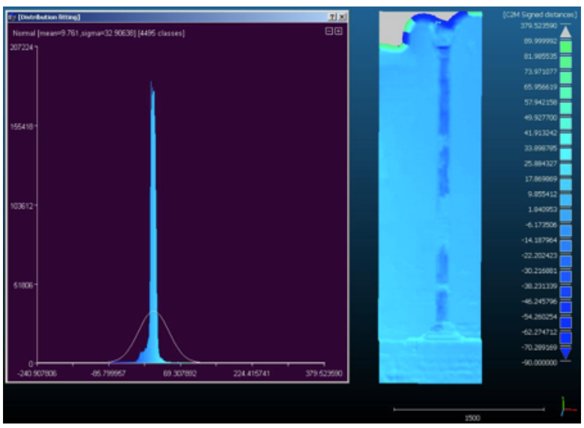
The main entrance of the Castello dell'Imperatore in Prato

The result of the comparison with the 123D Catch model was actually more satisfactory than the one with the Arc3D model. For the first one, the average gap found between the two surfaces was approximately 10 mm whereas for the second one, less homogeneous, the comparison showed an average gap of 20 mm between the two surfaces, with 50 mm peaks around the edges and near the column (areas with more relief).

Comparison **MicMac – Arc3D**



Comparison **MicMac – 123D Catch**

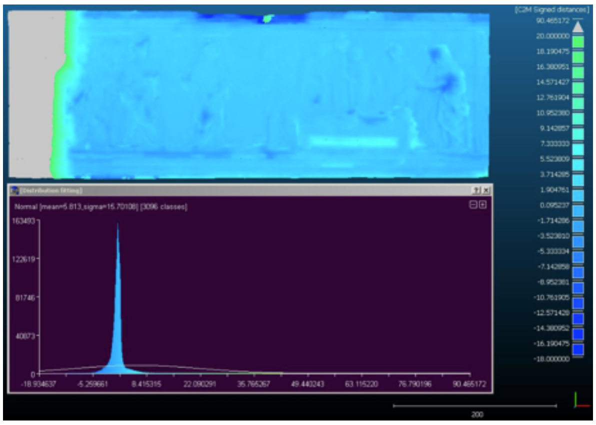


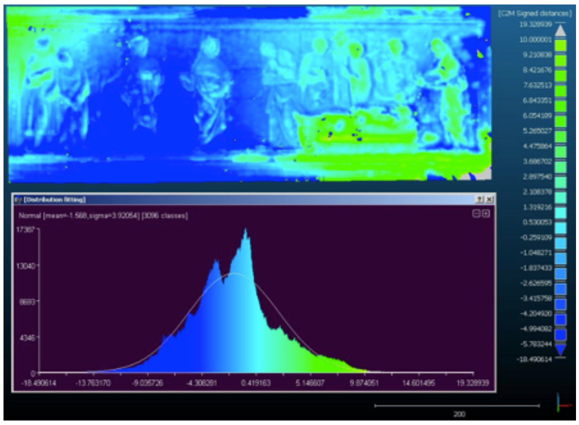
The frieze of the Ospedale del Ceppo in Pistoia

On the contrary, the result of the comparison this time showed that, as already noted in the testing phase, the 123D Catch model was somewhat better and more similar to the MicMac model than the one from Arc3D. For the first one, the average gap found between the two surfaces was approximately 5 mm whereas for the second one, less homogeneous, the comparison showed values widely disbursed throughout the Gaussian distribution, with many peaks around 10 mm on the right-hand side of the frieze, more particularly nearby the coffin. The meaning of the grey colour is a lack of data, as the left side of the frieze was unfortunately not digitized with Arc3D.

Comparison **MicMac – Arc3D**

Comparison **MicMac – 123D Catch**

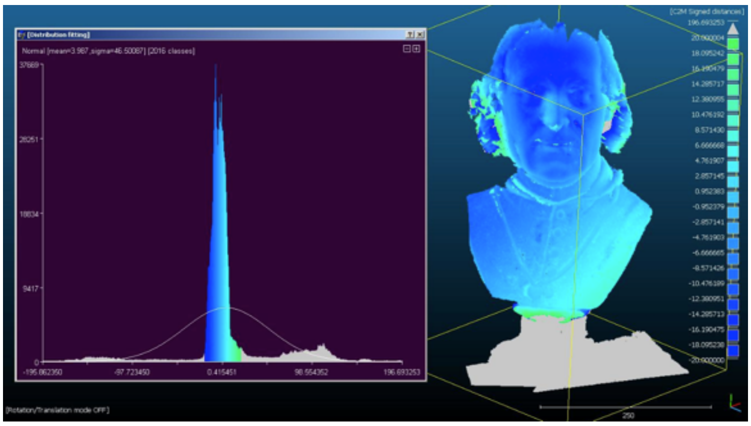




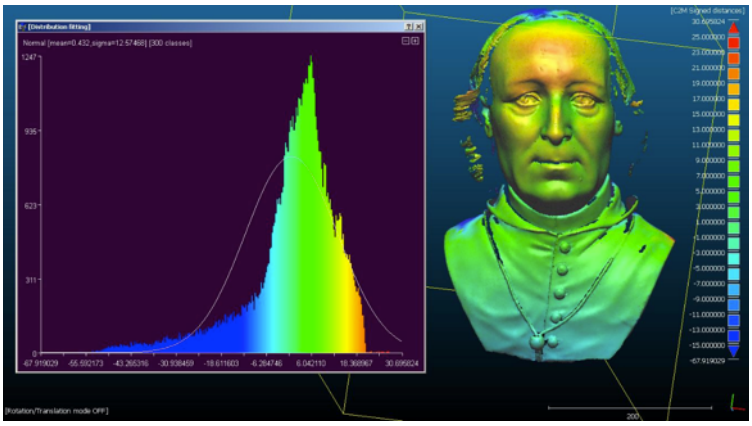
The bust of Scipione de' Ricci in Florence

Comparison **MicMac – Scanner**

Here, as expected, the comparison between the two models showed good results, the average gap found between the two surfaces was approximately 4 mm.

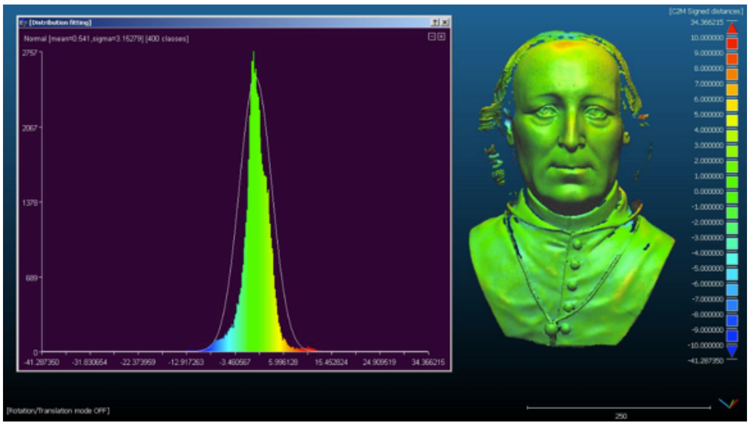


Comparison **Scanner – Arc3D**



In this case, the values were widely scattered. In fact the model obtained with Arc3D was quite misshapen, and so the comparison showed an average gap of 6 mm between the two surfaces with 20 mm peaks near the forehead.

Comparison **Scanner – 123D Catch**



The result of this final comparison was more homogeneous and really satisfactory, the average gap found between the two surfaces was approximately 1 mm (smoother model).

Conclusions

On the basis of the tests and comparisons carried out on different objects by type and size, some important conclusions can be drawn.

As for the two automatic 3D reconstruction softwares, Arc3D and 123D Catch, despite the many problems faced during the processing and the results sometimes quite dumpy or not so presentable, it is important to keep in mind that, first, the 3D models were all processed in a very short time with free softwares, accessible to the general public, and then that these results are not so bad in the light of the comparison phase. They are to some extent close to the results obtained with MicMac or a 3D scanner; then, it only depends on the intended use of the 3D models obtained.

In my opinion, it was really important to be aware of all that. In fact, the field of cultural heritage is characterized by a continuing lack of funds for research, documentation and restoration, and surveying implies the presence of specialists and above all, the use of extremely expensive « traditional » instruments such as tacheometers and 3D laser scanners. Thus, the possibility to use at no cost a 3D model reconstruction tool becomes a huge advantage in this area and may open new way in the documentation of cultural heritage.

One possible area of use of these two softwares could be for instance the education, where the method is often more important than the accuracy. Using them along with MeshLab or CloudCompare for instance would enable students in a course of architectural survey to learn how to work with data similar to those from a laser scanner, and then learn the methodologies and techniques to build 3D models and meshes.

However, one of the limits of these automatic 3D reconstruction softwares is that large objects need to be shot from a long distance but like this, the level of detail is lost. So in the case of large buildings for example, they can be used as tools of survey for small restitutions but they cannot substitute the traditional survey methods. To get more detailed and accurate 3D models of the scene, it would be necessary to use topography with more « traditional » tools of survey like tacheometers and laser scanners.

As for MicMac, we have clearly seen that it can adapt to almost every scene, even to specific cases, and then provide more than satisfactory results given the input data. Actually, it is less accessible to the general public or to non-initiated people at first, in particular because it works on Linux, uses command lines in a terminal window and manages every photogrammetric step during the processing, but this is the reason why this software is interesting and eventually brings satisfaction to the user. Understanding the computation and making it yourself is undoubtedly the gateway to satisfactory results.

IMPLEMENTATION OF MICMAC AND CLOUDCOMPARE WITHIN THE LABORATORY

Organization and logistics

After performing all the tests and comparisons, I really wanted to implement a couple of these softwares within the laboratory: first CloudCompare, because it is easy to use and could be pretty useful to them, and then MicMac with the installation of Linux, writing documentation and tutorials, and training the researchers of the laboratory with an introduction to the software and the command lines.

To this end, I thought ahead and achieved this last step at the very end of my internship, for two weeks. In fact, I had to spend enough time carrying it out, in order for them to feel more comfortable with the softwares after my departure : installing the softwares on their computer, preparing a training, selecting the persons to train, writing documentation and tutorials.

Training

As regards the software CloudCompare, I did not have the time to prepare and present a summary practical in front of everybody as I did for MicMac. Nevertheless, I installed it on a regularly used computer under Windows XP in the laboratory. The installation is really simple (compared to MicMac for instance), so it can be redone at any time on another computer of the laboratory without any problem, if necessary.

By the way, I contacted Daniel Girardeau-Montaut, the software developer and administrator of CloudCompare, to ask him first if there was an english version of the user documentation. He answered that it was not the case, so I offered to translate it partly into english. He supplied me with the latest version and I used subsequently what I translated to write the documentation I left and to present and describe CloudCompare in this report. As it is well-made and contains many good examples, I left the laboratory the french user documentation too.

I also made a tutorial « How to compare two 3D models » with CloudCompare, describing all the different steps, the method and the tools used. Daniel corrected it and gave me some really useful advice about the « Cloud to Mesh distance » function and some others. Then, I translated my tutorial into english and put it with the consent of Daniel on the wiki documentation of CloudCompare, for public use: http://www.danielgm.net/cc/doc/wiki/index.php5?title=How_to_compare_two_3D_models

As for MicMac, my supervisor at the laboratory kindly supplied me with one of her personal computer with a screen and a keyboard, so that it will be exclusively restricted to the use of Linux and MicMac within the laboratory. I installed the latest version of Ubuntu Linux on it, then installed and updated all the libraries and packages needed, and finally I performed the installation of MicMac, as I did at the beginning of my internship on my own laptop (Virtual box Linux on a Mac).

Once the installation finished, I wrote a technical explanatory document that I used to write the section « Functioning of the software » MicMac.

Finally, I wrote a personal user documentation in english for the people of the laboratory: it describes first all the different steps to install MicMac on any Linux system, with the explanation of all the command lines, and then there is a practical to learn how to use MicMac as a beginner. To write the latter, I used a practical work done in class before the internship, expanding it a lot so as to explain every command line typed. I also left them the complete user documentation made by Marc Pierrot-Deseilligny in english, as well as a link to the user forum, useful in case of specific problems or requests, with several tutorials made by some users.

All that in order for them to be able to re-use MicMac properly and under the best possible conditions after my departure.

The tutorial for CloudCompare and the user documentation and guidelines for MicMac are appended to this report.

Future prospects

The GeCo laboratory has an ambition in the long run to set up a photogrammetry complex where they will be able to teach and do some hands-on work or practical case studies with the students in architecture of the university of Florence. It is a project that has just begun, so the computer where MicMac was installed along with the documentation that I left may be a possible help for them in this direction. Furthermore, in addition to the training of students to the softwares they already used before such as Photomodeler or Cyclone, they can now add a new approach with the introduction of MicMac.

I tried to leave a maximum of information and documentation with this aim in view, and to increase their awareness of the use of Linux and the functioning of MicMac and the other softwares I tested, which I hope will be real assets for them in the near future, to carry out some of their incoming works and projects for instance.

CONCLUSION

Throughout these eleven weeks, I performed several tests on 3D digitizing softwares, obtained and compared different 3D models, and started a training to the softwares and methods used during my internship.

This time spent within the GeCo laboratory enriched my knowledge in the architectural and classical photogrammetry domains, using softwares and methods from research and experimenting them directly on different real case studies. I also learnt and gained a great deal of insight into computing, discovering better the operating system Linux and the problems associated with installation, libraries or else portability. Lastly, I appreciated a lot to convey the processing techniques to the members of the GeCo laboratory.

The fact that I was not guided so much during this internship increased my autonomy and forced me to understand and satisfy demands from non-expert backers who were not always able to articulate their needs acurately. My work was not only made up of technique and processing: this internship also enabled me to comprehend the importance of the communication within a team, the understanding of the needs and the accounting of requests. Preparing a formation and training people was also a way for me to understand how difficult and interesting it is to do it and to adapt oneself to a different working environment.

The GeCo laboratory team became aware of the existence, the importance and the usefulness of all these new 3D reconstruction softwares for their future work of activities. Before my departure, I have been able to convey some skills and techniques, in particular with MicMac, and it is expected that they use them for some future projects.

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SITES INTERNET

- Site officiel du laboratoire GeCo :
  http://www.geomaticaeconservazione.it/

- « Building MicMac from source code on Linux platforms », tutoriel pour la compilation de MicMac sous Linux :
  http://intranet.ideg.es/eurocow/BuildingMicmacFromSourceCodeOnLinuxPlatforms.pdf

- Site officiel du logiciel MicMac :
  http://www.micmac.ign.fr/

- Forum d'aide aux utilisateurs de MicMac :
  http://forum-micmac.forumprod.com/

- Site officiel du logiciel Arc3D :
  http://homes.esat.kuleuven.be/~visit3d/webservice/v2/index.php

- Site officiel du logiciel 123D Catch :
  http://www.123dapp.com/catch

- Site officiel du logiciel CloudCompare :
  http://www.danielgm.net/cc/

ANNEXES

ANNEXE 1 : TUTORIEL DE COMPARAISON DE MODELES 3D SOUS CLOUDCOMPARE

CloudCompare – Tutorial

HOW TO COMPARE TWO 3D MODELS

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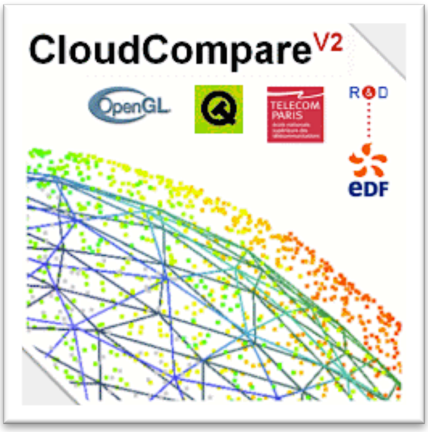
Version du 7 Août 2012



1. LOAD MODELS

Open the two 3D models with « File/Open » (triangular meshes only).

2. DATA PREPARATION

Scaling the models

In case the two models already have the same scale (because they come from the same 3D scanner or the same 3D reconstruction software for example), you can skip this step.

- First, choose an accurate element, visible in the two models: edge, cornice, line or every other rectilinear element. If you cannot manage to find such an element, then choose two specific points visible enough in the two models: crossing of two lines or curves, corner, etc.
- Then, measure this element (or the distance between the two specific points) on the model with the larger scale by selecting it with « Select two points and display segment info » with the aid of the tool « Point picking » (you may have first to make the model vertices appear or to sample points on the mesh - see last remark at the end of this tutorial).
- Note the value found down and do the same on the other model (i.e. the one with the smaller scale).
- Eventually, divide the first value by the second one and apply the corresponding scale factor: select the model with the smaller scale and do « Edit/Multiply ». In the *fx*, *fy* and *fz* fields, enter the factor found before.

Conversely, to scale-down the model with the larger scale, all you have to do is to divide the second value found by the first one and then do « Edit/Multiply » on this model in the same way as before.

Roughly registering the models

In case the two models are already roughly registered, you can skip this step.

- If both models are far apart, use the « Edit/Synchronize » tool to make the centers of gravity of both 3D models match.
- Then, select one of the two models (or directly its "vertices").
- With the help of the « Rotate/Translate » tool, you can interactively apply several rotations and/or translations so as to superimpose them roughly.

Precisely registering the models

In case the two models are precisely registered, you can skip this step.

- Refine and finish the superimposition of the two models with the « Tools/Register » tool (Iterative Closest Point algorithm).

Don't hesitate to use this tool several times, by changing the stop criterion and exchanging the assigned roles with the aid of the button Swap. *As for the research parameters, it is not necessary to change them.*

Check that the models are properly matching and apply some more transformations if necessary.

3. DATA COMPARISON

Select both 3D models and begin the comparison with the « Compute cloud/mesh distance » tool.

You'll have to choose the roles of each models (one will be the *reference* model, and the other one will be the *compared* one). The compared cloud will host the computed distances (one scalar value per vertex).

In the insert called *Dist. Computation*, you will found some results from the first **approximate** distance computation step (this step is automatically performed by CloudCompare when this tool is called). A histogram representing the distribution of these distances is also available to help you set some advanced parameters if necessary.

To finish the comparison process, press the *Compute* button.

Remarks:

- The color scale and the saturation can be adjusted in the *Properties* of the compared model (or its vertices) so as to display the results in a better way.

If the compared model vertices are sparse / with a low density, you may have first to sample points on it with the « Sample points on a mesh » tool. Select then the resulting cloud and the reference model and apply the « Compute cloud/mesh distance » tool again.

ANNEXE 2 :
GUIDE UTILISATEUR POUR L'INSTALLATION ET L'INITIATION AU LOGICIEL MICMAC

MICMAC – GENERAL GUIDE

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INSTALLATION GUIDE – How to install MicMac

First and foremost, the tools required to build a working version of MicMac are:
- A Linux-based computer (Ubuntu Linux 12.04 in our case).
- A working, command-line oriented, C++ development toolset.
- A subversion compatible client (as, for instance, svn or RapidSVN).

First of all, connect to the **geco** session on the computer.
User Password: **micmac2012**
Then, open a **terminal** window on the desktop.

Here are the main command lines you will have to use before installing and using the software MicMac:

sudo su
/// To log in the Root directory and get the administrator rights for all the commands. After executing it, type the user password.

export http_proxy="http://D097501:geco2012@proxy-auth.unifi.it:8888"

/// In order to specify the IP address, the username and the password of the proxy used.
IP Address: proxy-auth.unifi.it
User: D097501
Password: geco2012

gedit etc/apt/apt.conf
/// Edit the empty file 'apt.conf' and add this line :
Acquire::http::Proxy "http://D097501:geco2012@proxy-auth.unifi.it:8888";
Thus, it will let us use the *apt-get* command to download some essential packages and libraries on the internet.

env | grep proxy
wget -v www.google.com
/// The first command checks if the proxy has been configured properly on linux, and the second one checks if it manages to connect to the internet, using as an example the Google web address.

Now, to update and upgrade all the useful packages and libraries, we use several *apt-get* command lines:

First, **apt-get update**
Then, **apt-get upgrade**

Also, on Linux system, there are some so-called package dependencies that must be satisfied before compiling MicMac. These packages are for X.h, Xlib.h, Xutil.h, cursorfont.h and keysym.h.
The following command will install these dependencies:
apt-get install x11proto-core-dev libx11-dev

If you wish to use JPG images, the free, open-source program **convert** will be required. It is part of the imagemagick package. To install it, just type the following command:
apt-get install imagemagick

By the way, installing the build-essential package will let you compile files and sources with the command *make*:
apt-get install build-essential

Finally, install the subversion compatible client *svn*:
apt-get install subversion

Everything should be now ready to begin the installation of MicMac.
Before proceeding to download the source code and examples files, create two new folders in /home/geco/. Call them *micmac* and *micmac_data*.

The first one is the folder where the micmac source code will be copied. The second one, where all test data will be copied.

Important note: In case some files or folders created or computed are **locked** by linux, change its owner to **geco** (which is the name of the user) so as to unlock them, using the following command line:
chown -R geco:geco /path/to/my/locked/file/or/folder/

Now, to **download the sources**:

When using the classic subversion client tool *svn*, the command to issue to retrieve the source code is:
svn co http://www.micmac.ign.fr/svn/micmac/trunk <destination_directory>
where <destination_directory> stands for any valid folder in the computer / account ; for instance, the folder *micmac* created before.

Some of the examples require also some data. It can be downloaded using the following subversion command:
svn co http://www.micmac.ign.fr/svn/micmac_data/trunk <destination_directory>
where, again, <destination_directory> stands for any folder of your choice, such as the folder *micmac_data* created before.

However, in this specific case of a configured **proxy**, we must use these two command lines instead:

- For *micmac*:
svn --config-option servers:global:http-proxy-host=proxy-auth.unifi.it --config-option servers:global:http-proxy-port=8888 --config-option servers:global:http-proxy-username=D097501 --config-option servers:global:http-proxy-password=geco2012 checkout http://www.micmac.ign.fr/svn/micmac/trunk/ micmac

- For *micmac_data*:
svn --config-option servers:global:http-proxy-host=proxy-auth.unifi.it --config-option servers:global:http-proxy-port=8888 --config-option servers:global:http-proxy-username=D097501 --config-option servers:global:http-proxy-password=geco2012 checkout http://www.micmac.ign.fr/svn/micmac_data/trunk/ micmac_data

Finally, to **build MicMac**:

In the terminal window, go into the *micmac* folder containing all the sources you have just downloaded and type the following commands:
make clear
make install

make input

NB: To **update** the software tools and examples (*micmac* and/or *micmac_data*), type the same *svn* command lines but this time, replace checkout by update. Then, rebuild MicMac as explained before.

USER GUIDE – How to use MicMac

Here is a simple tutorial to get used to the functioning of the photogrammetric pipeline MicMac and its many possibilities. It presents the differents steps, the main command lines used, and provides some global explanations at each step.

FIRST INTRODUCTION TO MICMAC

Computation of a 3D point cloud and an orthophoto on the portal of the priory Notre-Dame de Salagon (Mane, France)

- Start the computer under Linux
- Log as *geco* (password: *micmac2012*)
- Open a terminal window: Type 'terminal' in *Dash Home* to find it quickly
- Type sudo su (password: *micmac2012*)
- Go to the project directory from the terminal:
  cd /home/geco/micmac/data/Salagon
- Display its content with the command ls

Compute the SIFT points on all the images of the directory

```
../../micmac/bin/Tapioca All ".*JPG" 1500
```

../../micmac/bin is used to get back and go to the directory *micmac* to find the tool *Tapioca*. This tool is a simplified « overlay » of the tool *Pastis* which is used to compute the tie points between images.
Then, an enumerated value specifies the functioning mode (i.e. a way to compute the pair of images that are to be matched). Here, the value *All* which stands for all possible pairs was chosen, but there also exists *MulScale* for a multi-scale optimization, *Line* for a selection adapted to linear images acquisition, and *File* for XML file describing the pairs.
Finally, *1500* is the resolution used for the computation. If you type *-1* instead, the full resolution of the image will be taking into account.

Compute the relative orientation of the images

```
../../micmac/bin/Tapas RadialExtended ".*JPG" Out=All
```

The tool *Tapas* is also a simplified « overlay » of the tool *Apero* which computes the relative orientation.
Then, the distortion parameter chosen here is *RadialExtended*, but there also exists *RadialBasic* (with less distortion parameters taken into acount).
After « Out= », we specify the name of the folder where the results of the computation will be put.

- *How to validate the computation ?*

By looking at the Medium Tie Residual (« Résidu Liaison Moyen » in French) at the end of the computation. It is quite acceptable when the latter is below 1, and optimum when close to 0.5.

- *Display the content of the directory Ori-All*

It contains notably the auto-calibration file of the scene « AutoCal240.xml », but also the files describing for each image the orientation of the camera. If you open for instance one of these description files (of the form « Orientation-IMG_*ImageNumber*.JPG.xml »), you will find some essential information such as the rotation and translation matrices R and S.

Compute a point cloud showing the tie points and the cameras in feature space

../../micmac/bin/AperiCloud .*.JPG All Out=SalagonCameras.ply

Additional option : If you don't want the tie points to be in colour in the point cloud created, you can add RGB=0 to the previous line.
The tool *AperiCloud* creates a file .ply from the result of the previous orientation, contained in the directory *Ori-All*. After « Out= », the user can type the name he wants for the file. You will found the latter in your main image folder (in this case, the project folder « Salagon »).
NB: The two writings *.*.JPG* et *.*JPG* are equivalent, whatever the file format used (JPG, TIF, NEF, etc.).

Prepare the image mosaic process
Defining a plan for the « Bascule »

../../micmac/bin/SaisieMasq "IMG_1148.JPG"

The chosen image should be the central or reference one of the project, if it exists (it is usually the case for a planar scene).
In the interactive window that opens up, the following commands will let you capture a mask on the photo :

- *Left Clic* - to capture a point
- *Ctrl Left Clic* - to delete a point
- *Shift Left Clic* - to close the mask
- *Right Clic – Coul* - on the mask, to begin a hole

- *Right Clic – Exit* - on the mask, to save and quit

Topple over all the images on the same planar coordinate system
Before that, use for instance the software Gimp to find two pairs of coordinates which define an horizontal line on the chosen image (here, on *IMG_1148.JPG*).
Then, type the following command:

../../micmac/bin/Bascule ".*JPG" All Repere.xml P1Rep=[825,853] P2Rep=[3421,775] ImRep=IMG_1148.JPG

This creates a file named *Repere.xml* (of course, you can call it differently). « Repere » is the French word for Coordinate system. In fact, this file will be used for the creation of the mosaic and the projection of the final orthophoto.
P1Rep et *P2Rep* are the two pairs of coordinates previously found.
ImRep is the image chosen for the capture of the mask and the coordinates.

Creation of the image mosaic

../../micmac/bin/Tarama ".*JPG" All Repere=Repere.xml Zoom=4

The mosaic is created from the coordinate system computed previously.
The option *Zoom* is not mandatory.

Prepare the dense correlation
Defining a mask on the image mosaic

../../micmac/bin/SaisieMasq "TA/TA_LeChantier.tif"

In French, « TA » stands for « Tableau d'Assemblage », and « Le Chantier » means 'The Scene' or 'The Project'.

Start the dense correlation – Generation of DTM & Orthophotos
Edit the parameter file « ParamMicMac.xml » in the image folder « Salagon » with the help of *TextEditor*, in order to specify which mask and images to work on.
Check that it works with multi-resolution mode and in ground geometry.

../../micmac/bin/MICMAC ParamMicMac.xml

In the directory *MEC*, the files of the form « Correl_XXX.tif » contain the mean of the correlation coefficients on all the pairs of images (white = 1 and black = 0).

Assemblage of the individual orthophotos
Check the parameters of the file « ParamPorto.xml », put it into the folder *ORTHO* and then start the process with the following command:

../../micmac/bin/Porto ORTHO/ParamPorto.xml

Display and qualify the results

Getting the shaded-relief images

../../micmac/bin/GrShade MEC/Z_Num9_DeZoom1_LeChantier.tif ModeOmbre=IgnE

ModeOmbre is an option here, it is not mandatory.
There exists also several other options, not used here.

Getting the depth maps

../../micmac/bin/to8Bits MEC/Z_Num9_DeZoom1_LeChantier.tif

Getting the 3D point clouds (.ply)

../../micmac/bin/Nuage2Ply MEC/NuageImProf_LeChantier_Etape_9.xml
Attr=ORTHO/SalagonOrtho.tif

Attr is used to specify the image which will be projected onto the 3D point cloud created. In this case, the orthophoto previously computed was chosen.

However, this first introduction to MicMac and its functonalities is not enough to get aware of all the possibilities the software can offer.

It is important to remember that every project is unique, and some specific problems may appear in some cases, more complex than the one we have just carried out:
Problems due to photo shot, scene location, focal length, cameras position, format of the images, texture or brightness of the objects, etc.

Thus, a forum was created specifically to support MicMac users and help them to overcome all these potential problems. It can be really useful in case you don't understand something in particular or face a specific problem: http://forum-micmac.forumprod.com/

Many problems have already been solved in both French and English, and some tutorials have also been made by a few users in the section « Prises de vue, paramétrage et post-traitement ».

ANNEXE 3 : PLANNING DES TACHES REALISEES