SIDART-A NEW INTEGRATED SYSTEM FOR DIAGNOSTIC OF THE CULTURAL HERITAGES

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ABSTRACT

To preserve the state of maintenance of good of historical interest - artistic involves investigations on the appearance, on the actual state and on the alteration and deterioration processes of artistic object. The project SIDART (Integrated System for the Diagnostic one of the ARTistic goods) allows to collect different kind of information in systematic and scientific way for an accurate diagnosis of the mechanisms that the deterioration and to operate with the most effective and appropriate remedies to the situation.
The objective is to create an integrated system for the diagnostic of the cultural heritages that allows acquisition, elaboration and aggregation of different kind of measure with the purpose to study interventions with maximum effectiveness, minimum cost and minimum risk for the integrity of the object. Such system includes the search and the debugging of new portable technologies, the online integration of classical methods, the export of the data toward vertical informative systems for the operators in the sector.
Particularly, the project is divided in different parts : The first consists to build a portable system for the preliminary diagnosis in place, for instance the creation of a new laser scanner system for high resolution 3D scanning. Then was developed some application techniques of complexes systems of diagnostic (tools of physical and chemistry analysis for the molecular knowledge of the work of art) and for reverse - engineering and virtual geometric modelling, that is visualization of three-dimensional images for virtual models and tools for the assistance to the diagnosis. Other parts of the project consists in the development of invadingless methods of analysis of the structures and the realization of simulation models of deterioration process of inquiry object.
At least the project provide for the realization of an integrated informative system, that collects and organizes all the information coming from the precedents parts allowing a diffusion of final results.

1. INTRODUCTION

1.1 The SIDART

This work takes place inside SIDART (Integrated System for Cultural Heritage Diagnostic) project, whose objective is to develop hardware and software package for cultural heritage diagnostic.
The tutelage of historical and artistic heritage suggest different kind of surveys to acquire data about structural aspects of the object, about conservation condition and about incidental deterioration and decay process. This information collection must be done in systematic and scientific way to permit an accurate diagnosis of decay mechanism and to operate with the affective and convenient cure.
If the diagnosis is based on scientific data and in-depth research, it's possible to activate preventive measures and restrict actions on the object. The current tendency is to spend the major effort for the prevention, and this means the capacity of monitoring the incidental deterioration rather than supply later with binding restoration works.
Generally the survey for diagnostic or preservative operation have the target to collect information about:
- Material and structure of the object
- The Chemical and physical composition of materials
- The geometry and study of spatial distribution of materials
- Construction technique aimed to the dating of the object.
- Conservation history of the object: identifying and acknowledgement of previous intervention, of kind of restoration materials, of their mapping.
- The cause and the "pathological" processes that compromise the stability

Aim is to create an integrated system to acquire and integrate information produced by different survey instruments (laser scanner, multi-spectral camera, calibrated metric fotogrammetric camera, termography) used in cultural heritage diagnostic. This would be a new completed tool useful for restoration in architectural and cultural study application in order to prepare aimed intervention with maximal efficacy and minimum risk for the object also supposing his reutilization.
The integrated system include the project of new portable technologies, the integration of the acquired information in the network, the exporting of data to information system for operator.

1.2 Research partner

The project involve some partner such as ENEA Group of Frascati, INOA, and CETMA that is leader of the project. The particular rule of our group of laboratory of Survey, Digital Mapping, GIS of Politecnico di Milano is to cooperate with CETMA to create a software able to display and to model laser scanner points clouds. The software is build by Ing. De Pascalis of information division of CETMA of Brindisi.
The analysed clouds come from a new prototype of laser scanner product from CETMA with Enea[1] competence.

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All test and other survey measures, such as multi-spectral and termographic survey are conducted by CETMA with Politecnico permanent collaboration.

2. THE INTEGRATED SYSTEM

2.1 Sidart – Software CH_P

The presented software, identified as CH_P (Cultural Heritage Project), has the aim to manage the collect, to organize and to elaborate every information that come from different instrument such as laser scanner, multi-spectral camera, Thermocamera, Digital Camera and to carry out a diagnosis on the conservation condition of the object.

This application lets an operator import two-dimensional image of the work art and makes diagnosis using a lot of tools for elaboration of digital images. This set of instruments allow to operate filtering operation (low-pass filter, high-pass filter etc.) equalization, stretch, binary operation, selection end highlight of decay zone like cracks, spots, crusts, biological attacks and patina. In the software you can use normal digital images or rectified images and orthophotos: the software is able to read the georeference TFW file. In this case is possible to calculate the real areas and perimeter of the interesting zone and create a kind of GIS of decay condition of the inquiry object. This tools can be very useful for restoration operator to calculate the amount of pigment and material to use for the restoration operation.

Another functionality in the application is the possibility to join enclosure and note file to every kind ok image. This let the operator take notes of every step of elaboration and to have at disposal all necessary material for the study of artistic object as text files, web pages, images, graphs, bibliography references etc..

The software let to save every phase of the elaboration project, so it's possible to:

- ✓ Freeze the project and restore it in a second time
- ✓ Transfer data and results on support database or on remote server
- ✓ Visualize online the information about an object using a GIS portal on a web site purposely built.
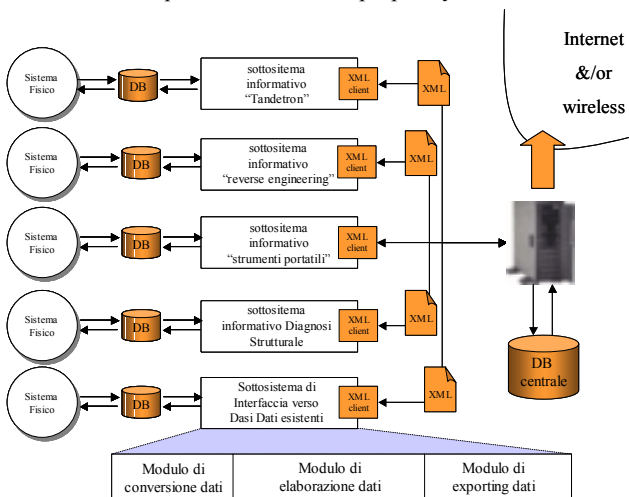

Figure 1. Flow diagram of the CH_P software. On left site you can see input information in the system coming from physical instruments. This information will be converted and stored in different kind of database. Second step is the work area where every data can be elaborate with different module of the

software. Every elaboration are later send to a central database and/or to the web.

All the project is stored in a XML file (Extensible Markup Language) that organize the data in nodes. Naturally the principal node is the ARTISTIC OBJECT with its all defined data. Inside this there is the PROJECT NODE that contain every information about author, beginning and end date and is composed with under-nodes ITEM that are the images to elaborate. For every item is defined the metadata PATH, that is the path of the images on the local host and some kind of other notes like INSTRUMENT that contain the data of the acquisition instrument, WIDENING that contain metadata and attachment connected to the ITEM, and OPERATION that contain all the elaboration list applied to the images.

Figure 2. Example of described XML structure

Figure 3. Mapping of decay on a georeferenced digital image

2.2 Point clouds

The Points Clouds module is a dedicated software for visualization, elaboration and modelling of 3D laser scanner points clouds.

The software is able to load files with PLY format. The PLY file format is a simple object description that was designed as a convenient format for researchers who work with polygonal models. Early versions of this file format were used at Stanford University and at UNC Chapel Hill.

A PLY file consists of a header followed by a list of vertices and then a list of polygons. The header specifies how many vertices and polygons are in the file, and also states what properties are associated with each vertex, such as (x,y,z) coordinates, normals and colour. The polygon faces are simply

lists of indices into the vertex list, and each face begins with a count of the number of elements in each list.

This files come direct from the laser instrument that provide the triangulated surface of the acquired object and infrared colour information.

The most application implemented in the software is the possibility to create 3D orthophoto from the triangulated surface and digital images.

The implemented algorithm is the DLT (direct linear transformation) equation solved with least squares method.

The equations of the DLT are linearised around approximate values of the parameters that we have previously obtained.

We need a set of points that are known in the two spaces; each point enables to write two equations.

With at least six points we get the unknowns.

The DLT method guarantees in that case sufficient precision because the laser surface and digital image has very deep resolution.

Furthermore the surface has infrared information, that allow to pick points and particular with optimal accuracy.

We implement also the possibility to create Ortofoto 3D of flat surface.

In this case we use the omografy algorithm.

This method can be used with some type of digital image.

We test with multi-spectral image (infrared, ultraviolet) and also with image from thermocamera.

Figure 4. Colour application of digital high resolution image, The pick point and the result of the operation are showed

Is possible to register clouds range maps. In the software is implemented the rototraslation with direction cosine.

You need three common point between two rangemap to complete the registration.

Always for the good resolution and accuracy of the laser, the precision of this procedure can be considered adequate.

In the software is implemented the possibility of choose some cut plane and extract the corresponding sections.

This procedure works on the triangulated surface.

This is different from other software that normally create sections collecting points between two planes that are very close.

In this case you don't have a real line section but a little slice of point that needs to be interpolated and approximated with other software or application.

In our software the cut plane dissect a triangulated surface so return a "line of point" that is the intersection between the plan and the sides of each triangles.
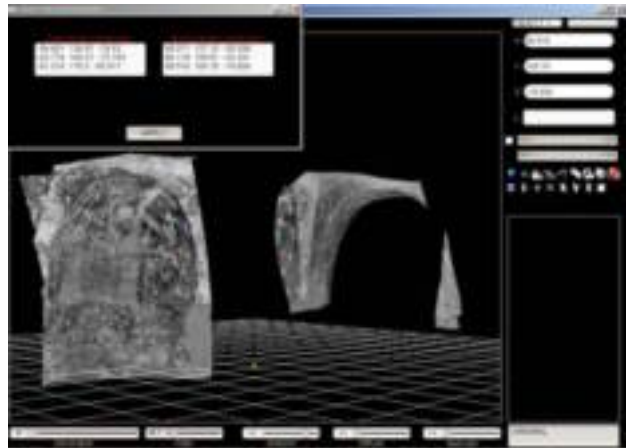

Figure 5. Registration procedure in the software. You can see the two 3D surfaces and the two coordinate list collected for the roto-translation
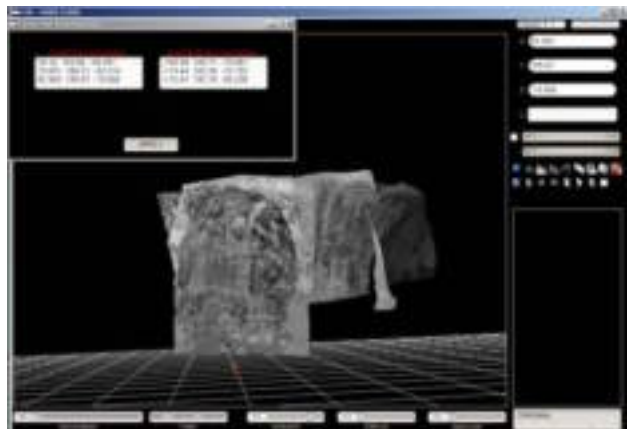

Figure 6. Registered surface at the end of procedure. The created surface can be saved in new PLY binary file or in TXT ascii format
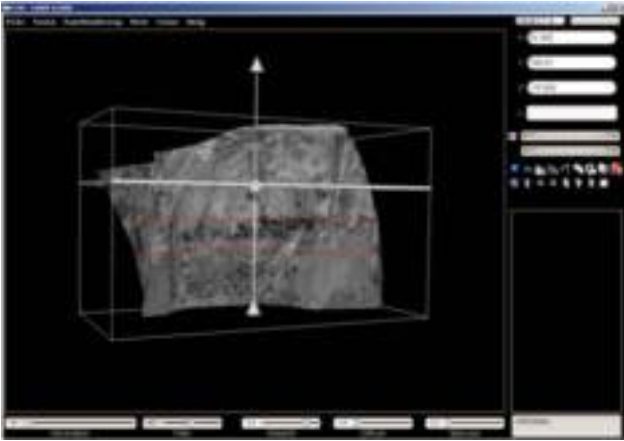
Figure 7. Multiple Plane clipping procedure. It's possible to cut the surface with plane parallel to the axis or in free mode
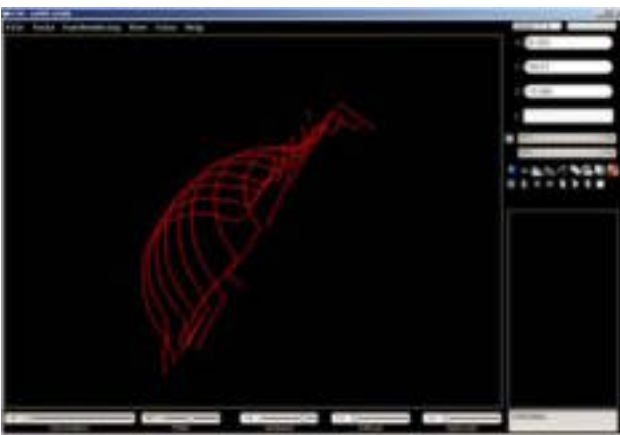

Figure 8. Visualization of multiple sections that can be export to other software in ascii format

Other application implemented in the software are the surface **filtering**. In the ply surface can be some "long triangle" due by laser rays hitting some edge. The triangulation create so long triangle from point that are on different plane. This triangle had to be delete and the hole can be filled from other clouds taken from different position.

Another application is **decimation** of points to return a lighter surface when the geometric information are redundant.

Shaving light simulation is also implemented. This can be useful to inspect the surface and to study micro elevation, fractures or little defect of the surface such as paint detaching. This is possible always thank the high resolution and precision reached with laser scanner that can detect very little particular.
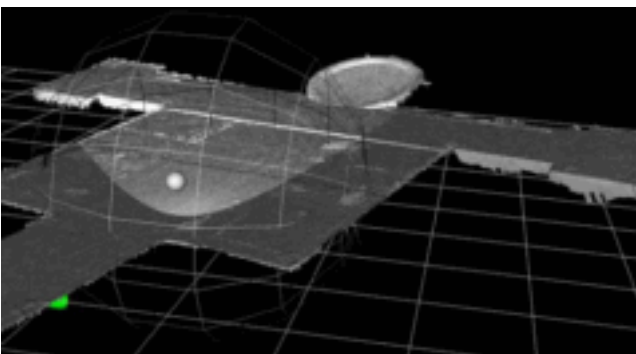

Figure 9. Shaving light simulation on Rosano cross

All the operation that are described above can be saved and the operator can work using the laser surface preserving previous application results. In particular the assigned colour from Ortofoto procedure can be saved in the ply file and all other operation can be done using this useful information providing a great sense of reality and major control during the diagnose.

3. TEST AND APPLICATION

All the procedure and the integrated system are tested with real cultural object what are object of future restoration. In particular we make measure survey with new laser scanner prototype SIDART 100 This instrument has a very good accuracy (at test phase) and assure 10^{-1} space resolution.

We use multi-spectral camera for IR and UV inspection of frescos and digital fotogrammetric camera Rollei DB 44 for high resolution (16 Mega pixel) image.

Figure 10. Laser scanner prototype Sidart 100 and multi-spectral camera used in our tests

3.1 S.S.Stefani of Vaste

The crypt of S. Stefani is excavated in the stone and is formed by three naves separated with pillars. The crypt was used for a long time like a depository of corn, sheepfold and drying room for tobacco.

It's decorated with frescos, even if some of them are in abandonment condition. The frescos show images of Saints, Archangels, Our Lady and Christ. The original frescos date back to Xth century, but they were substituted with other paints afterwards (about XIVth and XVth century). In the following figures are represented some example of laser clouds and Ortofoto 3D of S.S. Stefani crypt.
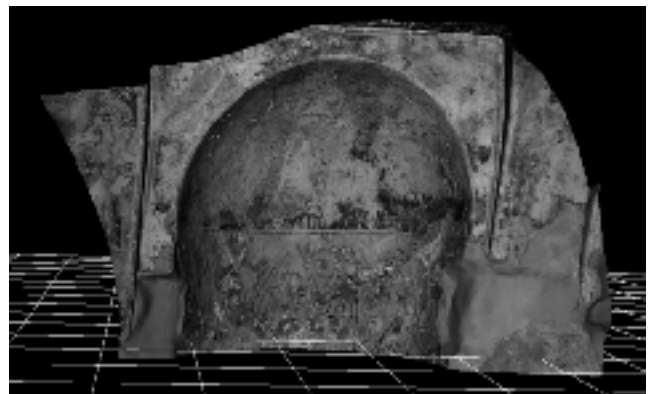

Figure 11. Surface of central apse. Spatial resolution of 1 mm. It's visible the colour information on infrared range

Figure 12. Ortofoto 3D from a digital image of metric camera (16Mpixel) Rollei
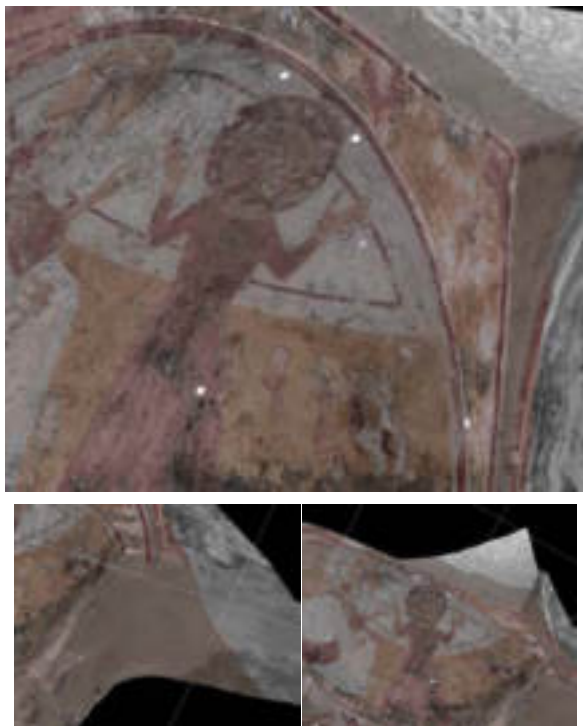

Figure 13. Some particulars. Image residuals is 2 pixel that correspond to 0.0014 m on the surface

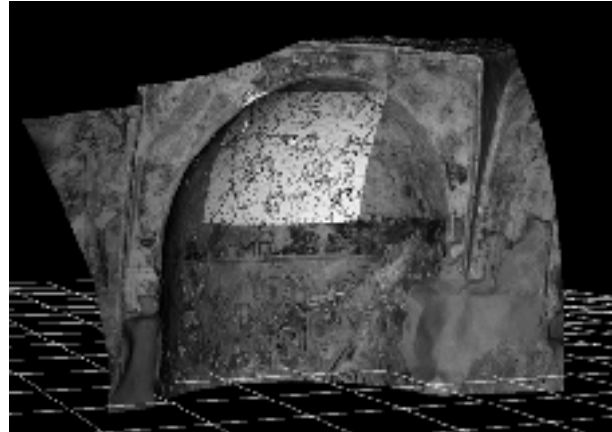Figure 14. Complete 3D Ortofoto of the three apses that are registered in the same reference system

Figure 15. Application of a filtered digital image. This demonstrate how useful can be this method for analyse an object. In this case we have georeferenced a digital image from multi-spectral camera on infrared range and with the applied filter we can highlight the contours of the image. This can help the operator to analyse the fresco on the apse.

3.2 Cross of Rosano

It' s a painted wooden cross temporarily sited by "Opificio delle Pietre Dure" in Florence for restoration.

This cross probably represents the most ancient example of the Florence school of painting (XIIth century). It represents the Christus triumphans with the passion story at the side of principle table

Figure 16. In this case the cross is to be considered flat, so was used the omography algorithm to create the 3D Ortofoto with a digital image coming from commercial digital camera

Figure 17. Colour application from colourimetryc data from INOA. RMS on the image is 4 pixel that correspond to 0.0009 m on the laser surface

4. CONCLUSION

The presented work shows the first result of some years of research conducted from CETMA and Politecnico of Milan inside SIDART project. The effort is to create a complex system able to elaborate different kind of physical data and to store, visualize all these data in one database with the possibility to transfer information and the restoration history of the inquiry object to different levels of users. The system will be a good instrument for operators who are able to enter the database and get to know about previous operation executed on the object. It's also dedicated for common people that can get information with the projected GIS module .

SIDART would be the first step for elaborate and organize the big amount of data of artistic pieces that characterizes our Italian culture heritage with a common standard and with the most modern technologies in the field of surveying and measuring.

Next projects will improve the system specially in the field of 3D surface modelling of points clouds coming from laser scanner history.

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