3D VISUALIZATION AND VIRTUAL REALITY FOR CULTURAL HERITAGE DIAGNOSTIC

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1. Introduction

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 project involves some partner such as ENEA Group of Frascati, CNR-INOA and CETMA that is a private research center located in the south-east of Italy and also leader of the project. The aim is to develop an integrated system to acquire, integrate, process and distribute information produced by different survey instruments (laser scanner, multi-spectral camera, calibrated metric photogrammetric camera, thermography) used in cultural heritage diagnostic. This would be a new completed tool useful to restoration in architectural and cultural study application.

The Laboratory of Survey, Digital Mapping, GIS of Politecnico di Milano has cooperated with CETMA to create the software able to display and to model laser scanner points clouds. The analysed clouds come from a new prototype of laser scanner product from CETMA with Enea (Frascati Group) competence [1]. This instrument has a very good accuracy (at test phase) and guarantee 10-1 space resolution. All test and other survey measures, such as multi-spectral and thermographic survey are conducted by CETMA with Politecnico permanent collaboration.

2. The software: laser clouds

2.1. The language: VTK Library

The software has been developed using VTK library. The Visualization ToolKit (VTK) [2] is an open source, freely available software system for 3D computer graphics, image processing, and visualization used by thousands of researchers and developers around the world. VTK consists of a C++ class library, and several interpreted interface layers including Tcl/Tk, Java, and Python. VTK supports a wide variety of visualization algorithms including scalar, vector, tensor, texture, and volumetric methods; and advanced modeling techniques such as implicit modeling, polygon reduction, mesh smoothing, cutting, contouring, and Delaunay triangulation.

2.2. The PLY format

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, normal 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. These files come directly from the laser instrument that provides the triangulated surface of the acquired object and infrared colour information.

Here is a script to load and view 3d scanned object in ply format:

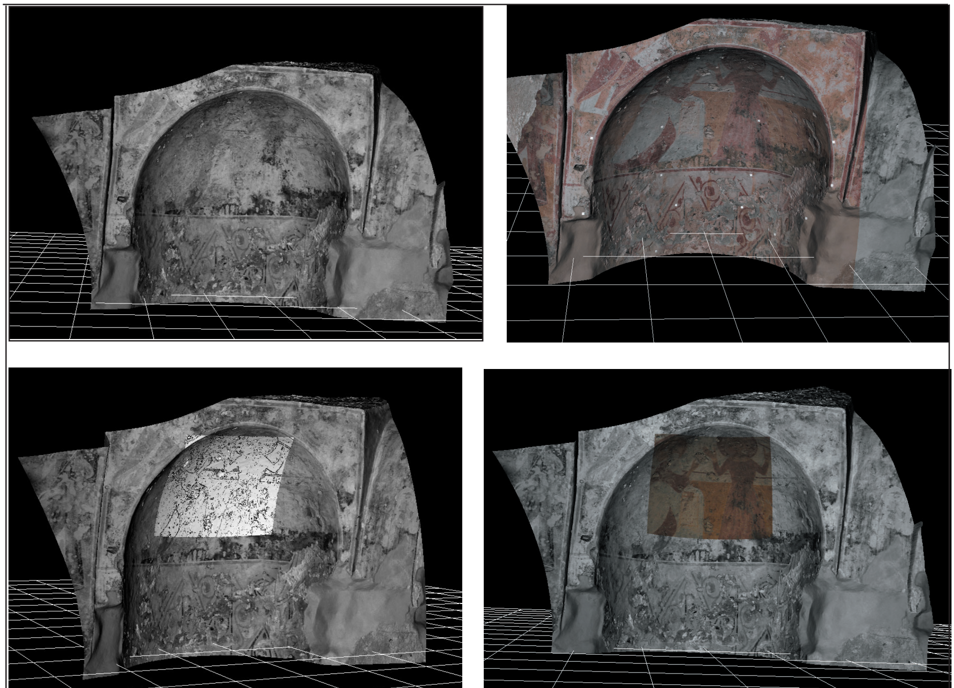
```
vtkPLYReader *reader=vtkPLYReader::New();
        reader→SetFileName(file);
vtkPolyDataMapper *mapPD = vtkPolyDataMapper::New();
        mapPD→SetInput(reader→GetOutput());
vtkActor *actorPD = vtkActor::New();
        actorPD→SetMapper(mapPD);
  vtkRenderWindow *renWin = vtkRenderWindow::New();
vtkRenderer *renderer=vtkRenderer::New();
renWin→AddRenderer(renderer);
renderer→AddActor(actorPD);
renWin→Render();
```

2.3. Data matching

The most important application implemented in the software is the possibility to create a data matching from the triangulated surface and digital images.

The aim is to place the colour information obtained in other diagnosis instrument images on the 3D laser surface model.

The implemented algorithm is the DLT equation (Direct Linear Transformation) solved with least squares method [3-4]. We need a set of points that are known in the two spaces; each point enables to write two equations. As a result, by matching at least six



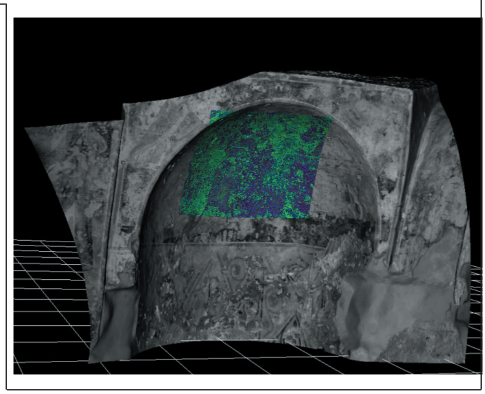


Figure 1. Our first test. Clockwise from the top: The raw image of a niche of the S. Stefani Crypt in Poggiardo*, Vasto (Lecce)*[1]*.*

points between the 3D object and 2D image, we are able to know for each 3d coordinates the corresponding point on the image. From the coordinates it is then possible to extract the RGB values and to associate them at the laser cloud.

The DLT methods guarantee in this type of analysis adequate precision because the laser surface and digital image have very deep resolution.

The presented software allows to georeference different kinds of digital image. We test with multispectral image (infrared, ultraviolet) and also with image from thermocamera. Integration of different diagnosis data and technique (Laser scanner, thermographic, multispectral) is a good valuation method of the state of the cultural object (fig. 1). Different colour layers can be added to 3d object, furthermore every layer is stored in a list, so the user can switch between different views of the object.

A perfect point matching is possible because the laser SIDART 100 enables to acquire both depth and intensity images (in infrared band): so it is easy to find features in common between the 3D object and the corresponding image.

The software allows to use a particular interceptor manipulator to place the marker (fig. 2). Furthermore a better accuracy is possible using the stereoscopic visualization. This manipulator has been developed inheriting functions by the vtkInteractorObserver class, whose instances are generally used to control the camera and provide simple key-press and mouse oriented techniques [2]. This manipulator allows to place in correct position the marker, viewing around the object a gridbox on which the user can move a mobile intersector line. It is not difficult that way to choose the point with good accuracy.

2.4. Other function

With the software it is possible to carry out some elaboration of the 3D surface:

- export in ascii file and in 3ds format, cut with plane, filtering of large triangles, decimate, modify light illumination, shave light simulation, exporting section in ascii or dxf format.

3. 3D Visualization and Virtual Reality

The "Virtual Cultural Heritage" is a recent area where some spectacular growth look place over the past few years.

At the beginning the Virtual Reality was used in design or industry contest to have a whole and immersive representation of the projected objects or in the entertainment field for immersive games and virtual adventure.

Nowadays VR can be considered the most powerful "knowledge tool" developed at the beginning of this millennium. To understand this importance we must realize what the Virtual Reality is. The VR allows to reproduce an environment or an object by a software technology, but this is done in a way that it is not distinguishable from reality. So it is possible evolve in this environment, observe and examine it and also work with it inside it, as though it were a real and natural world. So the VR allows an intuitive, unconscious, almost childish approach to a phenomenon: this is the first and the most natural knowledge form [5].

Today Virtual Reality (VR) technologies are becoming very useful techniques also in the field of cultural heritage to represent, show, explain historical and architectonical

Figure 2. Example of 3D Surface scanned with Laser SIDART100. The left image shows the raw surface and the right image the coloured mesh. The example shows the fresco in Saint Mary Antiqua[2].

object to a large public. It also provides a useful and powerful instrument for the operators in restoration fields.

We believe that the combination of computer graphics and VR technique may provide an important set of information to better understand the decay phenomenon and choose the most appropriate restoration intervention.

3.1. Virtual Reality Device

Our VR device is a Table Projector Baron (fig. 3) [6], with workstation equipped with nVidia Quadro 4500 graphic card. Such system allows us to make both passive and active stereoscopic visualization.

Figure 3. Table Projector Baron (Barco).

During the active 3D projection, the viewer wears special eyewear (two IR-controlled LCD light shutters working in synchronization with the projector). When the projector displays the left eye image, the right eye shutter of the active stereo eyewear is closed, and vice versa. The used projector must be able to display at a very high refresh frequency so that the viewer cannot perceive the flicker effect.

We also develop the passive (Anaglife) technology, so the two images (the right and the left ones) are processed with two filters of complementary colours. In accordance with the International Stereoscopic Union the red colours is used for the left image and Cyan for the right one. The 3D image can be seen with the famous “red and green glasses”.

The first technology gives better results and is certainly more useful than the second one. We develop the two techniques only to give the 3D possibility also when is not possible to use or to have the active visualization that is more expensive.

We have also tested the software inside a CETMA’s Virtual Reality Center. This system is based on a ORAD cluster architecture (fig. 4) [7] with twelve DVG (digital videographic).

Figure 4. ORAD cluster architecture with twelve DVG.

Each DVG is composed of two render units. Each unit has: a Motherboard ASUS PC-DL Deluxe 2, two INTEL XEON CPU 3.06 GHz (on each motherboard), a BFG 6800 ULTRA by NVIDIA graphic card. These renderers are linked by means 1Gb ethernet network and their output is made up with a genlock.

The virtual theatre (fig. 5) is composed of three mobile screens that can assume two configurations like traditional cad wall or immersive cave.

The system uses six Infitec Technology Projectors (two for each screen).

Infitec is the latest stereo technology. It delivers superior stereo separation without ghosting, with full freedom of motion, independent of head tilt. Left and right eye image are simultaneously displayed, while the Left/Right image separation is made through Infitec Filter Technology.

This technology requires two projectors with two optical Infitec filters that split the colour spectrum in two parts: one for the left and one for the right eye information. If each of the two Infitec filters is mounted into the optical light path of its own projector, a stereoscopic image can then be made by putting the left eye information in the image of one projector, the right eye information in the image of the other and by using the matching

Figure 5. The virtual theatre is composed of three mobile screens that can assume two configurations like traditional cad wall or immersive cave.

Infitec filter in the pair of Infitec glasses in front of the corresponding eye. Both projectors display their information at standard refresh rate.

Compared to active stereo it is completely free of flickering, more efficient and comes with more affordable glasses. Compared to passive stereo it achieves superior color fidelity.

3.2. Stereoscopic Visualization (fig. 6-7)

This software can work using classic prospective visualization or with 3D visualization. The high resolution of the laser product in the project plus the 3D vision allows to detect anomalies easily. The 3D picking of the points for data matching will be more accurate and enables to produce more precise colour transfer. The possibility to add to the geometry colour information obtained by diagnostic instruments such as thermo-camera, multi-spectral machine, allows to investigate the damage cause in a deeper level.

Using VTK is simple enough to manage the stereo capability; indeed the library provides a complete set of classes to develop rendering window adapt to view the two scenes (right and left) for stereoscopic visualization.

Here is below a part of the code in order to manage passive and active stereo.

```
renWin→StereoCapableWindowOn();
renWin→SetStereoTypeToCrystalEyes(); or renWin->StereoTypeToRedBlue
renWin→StereoRenderOn().
```

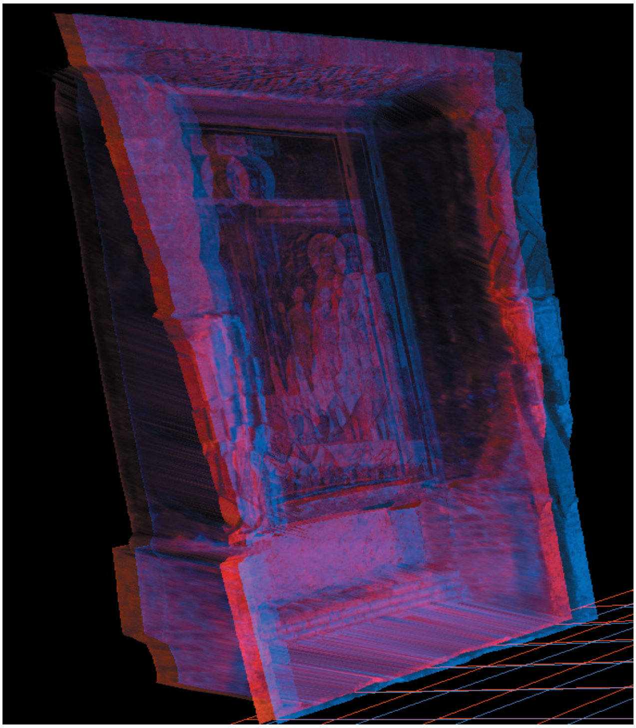


Figure 6. Passive 3D visualization of frescoed wall in Saint Mary Antiqua in Rome[3].

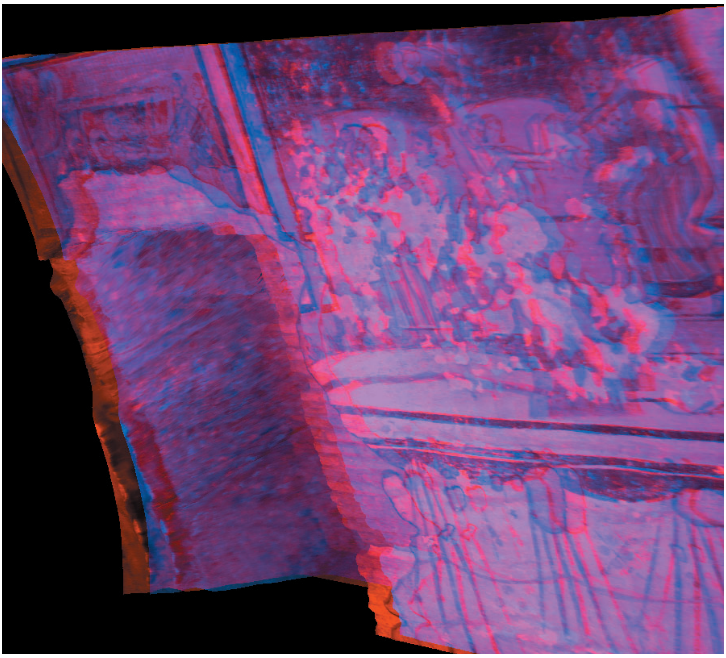


Figure 7. 3D picking in passive stereo.

Notes

[1] The S. Stefani Crypt in Vasto province of Lecce (LE). It is excavated in the stone and is formed by three naves separated with pillars. The crypt is decorated with frescos, even if some of them are in deterioration state. The frescos show images of Saints, Archangels, Our Lady and Christ. The original frescos date back to the Xth century, but they were substituted with other paintings afterwards (around the XIVth and XVth century). The laser SIDART 100 and the software with high resolution photogrammetric digital camera Rolleiflex 6008 were tested.

[2] Saint Mary Antiqua (Rome) was erected in the middle of the 6th century on the Palatino Hill; it is the most ancient and important Christian monument of the Roman Forum. All the walls are painted with frescos. We test our technology before the beginning of restoration works.

[3] You can see this image with Anaglife glasses.

References

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[9] BRUMANA R., FASSI F., FREGONESE L., MONTI C., POTENZA A., COLIZZI L., DE PASCALIS F. (2005), *SIDART-A New Integrated System for diagnostic of the cultural heritages*, CIPA 2005, Torino, XX International Symposium.

Summary

In the past years, many different new technologies for Cultural Heritage Diagnostic have been developed. In particular laser scanner surveys with digital photogrammetry and also multi-spectral surveys are becoming very useful and inalienable tools for non invasive diagnosis. In the SIDART Project (Integrated System for Cultural Heritage diagnosis), we develop a software able to visualize and elaborate triangulated surfaces coming from high resolution laser scanner survey. In this paper, we

want to present the most innovative aspect of our study, that is the possibility to visualize and work in default mode or in immersive Stereoscopy (3D mode). This lets the operator perceive the third dimension and the “virtual investigation” of the object becomes more realistic. This lets us take into consideration in a more simple, natural and correct way and also reduce the possibility to make wrong evaluation due to the false prospective of the classic visualization.

Riassunto

Negli ultimi anni sono state sviluppate diverse tecnologie informatiche per la diagnostica dei beni culturali. In particolare analisi morfologiche condotte con laser scanner o tecniche di fotogrammetria digitale, o ancora imaging multispettrale, cominciano ad affermarsi e nello stesso tempo ad imporsi per la diagnosi non invasiva. Nell’ambito del progetto SIDART (Sistema integrato per la diagnostica dei beni artistici), è stato sviluppato un software per visualizzare ed elaborare superfici triangolarizzate ottenute da un radar ottico ad altissima risoluzione. In questo articolo vogliamo evidenziare gli aspetti più innovativi del software con particolare attenzione alle potenzialità avanzate di visualizzazione anche stereoscopica, con le molteplici possibilità di ispezionare i modelli 3D in modo più immersivo e realistico. La visualizzazione immersiva consente di effettuare considerazioni in modo naturale e semplice, riducendo la probabilità di errore.

Résumé

Ces dernières années, différentes nouvelles technologies ont été développées dans le domaine du patrimoine culturel. Tout particulièrement, les enquêtes laser scanner à photogrammétrie digitale et multi-spectrales sont devenues des instruments de plus en plus importants pour effectuer un diagnostic non invasif. Dans le projet SIDART, nous développons un logiciel qui permet de visualiser et élaborer des surfaces triangulaires tirées de l’enquête à haute résolution laser scanner. Dans cet article, nous voulons présenter l’aspect le plus innovateur de notre étude, la possibilité de visualiser et travailler in default ou en stéréoscopie (3D). Ceci permet à l’opérateur de percevoir la troisième dimension et l’enquête virtuelle de l’objet devient plus réaliste. La visualisation immersive nous permet de faire des analyses d’une manière plus simple, plus naturelle et plus correcte, et surtout de réduire la possibilité d’effectuer une mauvaise évaluation due à une fausse perspective de la visualisation classique.

Zusammenfassung

In den letzen Jahren wurden viele verschiedene neue Technologien zur Diagnostik des Kulturerbes entwickelt. Im Besonderen Laserscanner mit digitaler Photogrammetrie und multi-spektraler Bildverarbeitung, nützlich und unverzichtbar für die nicht invasive Diagnostik. Mit dem SIDART Projekt haben wir eine Software entwiceklt, die imstande ist, trianguläre Flächen aus hochaufgelösten Bildern zu visualisieren und elaborieren.

In diesem Beitrag möchten wir den innovativsten Aspekt dieser Studie präsentieren, nämlich die Möglichkeit in Standardverfahren oder immensiven Stereocopien zu visualisieren.

Das erlaubt dem Bediener die 3. Dimension wahrzunehmen, um die virtuelle Recherche des Objekts realistischer zu machen.

Das ermöglicht, es in einem simpleren, natürlicheren und korrekteren Weg zu erkennen und reduziert die Möglichkeit, einer falschen Evaluation als Ergebnis einer falschen Prospektive der klassischen Evaluierung.

Resumen

En los últimos años se han desarrollado diferentes tecnologías para el diagnóstico de los bienes culturales. En particular, se están volviendo cada vez más usados para diagnósticos no invasivos los análisis morfológicos con láser escáner, técnicas de fotogrametría digital o imagen multiespectro

imaging. En el ámbito del proyecto SIDART (Sistema integrado para el diagnóstico de los bienes artísticos), se ha desarrollado un software para visualizar y elaborar superficies triangularizadas obtenidas con un radar óptico de altísima resolución. En este artículo queremos poner de manifiesto los aspectos más innovadores del software, que permite también una visulización estereoscópica: esto hace que se puedan inspeccionar los modelos 3D de manera más inmersiva y realista. La visualización inmersiva permite realizar consideraciones de forma más natural y simple, reduciendo las probabilidades de error.

Резюме

В последние годы в области информатики были разработаны различные технологии оценки состояния объектов культурного наследия. В частности, морфологический анализ при помощи лазерного сканирования и методы цифровой фотограмметрии, а также многоспектральный imaging начинают завоёвывать популярность и в то же время становятся необходимыми при щадящей диагностике. При проекте SIDART (Единая система исследования произведений искусства) был создан softwar для наглядного показа и обработки угловых поверхностей, полученных при помощи оптического радара очень высокой разрешающей способности. В этой статье мы хотим показать инновационные аспекты softwar, акцентируя особое внимание на передовых возможностях наглядного стереоскопического показа с многочисленными вариантами изучения объёмных моделей (3D) более глубоким и реалистичным способом. Наглядная детальная демонстрация позволяет проводить наблюдения более естественным и простым способом, сокращая тем самым вероятность возникновения ошибок.