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ABSTRACT

In this paper some experiences about the data fusion for cultural heritage documentation are presented. The goal is the production of metric documentation for immersive and three-dimensional navigation. The resulting products are also very useful for web-based animation purposes.

The main stairway of the Chancellor building at the Padua University was chosen as test site and some different methodologies were applied to realise navigable products.

Traditional surveys and historical analysis are performed to document the main stairway from Gio Ponti also in terms of differences between the project and the realisation itself.

The panoramic photos acquisition is used with some image processing techniques to mosaic and to filter the raw data. Different software is used to test different interpolation algorithms also in terms of computational effort. The anaglyphs are created for this site. The laser scanning survey is performed using the Leica HDS2500 3D laser scanner (re-branded Cyrax 2500 scanner). Some acquired point clouds are presented with different acquisition parameters (point of view and resolution) in the Cyclone 5.1 and Reconstructure environment. Furthermore, algorithms coming from image processing, like the Sobel filter, are applied to produce detailed silhouettes and perform edge extraction.



Figure 1 - Panoramic photo of the stairway

1. INTRODUCTION

In this paper some experiences about data fusion for cultural heritage documentation are presented.

The main stairway of the Chancellor building at the Padua University was chosen as test site (Figure 1) and some different methodologies were applied to produce different analysis.

1. Project analysis: traditional surveys are performed to document the differences between the project and the realisation of the structure.

2. Shape analysis: stereoscopic photos and three dimensional models, using AutoCAD and laser scanner, are produced to analyse the architectonic shape of the stairway.

3. Space analysis: panoramic photos and three dimensional models are realised to analyse the room where the stairway is placed.

4. Marble analysis: Photographic surveys are performed to verify the correspondence between the marble sequence noted in the project and real sequence.

The different methodologies, used to perform the analysis, as explained in the following, are: panoramic surveying, stereoscopy, laser scanning.

2. HISTORICAL REVIEW

The Bo, the historical palace of the University of Padua, from the '30 to the '40, is involved in an architectural program of renovation wanted by the provost Carlo Anti. The program concerned the adjustment of the old buildings, and also the construction of new buildings in the city and in the neighbourhood.

In July 1936 the directorate of the building-consortium (found in the 1933), with the goodwill of the provost, approved an agreement with the famous architecture Gio Ponti for the interior decoration of the University.

Furthermore Gio Ponti built the stairway of the Chancellor. The main feature of the stairway is the big fresco that Gio Ponti painted with the assistance of Pendini, Dandolo and his daughter Lisa.

The fresco represents the origin of the mankind and of the knowledge and the development of the science.

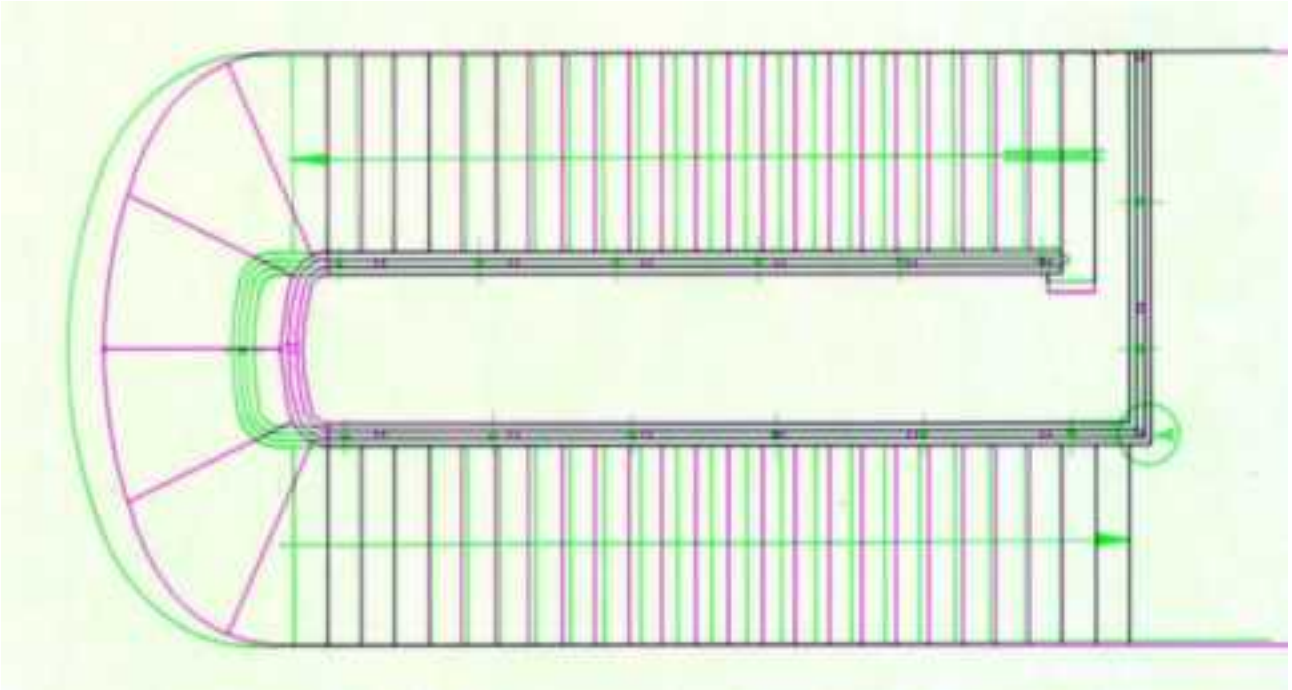


Figure 2 - Overlap of project plant (green lines) and AutoCAD plant (red lines)

3. GIO PONTI'S PLAN ANALYSIS

Traditional surveys are performed to document the differences between the project (made from the 1939 to the 1940 and stored in the central archive of the University of Padua) and the realisation of the stairway.

The analysis confirms that the stairway presents some metrical difference (with an error of 0,5 cm) with the data written on the project. The main difference is about 5 centimetres while the littlest one is about 0,5 centimetres.

These differences aren't caused by the subsidence of the structure, because there aren't rifts in the wall. Therefore new plants and prospects are realised in AutoCAD environment using data collected by the survey; after, a global three-dimensional model is created.

The overlap of the plant drawn in the project (the green one) and that one realised with AutoCAD (the red one), show the main geometrical difference noticed during the traditional survey (Figure 2).

4. STAIRWAY SHAPE ANALYSIS

The shape analysis of the stairway is based on the anaglyph made with Anabuilder software (Figure 3) and on the analysis of the three dimensional model (Figure 4).

The stairway has 49 steps (the first ramp has 24 steps and the second 25; riser = 16,6 cm; tread = 33,5) that lift up to 8,03 metres.

Each step is repotted of 2 cm, and so the step, in the plant of the project, seems to be 31,5 cm long.

The stairway has two rectilinear ramps linked by a round landing. The two ramps are long (8,19 m the first one and 8.53 m the second one) and they are 2 metres width; this fact increases the sense of depth.

While the first ramp seems to be very heavy for to the dark colour of the fresco, the second one seems to be very slight for to the brighter colour of the fresco and for its shape that reminds a white bar.



Figure 3 - Anaglyph obtained whit the "cha-cha" method

5. SPACE ANALYSIS

The room, where the stairway is located, is quite singular: it is narrow (5,34 m), long (14,58 m) and tall (13,01 m).

The room has only one wall that encloses completely the stairway and this gives a sense of continuity to the allegory painted by Gio Ponti. The wall looks like a big sheet prepared to be painted, so the space (Figure 5) has to be analysed in its wholeness to avoid missing the sense of continuity.

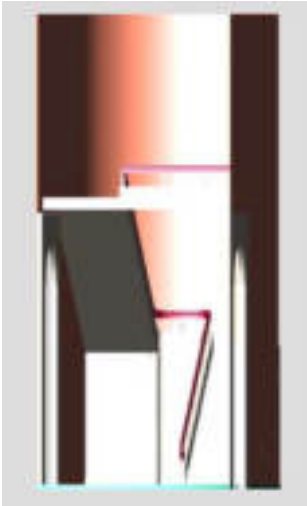


Figure 4 - AutoCAD three dimensional model of the stairway



Figure 5 – The walls with the big fresco surround the stairway

6. MARBLE ANALYSIS

The multicolour of the marble is one of the main features of the stairway. Photographic survey is performed to verify the correspondence (Figures 6, 7) between the real sequence of the stairway and the marble sequence noted in the project.

A sequence of six colours is presented as a table in the original project (white, fantasy, black, red, yellow, green). This sequence should be iterated on the whole stairway. Indeed the sequence is not presented except for some random sequence repetition (different from the one of the project).

Anyway a chromatic relationship exists between the colours of the fresco and the colours of the marbles.



Figure 6 - Actual sequence of the stairway marbles

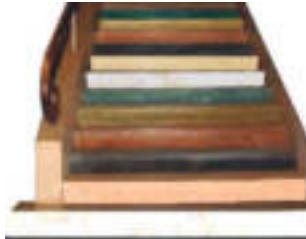


Figure 7 - Virtual reconstruction of the marbles sequence

7. ANAGLYPH

Stereoscopic photograph is the perception of the deepness of an object that is a consequence of the binocular vision. Each eye sees a different image which is elaborated by the brain to create only one image which gives the exact idea of depth.

So, two different photos of the same object should be taken to realise three dimensional photos.

There are different ways to visualize 3D images: liquid crystal glass, Polaroid, stereoscope, “free” vision, and anaglyph.

Anaglyphs are realized “merging” the channels of the complementary colours of the right and left images.

Anaglyphs are viewed through Red/Cyan glasses. These glasses let the homologous components combine themselves.



Figure 8 - Anaglyph obtained with Anabuilder software

AnaBuilder is a program for the creation of stereoscopic photographs like anaglyph. The program makes it possible to adjust the two views manually or fully automatically.

Anaglyphs of panoramic photos are not realized taking a right and left photo, but just splitting the panoramic photo into right and left channel. Some anaglyphs of some portion of the stairway are made taking right and left photo using the “cha-cha” process and a commercial digital camera. The result is very good (Figure 8).

8. PANORAMIC SURVEY

Panoramic photographs are realised overlapping different sequenced photos. The overlapping should be 20 - 30% at least. Colour and brightness variations, due to constant exposure for each image, often make it difficult to combine photographs into panoramic images. The individual source images remain distinguishable. This effect counteracts any effort to improve panorama resolution by using many photographs as sources. In vertical panoramic photograph (Figure 9), top and bottom lines are warped due to the shift of the visual angle of the camera in single photos. In horizontal panoramic photograph (Figure 10) camera shift from right to left and at the edges lines are warped. These deformations are called “barrel deformation”. 360° panoramic photograph (Figure 11) is realized rolling the camera along the vertical axis for 360 degrees. The final panorama looks bent on big bends.



Figure 9 - Vertical panoramic photo



Figure 10 - Horizontal panoramic photos



Figure 11 - 360° panoramic photo

Digital images manipulation often requires resampling of the pixel data. Therefore, an interpolation algorithm has to be applied and the computational effort is crucial to improve the image quality of the final result.

The pixel value evaluation of a particular position in the result image comes from the interpolator work combining several pixels of the source image. The closer pixels to this position have more weight.

Two photographs are mosaicked (with 26 control points) using three different algorithms:

- Linear Interpolation:

The weight of the source pixel is calculated by

$$(1) \text{ weight} = 1-x$$

X = 0 corresponds to matching source and result pixels.

2 pixels are used for 1-dimensional interpolation.

4 or 2-dimensional calculations.

- Cubic Interpolation

$$(2) \text{ weight} = [(A + 2.0) \cdot x - (A + 3.0)] \cdot x^2 + 1.0$$

Where: $0 < x < 1$

$$(3) \text{ weight} = [(A \cdot x - 5.0 \cdot A) \cdot x + 8.0 \cdot A] \cdot x - 4.0 \cdot A$$

where: $1 < x < 2$

It uses 4 pixels in one, and 16 pixels in 2 dimensions.

The parameter 'A' determines the behaviour of this function.

It is set to -0.75.

- Sinc Interpolation

$$(4) \text{ weight} = \left[\frac{\sin(x^{1/4})}{(x^{1/4})} \cdot \frac{\sin(x^{1/4} / 8)}{(x^{1/4} / 8)} \right]$$

This interpolator uses $16 * 16 = 256$ pixels.

Different algorithms are tested for a stitching example. There are no important variations in the final photo restitution: slight colour and shape variations are marked in the stitching area. Therefore one algorithm doesn't look better than the others.

The main differences are noticed in the processing time: time is proportional to the complexity of the algorithm (from some seconds for linear interpolation to few minutes for cubic and sinc interpolation).

Because colour and brightness variations often make it difficult to combine several photos into a single homogeneous panoramic image, the individual source images remain

distinguishable. This effect counteracts any effort to improve panorama resolution by using many photographs as sources. Due to different sources of colour variations, it is quite difficult to manually correct them, so automatic adjustment tools are desirable.

A quality criterium is the matching of colours histograms in the overlapping region of images A and B. The histogram denotes the number of occurrences of each colour value as a function of this colour value. If two images are perfectly colour balanced, their histograms are identical (Figure 12).

The algorithm calculates gradation-curves for each colour channel which match the corresponding histograms. These gradation curves are then used to correct image B. The method adjusts one single image A with respect to another image B, but can easily be extended to adjust a single image relative to many images.

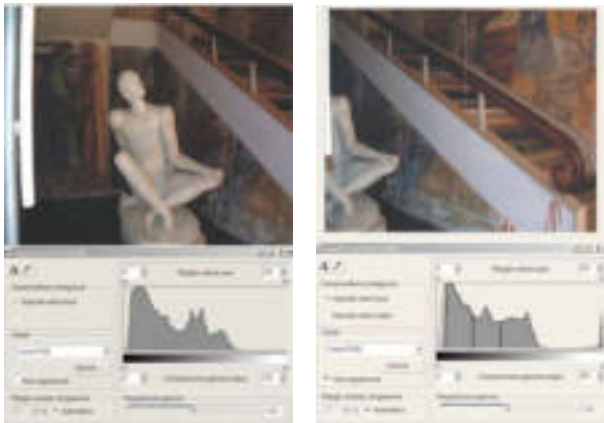


Figure 12 – Example of the histograms for the overlapping area of two different images

Two different software are used to assembly panoramic photos: PTGui can easily stitching images into high quality panoramas, using a visual interface to Panorama Tools. The user writes command 'scripts' and PTGui hides all Panorama Tools scripting commands from the user.

The main features are:

- Images Correction.
- Perspective Control
- Remapping from any projection to any projection
- Warping and un-warping standard, panoramic and fisheye images.
- Real-time Panorama Editor

Some problems come out using PTgui: sometimes, panoramas are very warped and colour-brightness correction fail, due to the difficulty of setting parameters; forced alignment of control points garbles the edges of the imagine.

PixMakerPro delivers a different environment to create high-quality panoramas that can be easily transformed into interactive content for viewing on the Web and offline.

Following the simple 3-phases Snap-Stitch-Publish, PixMaker Pro enables to create panoramic interactive photos using:

- Intuitive controls
- Automatic colour and brightness correction

Unfortunately, PixMakerPro can create only horizontal panorama; so, to realize the panoramic photo of the stairway it is necessary align horizontal and vertical photos.

Therefore the panorama of the stairway is realized in 2 steps: aligning vertical photos rolling them of 90° and the stitching the vertical panoramas created before.

9. LASER SCANNING SURVEY

To obtain the coverage of the visible part of the stairway surface, the acquisitions have been performed from three levels: 16 laser scanner acquisitions have been executed from the first floor, the round landing and the ground floor (Figure 13).

The laser scanning survey is performed using the Leica HDS2500 3D laser scanner (Cyrax 2500 rebranded).

Its main characteristics are:

- Instrument type: High-speed, high-accuracy laser radar.
- Single point accuracy:
 - Position: ± 6 mm @ 1.5m - 50m range, 1 Sigma.
 - Distance: ± 4 mm, 1 Sigma.
 - Angle: ± 60 micro-radians.
- Modelled surface precision: ± 2 mm.
- Laser type: pulsed; proprietary microchip.
- Safety: Class II (ref. CFR 1040).
- Spot sizes: ≤ 6 mm from 0 - 50 meters.
- Range: maximum up to 100m; recommended: 1.5 m- 50 m.
- Scan rate: 1 column/sec @ 1000 pts/column @ full FOV
2 column/sec @ 200 pts/column @ full FOV.
- Scan density:
 - Vertical: 0.25mm minimum point-to-point spacing (@50m)
 - Horizontal: 0.25mm minimum point-to-point spacing (@50m).
 - Scan column: 1.000 points/column, max.
 - Scan raw: 1.000 points/raw, max
- Field of view: Vertical: 40° - Horizontal: 40°.
- Volume of space addressed (max): 20,000 m³ /scan (@6mm accuracy) - 160,000 m³ /scan (@100m range).
- Scanning optics: dual mirror, random access protected by housing and glass shield.
- Video targeting: 480 x 480 colour resolution.

The data obtained by the acquisitions have been processed with Cyclone 5.1 and Reconstructor environments.

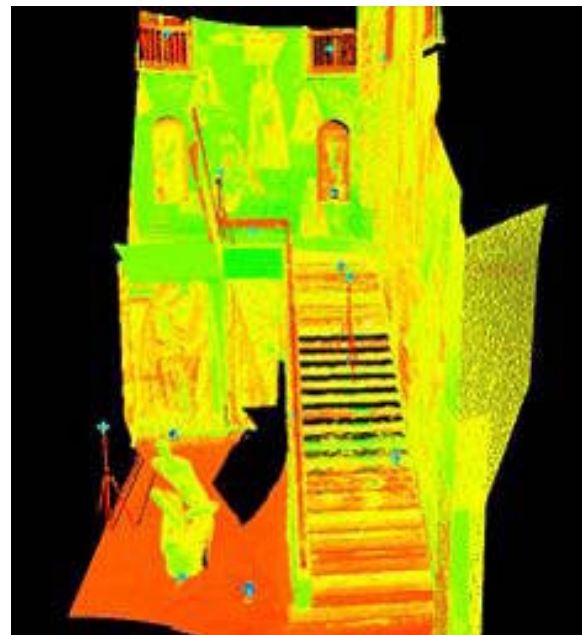


Figure 13 - Point clouds of the stairway with Cyclone

A grid of 1cm is used to performed laser scanner survey (Figure 14). It is enough to see that the marble surface is quite rough (Figure15) and to underline some irregularities on the plaster of the wall like rifts and bulges (Figure 16). This kind of survey is very useful to set up a restoration plan of the stairway.

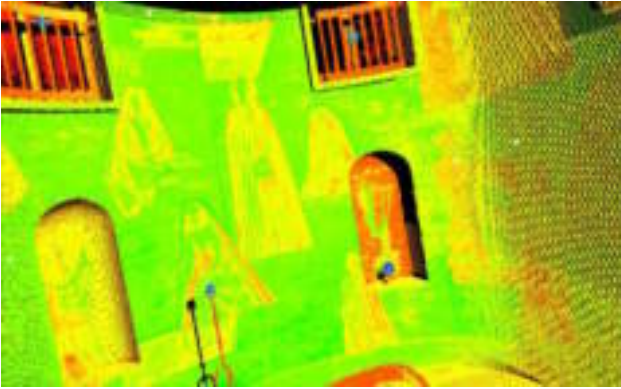


Figure 14 - Cloud points: detail of the niches of the stairway

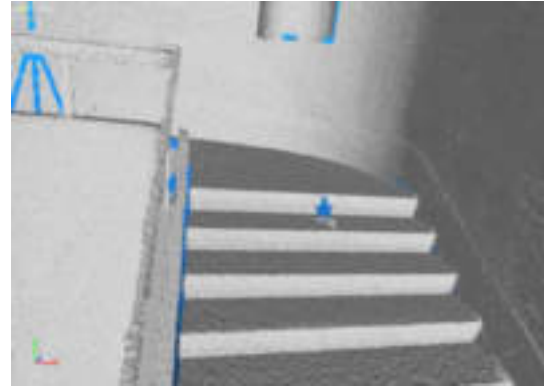


Figure 15 - Detail of the rough surface of the marble of the step



Figure 16 - Rifts and bulges are visible on the plaster (on the right and on the top in the centre)

10. CONCLUSION

The stairway in some geometric dimension is a little bit different from the project. These differences aren't caused by the subsidence of the structure.

The incongruity between the "idea" and "reality" should be ascribed to different rectifications like manpower's autonomy and difficulty to realise perfectly what is projected.

Different methodologies are performed to analyse the stairway space and the stairway itself like panoramic photos, stereoscopic photos (anaglyphs), three dimensional models (from AutoCAD to laser scanning models).

The multi-disciplinary survey furnishes:

- Three dimensional models useful to analyse the shape and the space of the stairway;
- Stereoscopic photos that allow studying space relationship amongst the stairway's elements;
- Panoramic photos that are the graphic base to realise navigable products useful for web-based animation and for immersive navigation.
- Realistic 3D model which are metric models with a very high accuracy; they are fundamental for set up a restoration plan and to monitoring the health status of the global structure.

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