DATA ACQUISITION FOR CULTURAL HERITAGE NAVIGATION: INTEGRATION OF PANORAMIC IMAGING, TERRESTRIAL LASER SCANNING AND ANAGLYPHS

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ABSTRACT:

In this paper some experiences about the integration of panoramic imaging and terrestrial laser scanning surveys are presented. The main goal is to produce documentation with metric information for the cultural heritage panoramic navigation; furthermore, a subordinate result is to use cheap and user-friendly 3-dimensional images for a wide range of applications like the custom navigation. Three historical sites were chosen: the main stairway of the Chancellor building at the Padua University, some ancient buildings in Venice, the Santo Sepolcro Church in Bologna. The panoramic photos acquisition is treated for all the three sites; in addition some image processing techniques are used to mosaic and to filter the raw data. The laser scanning survey is related to the Venice site using the 3D laser imaging sensor Riegl LMS-Z210 and the software Riscan Pro; the Sobel filter is used to produce detailed silhouettes and to perform edge extraction. About the Bologna site some point clouds acquired with the Leica HDS2500 3D laser scanner (re-branded Cyrax 2500 scanner) are presented with different acquisitions (point of view and resolution) in the Cyclone 5.1 environment. The creation of anaglyphs is performed for Padua and Bologna sites, using the Anabuilder software; some notes are drawn about the interpolation algorithms. The results are very useful for web-based animation purposes especially for recording indoor scenes using standard cameras for panoramic surveys, which have proven to be rather economical also in terms of computational effort.

1. INTRODUCTION

1.1 General

The data acquisition for cultural heritage navigation is the main task to produce accurate and metric documentation. Many sensors are today available and many techniques are able to combine raw and filtered data coming from different acquisition methodologies.

The production of 3-dimensional models has a wide range of applications, like the custom navigation and the web-based animations.

In this paper, we present some results for three different sites in Italy: Padua, Venice and Bologna. The techniques are based on the panoramic data collections coming from terrestrial laser scanning and digital images mosaicking.

We use integration of methodologies either than data fusion; this approach permits, furthermore, some added values like edge analysis from point clouds and features extraction from 3dimensional images.

2. HARDWARE AND SOFTWARE

2.1 Laser scanner systems

Two laser scanner systems were used for the data acquisition. For the Venice test site, the 3D laser-imaging sensor Riegl LMS-Z210 was useful to produce quasi-circular panoramic laser scanning. The 3D images are acquired by sequentially performing range measurements based on the pulsed-laser timeof-flight principle.

A rangefinder unit is optimised for high speed scanning with fast laser repetition rate and fast signal processing to perform accurate ranging. A rotating polygon mirror wheel realizes fast angular deflection ("line scan") of the laser beam. It rotates continuously at an adjustable speed to provide a unidirectional scan within an angle of 80°. Slow scanning ("frame scan") is provided by rotating the complete optical head up to 333°.

For the Padua and Bologna sites the Leica HDS2500 3D laser scanner (re-branded Cyrax 2500 scanner) was used. The HDS2500 has a maximum 40° x 40° field-of-view and SmartScan TechnologyTM that combines the small beam size with fully adjustable scanning density. With this combination, including point-to-point spacing as fine as 0.25mm @50m, *Cyrax* 2500 can capture fine details, accurately determine edge locations, and accurately establish coordinates of targets, even at long range. Other SmartScan Technology advantages include the ability to optimise scan density selectively within a scene; filter certain unwanted data while scanning; automatically identify and model targets; overlay a true colour image on scans.

With a single-point range accuracy of +/- 4mm, angular accuracies of +/- 60 micro-radians, and a beam spot size of only 6mm from 0-50m range, the HDS2500 delivers survey-grade accuracy and addresses a full "dome" field-of-view (360° x 195°) from a single tripod set-up

2.2 Point clouds management software

Two kinds of point cloud management software have been used. The first kind is the proprietary software to capture multiple 3D datasets of an object: 3D-RiSCAN is the acquisition software for the Riegl LMS-Z210 while Cyclone-SCAN software is used to operate the HDS2500 scanner.

Of course, other modules can be used in the same environment: for example, Cyclone-REGISTER is a tools collection for accurately geo-referencing point clouds to a common coordinate system and for accurately aligning point clouds captured from different scanning positions, with or without targets; Cyclone-MODEL provides a set of viewing, processing, and export/import functionality; Cyclone-SERVER is used when multiple users must access scan data and models simultaneously for collaborative engineering.

The second type is used to generate accurate polygonal models from 3D data like PolyWorks/Modeler from InnovMetrics. The typical data flow is the following:

- Exporting the data in PIF format;
- Accurately aligning the multiple 3D datasets into a single coordinate system;
- Merging overlapping 3D datasets into a high-precision polygonal mesh;
- Editing & reducing polygonal meshes, preparing them for different applications.

A note must be stressed out: the data export into PIF format generates files covering a limited field-of-view (default 40 x 40 deg): for example, the field-of-view of about 40 x 80 deg is segmented into 6 files of less than 40 x 40 deg with 5 deg overlapping. In such way, programs like IMAlign can automatically adjust the scan data to form a common 3d model of all data sets by minimizing the error in overlapping regions. The resulting alignment of the data is so based on a large number of measurement points and not on just a few pairs of corresponding measurements.

Also viewers are very useful like the view-only *Cyclone*-VIEWER module where the users can take advantage of point clouds directly in AutoCAD and MicroStation based applications.

2.3 Anabuilder and PTViewer

Anabuilder is software by Etienne Monneret and Didier Leboutte to manage anaglyphs, which are images obtained by the superposition of 2 images in complementary colors, for example Red and Cyan. By looking at this image with Red/Cyan glasses, the left eye sees the Red image (original left), while the right eye sees the Cyan (original right) image. The brain recomposes the full colours and we are able to see depth. AnaBuilder integrates some basic functions to improve the quality of the 3D perception as the filter of vertical edges improvement; it is also possible to catch up with certain errors made during photo shooting like luminosity set-up and colours management.

PTViewer.exe is the Helmut Dersch native port of PTViewer 3.2 to Windows. It does not require Java and it reads and displays the same HTML files as the Java version. It is therefore possible to distribute shared tours displayable on any system (Linux, MacOS, Windows, Java, non-Java). Like the Java viewer, PTViewer.exe may be invoked directly loading a Jpeg or Quicktime ('.mov') panorama. It is also possible to set up autostart tours. The most severe restriction is that GIF images are not supported and therefore PNG extension must be used for transparent images. This software is based in part on the work of the Independent JPEG Group. It is linked with their JPEG library and with the PNG library to read PNG format images.

3. TEST SITES

3.1 The Chancellor Building of Padua University

The first test site is the Chancellor Building of Padua University. In the main entrance of the so-called Bo Building there is a great stairway with a large fresco from the famous architect Giò Ponti. The fresco deals about the knowledge from the bottom to the up, where the knowledge rises up like the stairway itself. Using the anaglyph technique, more acquisitions were treated separating the RGB components with the program Anabuilder. Only two fundamentals colours are used (Red/Cyan, Red/Blue, Red/Green, Magenta/Green, Yellow/Purple) and many filters can be applied like the reds/cyans desaturation filter, the whites filter, the deghosting filter and the matricial filter.

The anaglyph technique is therefore very useful because it permits to operate also on panoramic photos without the restriction to manage only two small photos (left and right ones) in terms of field of view. The results are quite good (Figure 1); of course the focus set up is a little bit more complicated.



Figure 1. The stairway from the first ramp to the second: the raw image (left), the anaglyph (right).

Some digital cameras are able to produce panoramic scenarios, which are created from a set of contiguous photos. Very often, such photos are taken using "portrait" mode with a minimal zoom factor to improve the resolution and to acquire more pixels (numerical gain).



Figure 2. Giò Ponti main stairway in the Bo Building: anaglyph of the panoramic photo. The separation between red and cyan components is obtained with the Anabuilder software.

When it is possible, the exposimeter must be used in manual mode or the automatic one must be setted up to "Exposition lock" in order to furnish the same exposition for each photo with a 20%-30% overlapping region between contiguous ones (Figure 2).

Horizontal panoramic photos were created with the PixMaker Pro software (Figure 3). The resulting assembly seems to be back folded, but when the same is "navigated" using the mouse, the panorama, in the middle of the scene, is quit flat and no evidence of distortion is present.



Figure 3. Horizontal panoramic photo created with PixmakerPro software.

Also the well know QuickTime environment can be used to observe the 360° panorama with the right proportions (Figure 4). Some brightness problems can be occurring in such kind of photo assembly, because the luminosity factor is constant for all the photos to minimize the stitch problem. This approach is to be preferred to avoid different brightness values in the resulting photo assembly.



Figure 4. 360° panoramic photo: in static mode the image seems deformed, but the entire photo is navigable from left to right and viceversa using the mouse.

Some notes must be drawn about interpolators applied to digital images analysis. The bilinear interpolation produces significant losses, which become acceptable after two or more steps.

The bicubic approach use different pixels number; the default value is 16. In such way, we can obtain images very clean and marked, or images more smoothed but more homogenous.

For example, the algorithm "Poly 3" from Panorama Tools works like the one from Photoshop: both furnish edges very sharp. The "Spline 16" is very fast, ma the result are more smooth; the "Spline 36" is like the previous, but works with 36 pixels obtaining a better resolution.

The better results are obtained with the function "Sinc": it is more complex than a 3-degree polynomial and it uses 256 pixels to interpolate for each input pixel. Of course a greater pixel number can be used, but the computational effort grows up.

The main task of such interpolator functions is to combine many pixels from the starting image in order to compute the pixel value in the resulting image. Therefore, the weight of the closest pixels is more significant. The goal of such kind of function is to determine the optimal weight for each pixel.

3.2 Ancient buildings in Venice

Starting from panoramic surveys with laser scanner, features extraction can be applied to resulting images. For this site, the main goal was the edge extraction to separate the "in" and "out" contribution of single elements in the buildings facades.

The software environment is a standard one as GIMP, where different gradient filters are available like Roberts, Sobel and Prewitt.

We start with images stored with the RiSCAN software; the contrast and the brightness controls must be setted up after each passage in order to maximise the object edges. The flow extraction is a three-phases process:

- the first one is the Edge-Sobel filter application on the grey values image, and then the colours inversion is applied.
- the second one is the application of the same filter using the "Keep sign of result (one direction only)" mode; in such way the edges are outlined, the inner colours are stored, all the rest is obscured.
- the last one permits the colours translation in black/white image, where the black objects are on a white background.

The first test was performed on the Surian Bellotto building in Venice, applying the above-depicted procedure on three images coming from the same Riegl laser acquisition. Three modalities are used: the visible image in real colours, the reflectance scale in grey tones, the distance scale in false colours.

The first result is quite good (Figure 5) and many edges are visible like the windows in the middle of the facade; also the entablature on the top is well outlined; but not so well the cornice between the second and the last floor. Also the edges from close buildings are visible.

Is very interesting the edges extraction at the earth-water interface: the sea surface is in foreground, the waves are visible and also some boats.



Figure 5. Surian Bellotto building in Venice: example of edge extraction from visible panoramic image acquired with the internal camera of the Riegl laser scanner.

The same process has been applied to grey tones image coming from the reflectance analysis (Figure 6). The resulting image is more sharped and detailed: in fact, a great number of particulars and details are visible on the facade like the windows on the last floor and the doors on the first floor.

The central balcony in the main floor is depicted in a quasi complete way: the decorated arcs ands the windows frames are drawn in a more complete way.



Figure 6. Features extraction from reflectance panoramic image.

The details number is so great that a quite low value for the contrast was chosen in order to present only the main structures. In fact, the waves are no more visible in the foreground.



Figure 7. Features extraction from distance panoramic image.

The distance analysis image furnishes results very different: the number of details is very low and only the external edge is visible, but the use of this low information extraction is very useful to compute surfaces and to separate the border building from the sky.

Another example of panoramic acquisition performed with the Riegl for LMS-Z210 is presented in Figure 8. The acquisition uses default velocity value and a vertical field of view of 80°. The same considerations can be drawn. In the reflectance image only the inner parts are visible using a contrast value quite high; in the same way, the distance image provides a better definition between sea and buildings



Figure 8. Example of edges extraction from panoramic laser scanner surveys using high contrast value.

Figure 9 presents a comparative view among laser acquisitions and images processing using the Sobel filter again. The acquisitions are performed with a standard velocity value (line and frame speed) and a field of view of $355^{\circ} \times 80^{\circ}$; the distance image in false colours is superimposed with the reflectance image. The set up of the distance filter allows isolating only the central part of the acquisition.

Figure 10 draws the edges for Villa Pisani in Stra near Venice. Also in this application, the adjustments of brightness, contrast and luminosity are important to maximise the Sobel filter work: in the reflectance image (middle) also some features from the foreground landscape are drawn and in the distance image (bottom) the car silhouette isn't more outlined.



Figure 9. Panoramic laser acquisitions in Venice. At left the Riegl laser scanner acquisitions; at right the related filtered images. From top to bottom: raw image in real colours, reflectance image in grey tones, and distance analysis in false colours.



Figure 10. Villa Pisani in Stra (Venice). Panoramic edge extraction coming from three different modalities: visible (top), reflectance (middle), distance (bottom). The field of view is 355°x 80° at maximum acquisition velocity using the Riegl LMS–Z210

3.3 The Santo Sepolcro Church in Bologna

The full integration of panoramic imaging, terrestrial laser scanning and anaglyphs creation has been realised for the Santo Sepolcro Church in Bologna (Figures 11, 12 and 13).

The panoramic images have been shooted using standard digital camera, but the presence of high contrast targets (by Leica), used for the points clouds co-registration, has been extremely useful to shift the RGB images in the Anabuilder software (Figure 12).



Figure 11. Panoramic image of the small Chapel among the columns in the Santo Sepolcro Church in Bologna.



Figure 13. Multiresolution laser scanning of the pulpit. The blue crosses are the Leica targets.

4. CONCLUSIONS

Some final notes can be stressed out from this work. The integration of different data coming from different sensors provides a powerful tool to investigate the same object from different points of view. The availability of complex software allows integrating laser scannings obtained with different sensors. Furthermore, the image processing techniques can be considered as the common tool to investigate results derived from different acquisition techniques. The proposed examples are meaningful of this kind of approach.

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Figure 12. Panoramic anaglyph of the central pulpit; the high contrast targets are separated in two components.