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Web-Based Modeling. Google's Imagery to Draw Landscape

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Abstract

Following the seismic events that hit the centre of Italy since August 2016, a procedure has been devised to acquire models in conditions where the object cannot be visited or no longer exists. These are a series of operations that go beyond the need to go to places, in some cases inaccessible or substantially modified by even catastrophic environmental phenomena. The procedure also includes possible integrations with data from usual detection operations (point cloud from laser-scanner and photogrammetry etc.) The procedure is applicable to the urban scale and the territorial scale. As for the city's image, reconstruction is also done using the information on the web. Data available on internet are implicit and explicit. The first, numerical and textual metadata, can be made accessible through procedures; seconds, photos, spherical views, geo-referenced maps, etc., can be processed by photogrammetric operations to integrate digital models.

Likewise, the form of the territory today is documented by scientific portals and websites for sharing information on buildings and landscape. By linking images and metadata, we are able to return prospective conditions that have generated site representations and use digital space by returning informed 3D models. The use of parametric procedures applied to data extrapolated from the web, allows expressive information otherwise unusable, contributing and widening the techniques of indirect survey for the reconstruction of urban models.

Keywords: survey; BIM; photogrammetry; Google; VPL modeling

INTRODUCTION

The web, beyond to be a formidable means of communication, is also a huge container of information, constantly updated, which together are an important source of historical documentation. There we find information of various types: numeric, alphanumeric, vector, raster and text. That, by applying appropriate search engines, can be easily categorized, filtered and selected according to specific requirements. The study of the potentiality of these information to document (also through 3D models) the cultural heritage is a current practice. This procedure can be useful when other consolidated methods like photogrammetry and laser scan are impossible to use. It happens for the huge cultural heritage present in war scenarios or already destroyed because of bombing. We also refer to the cultural heritage sometimes devastated by catastrophic events such as those that have recently hit central Italy. The knowledge of these heritage, lost or inaccessible, is a primary goal for retrieve and transmit the historical memory [1]. Survey and 3D modeling of Palmyra Temple was an interesting application of digital reconstruction for a recently destroyed archaeological site [2]. Research investigated the potentiality of downloaded photos from web combined with photos taken by Gabriele Fangi before the temple's destruction and used for photogrammetric procedures.

What we wanted to investigate in this paper is something similar, but using another type of photographic image: the widely used spherical panorama by Google never tested in a photogrammetric method. The opportunity to try this type of data occurred following the earthquake that hit recently the central Italy; an event that has unfortunately devastated entire cities and destroyed many historical Centres of incomparable beauty.

Google Street View spherical panoramas

The use of spherical panoramas in the field of photogrammetry has been extensively tested and verified [3] according to a scientific methodology in which the step of photographic acquisition is an integral part (Fig. 1).
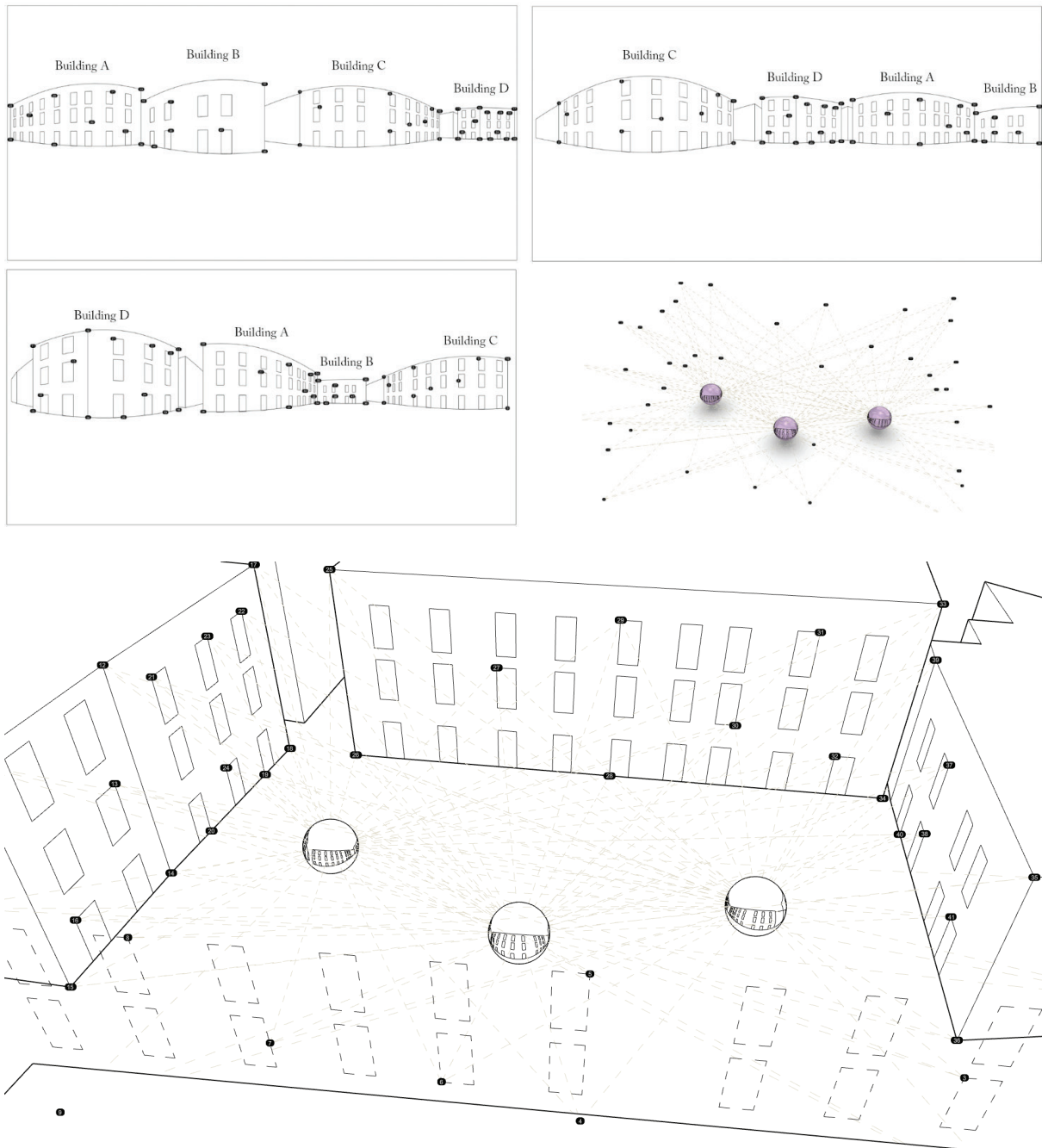
Figure 1. Photogrammetric procedures applied to Google's spherical views.

In fact, the most widespread method to acquire spherical images based on the images' stitching, requires that all images have the same centre of the objective. This condition is ensured by a rotary head applied to the base of the tripod on which is positioned the camera. There is therefore, in this case, the awareness of the accuracy level of the metric data because part of a single process (although in practice the photographic acquisition and the metric restitution are two distinct phases that it's possible to make also in very distant times between them).

To use Google spherical panoramas, we have first to do some preliminary considerations and then try to assess the reliability of the plotted data (which is one of the main concepts in photogrammetry). Google Street View is an online application that provides 360° spherical panoramas based on photo taken generally by a camera mounted on a vehicle. These images are continuously updated, to form a photographic archive widely used by the web user thanks to the simplicity of the interactive navigation. The shots are updated time by time so, in some contexts, it may have available a kind of time machine that documents the site transformations during years. The shooting techniques are updated constantly and often data have no-homogeneous characteristics. Dodeca 2369 is the commonly used camera [4] which takes 11 images at time. These are stitched together to form a single equi-rectangular image which is the basis of the spherical panorama. The camera is associated with a GPS tracking device combined with speed and orientation detectors that allow to geo-reference the location of the centre of the panorama with sub-metric accuracy. The Google shooting is not designed for photogrammetric use: the images have a quality that is far away to those normally used in photogrammetric process; the not rigorous acquisition of the several shots do not guarantee the same centre for all the images and the automatic stitching process produce several noise in the panorama.

The Case Study

We decided to use the Street View Panorama to reconstruct a 3D environment and an Architectonic subject: the environment is Piazza Borghese in Rome, the architectonic subject is the elevation of "Palazzo della Famiglia" a building along the edge of the square (Fig. 2). So we tested an algorithm that links the vector data of an urban map with spherical panoramas coordinates. The algorithm was developed into Rhinoceros / Grasshopper software [5, 6].

Figure 2. Case Study: Palazzo della Famiglia in Piazza Borghese, Rome.
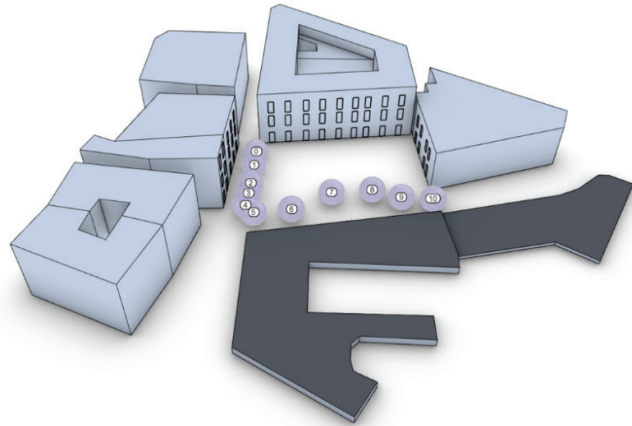
A particular feature of a Street View images is the ability to hold pyramidal information in five levels of resolution that can be investigated through the zoom-in and zoom-out. The solution was used in place of high-resolution images that would make it unmanageable in the web or via app. The switch from a level to another is performed with an appropriate programming lines (java script) that allows to coordinate zooming to images of the same subject with different quality. When you load an image, it opens with a 90 degrees angle (level 1), one quarter of the entire view. A succession of higher-resolution images is attached to this.

External orientation and relative orientation of the images in Street View

Each panorama image is described by two metadata groups: the first group is relative to the geographic coordinates of the projection centre, the second group is relative to the orientation of the view according to the main point (projection centre). A code sort the information of the two sets of data to implement the dynamism that characterizes the navigation from one panorama to another of Street View; the same information is also visible in the text form in the URL of each shot (fig. 3).
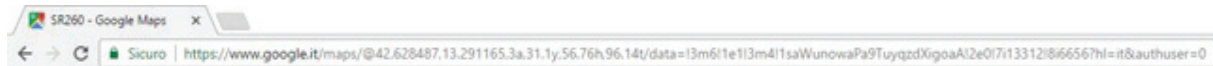

Figure 3. The URL you get by framing a subject within the panorama image.

Orbiting within a panorama, the projection centre position data do not change, while navigation projection changes. For example, we put the avatar inside a panorama of Piazza Borghese in Rome, our case study, in the URL we read:

https://www.google.it/maps/@41.9038803,12.4760933, 3a,75y,301.8h,86.3t/data=!3m6!1e1!3m4!1sqPeZ5GJDFFL zKaR9KF32_A!2e0!7i13312!8i6656

After the @ symbol we recognize:
• 42.6284482,13.2912731 - coordinates of the projection centre expressed in latitude and longitude in the form of decimal degrees;
• 75y - Zoom Level parameter;
• 40.41h - horizontal angle with respect to the north (0 ° / 360 °);
• 88.98t - slope angle with respect to the horizontal plane (-90 ° / 90 °).

Altitude of the main points

The last parameter useful for the perfect placement of projection centres on the Earth map is the altitude compared to the average sea level. Again, Google allows access to information packets (APIs) [7] useful to anyone developing desktop and smartphone applications. With It, you can find information about so many mapped points on the Earth's surface (nodes) for which you know the altimetry accurately. If you want to know the altitude of a non-mapped point, the Google service interprets and returns the average value of the four closest nodes.

The information provided by the APIs can be interrogated through scripts but also through an http interface; this last condition allows us to query the web with a formatted URL string as follows:

https://maps.googleapis.com/maps/api/elevation/json?l ocations=42.6284482,13.2912731&key=YOUR_API_KEY

The first part of the string up to the symbol = represents the web request of the altitude of a particular point whose geographic coordinates are known. After = there are the coordinates (latitude, longitude) of the point you want to get the altitude. After the junction & is the call for an API key provided by the system. The web interface proposes the following text string list as a response to the request (fig. 4):
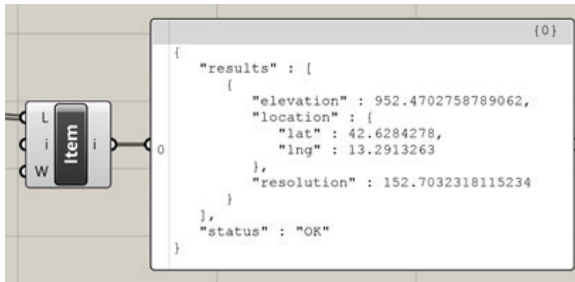
Figure 4. Textual list showing the characteristics of the elevation.

The "elevation" string is the numerical value of the required point. The term "resolution" instead refers to the

maximum distance (defined in meters) from the nodal points which are interpolated in order to obtain the elevation of the required point.

From web to 3D space

Even in the case of the "mediated survey", it is necessary to set up a survey project by proceeding with a "virtual inspection" of the object to acquire. It will proceed with the navigation of the views provided by Google Street View capable to see the building of interest. In each panorama, the camera will be oriented in the direction that best defines the chosen areas of the object to represent; finally, the details to returns are the ones that will be the points in the 3D space useful for the reconstruction of the 3D model (fig. 5).
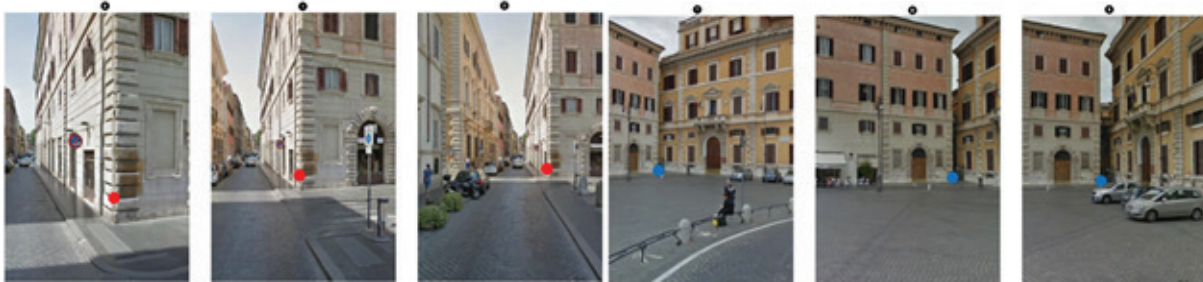

Figure 5. In red and blue homologous points framed by the most views for the return in CAD.

The goal at this stage is to reconstruct the data capture scene in digital space. Therefore we should return the x, y, z coordinates of the projection centres and the orientation of the camera with respect to the centre of the selected shots. After that, the identification of homologous points allows us to find the projective relationship between the images and then the spatial position of the support points (the blue and red spot) acquired with Google Maps. We will explain the procedures working on a case study: Piazza Borghese where there are 11 panoramas.

To collect the orienting information we save in a spreadsheet the URL of every panorama in Piazza Borghese. The chosen subject is the elevation of "Palazzo della Famiglia" which is one side of the square. Below there is the list of the string:

1. https://www.google.it/maps/@41.9035338,12.476 0938,3a,75y,325.61h,90.33t/data=!3m6!1e1!3m4!1slIScRx Sh0ezzwZ2DfRj_Lg!2e0!7i13312!8i6656!6m1!1e1
2. https://www.google.it/maps/@41. 9035643,12.4761767,3a,75y,336.5h,91.44t/ data=!3m6!1e1!3m4!1s48IyChc1590-qPMxVk- TZA!2e0!7i13312!8i6656!6m1! 1e1
3. https://www.google.it/maps/@41.903601,12.4762 795,3a,75y,79.97h,71.74t/data=!3m6!1e1!3m4!1sV6VKIK DbdkjYNF1AQDSeaA!2e0!7i13312!8i6656!6m1!1e1
4. https://www.google.it/maps/@41.9036193,12.476 3345,3a,75y,79.97h,71.74t/data=!3m6!1e1!3m4!1sAZEqcF izTdpDuY7gRLkP_g!2e0!7i13312!8i6656!6m1!1e1
5. https://www.google.it/maps/@41.9036395,12.47 63998,3a,75y,308.3h,88.45t/data=!3m6!1e1!3m4!1sAYg_ M0xLtw4Y0RCFx5xPTA!2e0!7i13312!8i6656!6m1!1e1

6. https://www.google.it/maps/@41.9036757,12.476 4196,3a,75y,321.99h,89.43t/data=!3m6!1e1!3m4!1skzdFFli B13OZZHAVDXypng!2e0!7i13312!8i6656!6m1!1e1
7. https://www.google.it/maps/@41.9037629,12.47 63346,3a,75y,278.68h,90.68t/data=!3m6!1e1!3m4!1sDQIK KYtwsfypbeGuJdc-KA!2e0!7i13312!8i6656!6m1!1e1
8. https://www.google.it/maps/@41.9038286,12.476 1735,3a,75y,278.68h,90.68t/data=!3m6!1e1!3m4!1sEDfR1 G4HchImgZJJ2SC8vw!2e0!7i13312!8i6656!6m1!1e1
9. https://www.google.it/maps/@41.9039267,12.476 0803,3a,75y,211.99h,96.12t/data=!3m6!1e1!3m4!1sF9yWs CS9zUEtuYFe-Fm6kA!2e0!7i13312!8i6656!6m1!1e1
10. https://www.google.it/maps/@41.9040134,12.476 0629,3a,75y,230.97h,92.34t/data=!3m6!1e1!3m4!1s6kNKo jtzbEA5KbBEM-tw2Q!2e0!7i13312!8i6656!6m1!1e1
11. https://www.google.it/maps/@41. 9040957,12.4760097,3a,75y,189.34h,91.98t/ data=!3m6!1e1!3m4!1scsonKnLhyT-QMyKZfdjSEA!2e0! 7i13312!8i6656!6m1!1e1

The latitude, longitude, y parameter, h angle and t angle must be extrapolated from the string to identify in a 3D CAD, external coordinates of main points and the orientation of images associated with them (fig. 6).

Figure 6. Part of code that captures an external spreadsheet and selects the parameters that are useful for continuing the nodal programming.

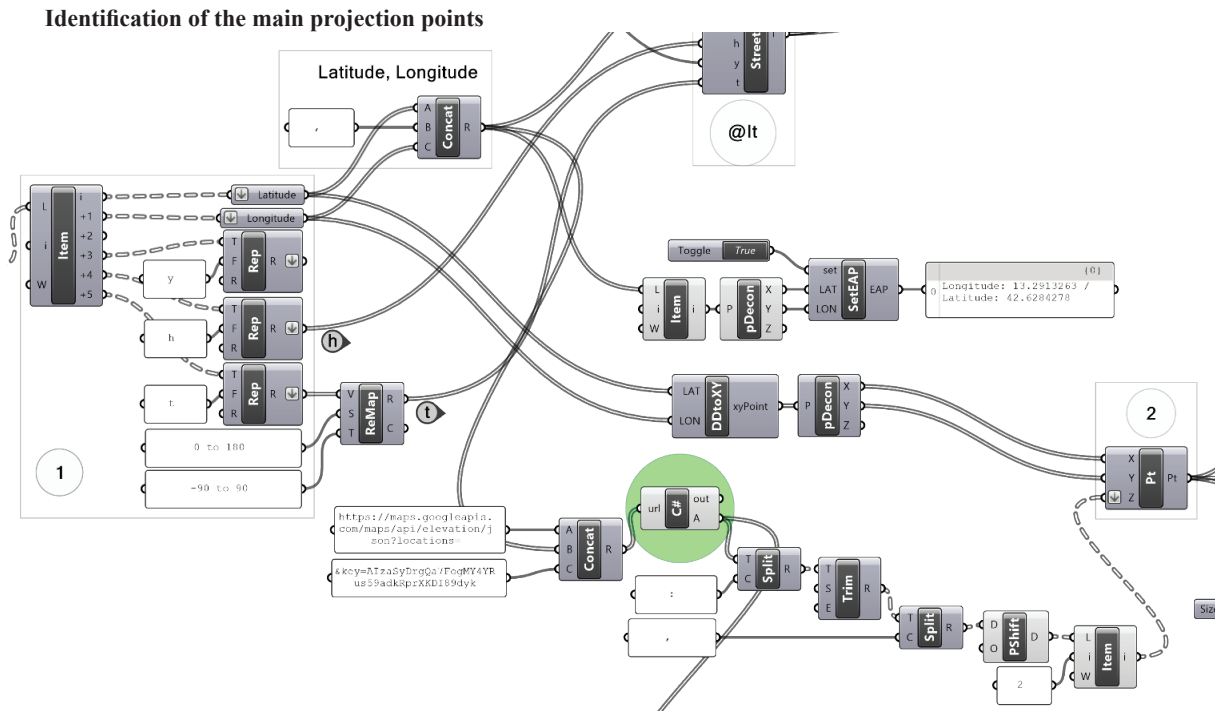**Identification of the main projection points**

Figure 7. Code GH which thanks to Heron allows to translate the geographic coordinates into Cartesian coordinates.

Figure 6 shows the code that allows extrapolation of the parameters for locating image projection centres (latitude, longitude) and the internal orientation parameters (y, h, t). Grasshopper has several applications including some dedicated to the development of cartographic coordinates (Heron) [8]. Once isolated the list of values related to the latitude and longitude, data is translated into x and y coordinates. The application needs an anchor point in cartographic coordinates that will be placed at the origin of the orthogonal system (fig. 7). In the figure is illustrated the part of code with which the cartographic coordinates (1) is passed to the Cartesian coordinates (2).

Each cartographic coordinate must also be qualified from the altitude deduced by interrogating the web with a formatted URL string as described above:

https://maps.googleapis.com/maps/api/elevation/json?locations=**latitudine,longitudine** & **key** = **AIzaSyDrgQa7FogMY4YRus59adkRprXKDI89dyk**

In bold the variables that must be replaced with the previously catalogued cartographic coordinates in a list and the API key obtained from Google. Highlighted in green (fig. 7) it is the component programmed in C # that allows the direct connection between Grasshopper and the web; It is written with the following content:

```
private void RunScript (string url, ref object A)
{
            System.Net.WebClient        System.Net.
WebClient client = new ();
            A = client.DownloadString (url);
}
```

With the work done up to now we have identified the location of the projection centres in a CAD space; next step is to orient the images chosen in relation to their main points in the digital scene.

Orientation of the image in 3D space

The plug-in @It [9], allows to display on the horizontal plane the views selected inside the spheres (fig. 8); the parameters needed to complete this operation are h, y and t, but also the geographic coordinates of latitude and longitude.
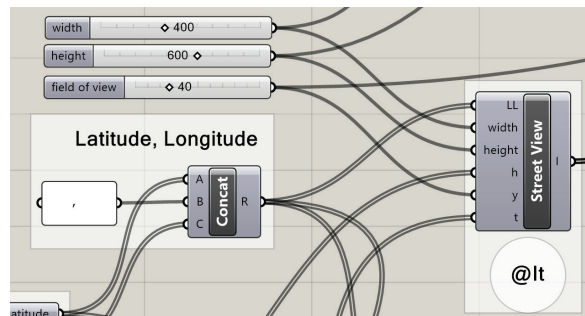

Figure 8. Input parameters of the @It component to load the selected images.

In addition to working on the image import component, the het parameters contribute to the construction of the main projection direction space, directions for positioning the selected images in 3D space.

The definition in figure 9 shows how the projection centres previously identified are also the origin of horizontal planes where the Y axis represents the north direction. Parameter h allow the horizontal rotation of the frame's axis with respect to the Y direction, parameter t rotates the axis of the frame vertically. The composition of the two rotations orient the frame, perpendicular to the main direction.

The projection centres distance from the image is detected by applying trigonometric operations involving the size of the image frame and the visual angle (parameter y) (fig. 10).
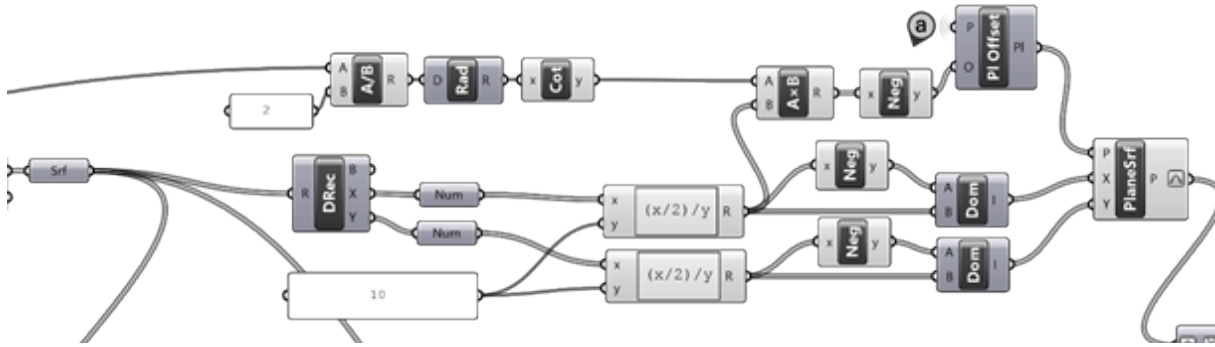
Figure 10. Sequence of components for the calculation of the main distance.

Locating the centres and the main distances for each frame, the position of these in the general system and the homologous points on each image, by means of rototracing calculation procedures we determine the projecting lines. The intersection of these, describes the position of the support points (blue and red spots) in the Cartesian space (fig. 11).
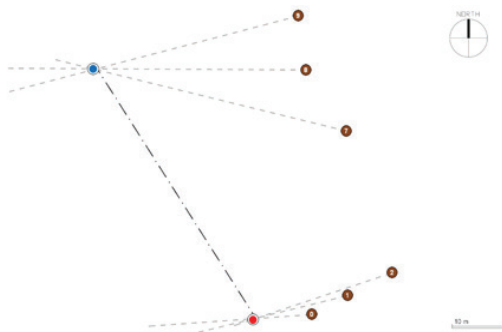

Figure 11. Intersection of projecting lines that pass through homologous points selected on the orientated panoramas.

Homologous projection lines intersect in the two points selected; the points are the extremes of a line that will be extruded vertically. In this way we have virtually reconstructed the prospective conditions of the shots. Then we choose the best panorama that sees the vertical surface, and project on it the equi-rectangular image from its centre; the new textured surface, returns the true shape and the true size of the chosen elevation (fig. 12).
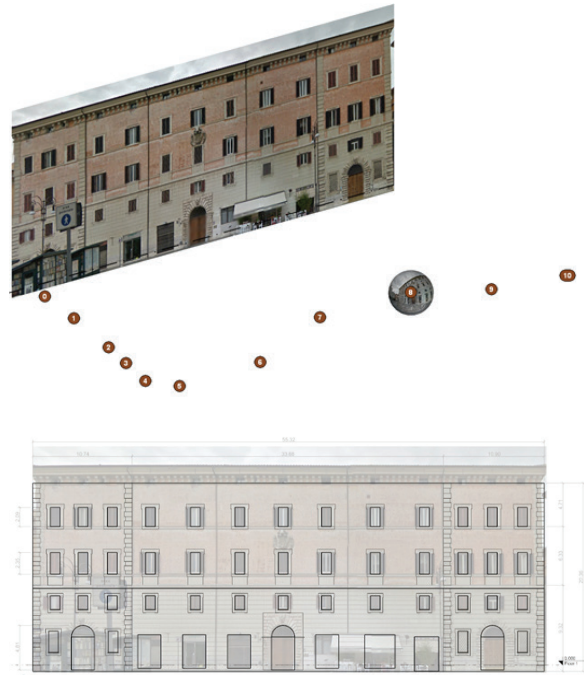
Figure 12. The equi-rectangular image projected from the centre of the oriented panorama on the plane identified, returns an image in true dimension.

Immediately we can proceed to a more detailed modeling, the continuous projection of the spherical image from its centre will help the 3D modeling process. Then we can add doors, windows, decorations and so on until we model the whole architecture (fig. 13).

Figure 13. 3D model of Palazzo della Famiglia in Piazza Borghese. The elevation is textured by projecting the equi-rectangular image from the Google panorama.

By solving the case study we have understood the conditions that affect the accuracy of the result. Google's main purpose is to document as quickly as possible not a specific reality, but all that the camera captures along the way. That is why the first important consideration, in this procedure, concerns the positioning data of spherical panoramas, available in relation to the object to survey. It can also happen to have several disturbing elements in the photographic image because of elements completely unrelated to the object. Other assessments concern the photographic image quality and reliability of metadata associated with each image, downloaded from the web. Furthermore the resolution of equi-rectangular images is 13312 × 6656 px is just barely sufficient for a photogrammetric use.

Figure 14. The construction of equi-rectangular images with the automatic stitching procedures of Google contains errors.

The accuracy of the procedure depends on the distance between the camera and the object: each photographic image pixels corresponds to an optimal graphical scale of restitution. For a metric documentation of an urban context (for example an historical centre), the correct scale of restitution is about 1: 200.

The construction of equi-rectangular images with the automatic stitching procedures of Google, It may contain errors (fig. 14). Usually in a controlled procedure, the errors could be eliminated or at least reduced. The biggest problems are mainly found in these panoramas with a lot of sky represented, so that the software is not able to determine, in the upper quarter of the image, constraint points to connect the frames (fig. 15).

Figure 15. Panoramas with a lot of sky represented, determine errors in the upper and lower part of the image, because of few homologous points to connect the frames.

Using the software "Sphere" developed by Gabriele Fangi [10] (Already tested in numerous spherical photogrammetric applications) has been possible to derive the relative orientation of the 11 centres of spherical panoramas with the best precision allowed with respect to the quality of the images. This allows us to say that on the urban scale, the data from Google have a sub-metric accuracy, which can be improved by selecting only the panorama that presents a less roughly stitching process.

Figure 16. On the left we see the church of S. Agostino of Amatrice after the first shock, on the right a sequence of images that show the church today in Street View.

Web-based modeling for Cultural Heritage

After a first experimentation we can apply our method to cultural heritage as well. Since August 2016, the centre of Italy has been hit by a series of seismic events that have completely destroyed some cities along the Tronto Valley as Amatrice and Accumoli. At this time, for the mentioned cities we recognize two realities, a physical reality where there are the ruins of buildings affected by the earthquake and a web reality where we see the buildings as if nothing had happened (fig. 16)

In the figures on the left we see the church of S. Agostino of Amatrice after the first shock, on the right a sequence of images that show the church today in Street View. By applying our method, even without a survey, we are able to model in 3D the destroyed church getting metric information from the panoramas of Street View. Thanks to Street View, we can download panoramas that best see the church of S. Agostino taken by Google Car before the disaster. After that, we position and orient the chosen views and we draw the vertical surface in the way explained previously; finally, we project on It the image from the chosen sphere. The projected image has the real shape, and from it, we can get measures (fig. 17).
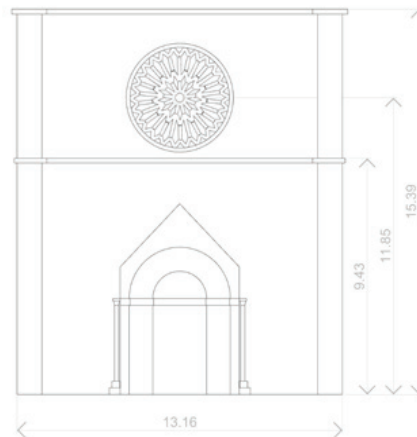

Figure 17. The equi-rectangular image projected from the centre of the panorama on the plane identified, returns an image in true dimension.

We are creating a plug-in for Grasshopper and It will be called Hawk which, after a testing period, it will be released to all interested scholars (fig. 18).

The mainly steps to follow with Hawk are:

1.   download from Street View the panoramas that best describe the wanted architecture;

2.   identify pairs of points in the image belonging to the same elevation and representing the same Z dimension in the reality;

3.   with custom components we filter the data and force them to flow into the main component;

4.   the main component, starting from clear geometric conditions, identifies the real position in 3D space of the chosen elevation, which is a vertical plane;

5.   finally, we will be able to project from the centre of the panorama, the equi-rectangular image on the plane. During the projection, we can model the details of the architecture.
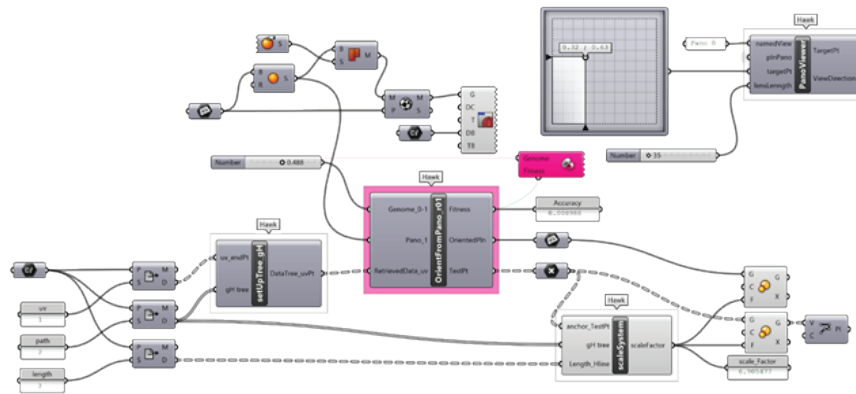
Figure 18. Procedure created by the research group to orient in Rhinoceros the Google panoramas.

CONCLUSIONS

This indirect survey becomes an important base for documenting and rebuilding goods with strong cultural value, destroyed by wars, earthquakes, or unexpected events (fig. 19). Thanks to our procedure based on photogrammetric principles, we can build 3D models from web information, in this case using an explicit data, but we could add more and more metadata coming from other Earth sites, which contain other kind of data. The procedure can also help the ordinary survey for prevention and preservation operations. We easily understand that this work opens the door to an immense database, made up of images acquired, over the years by Street View.

Figure 19. 3D model of the Church of St. Agostino in Amatrice. The elevation is textured by projecting the equi-rectangular immage from the Google panorama.

The experiment summarized here has allowed us to verify the powerful of the use, in a 3D modeling environment, of spherical panoramas by Google, considering that in some cases these images represent today the only evidence of a disappeared reality. For a surveyor, improve the methodologies to save historical memory of artistic and monumental places is the foremost moral and scientific duty. The digital revolution and the spread of the web applications have produced an important effect of democratization of information. Their sharing is determining an interesting amplification of the semantic value in communication processes, especially in a strategic, socially and economically sector such as cultural heritage.

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