THE VISUALIZATION OF THE SOLID IMAGE ON THE WEB: A NEW TOOL FOR 3D INFORMATION ON THE NET BASED ON AN OPEN SOURCE ENVIRONMENT

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ABSTRACT:

Full 3D geographic information has always been a real problem and it still causes problems today. Although computer software and Photogrammetric and LIDAR techniques make it possible to create full 3D models quite easily, 3D information involves another important problem: the way it can be used. The representation of complete 3D information is something that has to take into account the bi-dimensional supports where geographical information has been represented for years; even in this computer age, the visualization of a complete 3D model involves the use of a 2D video screen. At present, 3D visualization devices are expensive, and not very common, therefore a system that aims at distributing a 3D model has to deal with the bi-dimensionality of video screens.

In order to communicate 3D information, it is necessary to decide which infrastructure has to be used. The trend of society today is to become more mobile and distributed: if a tool to distribute 3D information has to be invented, it will have to be based on a web infrastructure.

Considering the fact that 2D supports are easy to use and that even modern computer science and the 3D models that can be generated can be used using 2D screens, with a successions of views of the 3D model, the Geomatics research group of the Land, Environment and Geo-Engineering Department, DITAG at the Politecnico di Torino has developed a new survey tool called *Solid Image*: this tool, which can be used in the analysis and presentation of survey data, allows the user to access and manage 3D data by simply viewing a 2D monoscopic image. The utility of this tool has been greatly appreciated by the users during its testing, therefore the Politecnico di Torino set up SIR – Innovative Surveys Resources – a spin-off company in January 2006 with the aim of producing and marketing *Solid Image* based services.

At present the *Solid Image* can only be used in a desktop environment utilizing a common commercial software such as Adobe Photoshop, using a freely distributed plug-in. The article deals with the development of a web visualization tool based on an Open Source architecture.

The advantages and disadvantages of each explored solution are presented, together with the functionality the viewer offers. The tests were made on a *Solid Image* of "La Fagianaia" building, a small building in the Royal Racconigi Park, Piedmont (Italy), a former residence of the Savoy Royal family, a site that was included in the UNESCO world heritage list in 1997.

1. INTRODUCTION

1.1 The 3D information challenge

Full 3D geographic information has always been a real problem for mankind; even now, thousands of years after the first attempts to manage 3D information, still it is problematic. The incredible scientific and technological progress that has been made over the years has led to the availability of increasingly new and more powerful instruments. Therefore, over the years, the acquisition of 3D information has become common practise. 3D information involves another important problem: the way it can be used. The representation of complete 3D information is something that has to take into account two-dimensional supports where geographical information has been represented for many years. 2D supports made it necessary to look for and find ways of "hiding" one dimension in order to have the control of metric information: perspective and ortho – projection are examples of such a process. Even the computer has not fully solved all the problems. Even though it is quite easy to create full 3D models, thanks to computer software and Photogrammetric and LIDAR techniques, the visualization of a complete 3D model involves the use of a 2D video screen. At present, 3D visualization devices are expensive, and not very common, therefore a system that aims at distributing a 3D model has to deal with the bi-dimensionality of video screens.

Considering the desire to develop such a tool, in other words, a tool to communicate 3D information, it is necessary to decide which infrastructure has to be used. In recent years, all informatics applications have had to face the challenge set by Internet: there is no computer science topic that has not been influenced by the fact that Internet has become a world-wide phenomenon. Mention can be made of the field of geographic information, where there has been the evolution from GIS to Web-GIS and from a file-system structure of data, to an accessible geo-database web structure. The trend of society today is to become more mobile and distributed: if a tool to distribute 3D information has to be invented, it will have to be based on such an infrastructure.

Considering the fact that 2D supports are easy to use and that even the modern computer science and the 3D models that can be generated can be used using 2D screens, with a successions of views of the 3D model, the Geomatics research group at the Land, Environment and Geo-Engineering Department, DITAG at the Politecnico di Torino has developed a new survey tool called *Solid Image* (Dequal, 2003).

1.2 The Solid Image

Solid Image is a tool that can be used in the analysis and presentation of survey data, allowing the user to access and manage 3D data by simply viewing a 2D monoscopic image. It adds correct 3D metric information to simple photographs, in such a way that those who are not experts in surveying can easily gain access to the information: the photographic image becomes the view of an object on the 3D model.

A "true colour" digital image is made up of 3 matrixes, named R, G and B, each one containing one of the 3 fundamental colours (Red, Green or Blue). The *Solid Image*, in addition to a classical digital image, records the distance values of the represented points from the taking centre. Assuming that the digital image is a central perspective of the photographed object and the internal and external orientations of the image have been determined, the spatial position is completely given, for each pixel, if the distance between the perspective centre and the photographed object point is known. This information is stored in an additional matrix that has the same size as the RGB ones (in terms of rows and columns). Therefore, a *Solid Image* consists of a 4 level matrix: RGB and distances d. The information on the spatial position of the photographed object points is obtained using a dense 3D model (DDEM), easily acquired by using a laser scanner. To obtain a correct *Solid Image*, the laser scanning and the photo should be taken from two points not too far from each other, in order to avoid hidden areas in the image, where the laser scanner is unable to determine the distance from the perspective centre or the object points.

This tool turns the philosophy of orthophotos upside down; using the same data, it reprojects the DDSM instead of the photographic image. The result of this procedure is a common 2D photo, without any decay due to a resampling process, each point of which has 3D coordinates.

Solid Image opened the way to a series of new products in the field of architectural and land surveying applications, making it makes possible to:

- Determine, in real time, the position of any point of a digital image in a 3D reference system, using a common PC;
- carry out three-dimensional correct measurements (lines, areas, volumes, angles, …), by just selecting points on the image;
- return vector elements of interest, to spread the fruition and analysis of the data to researchers who are not experts in the geomatic field, freeing them from the intermediation of a skilled photogrammetric operator ;
- integrate the information given by an original high quality colour image with the 3D geometry of every point represented in the photo.

1.3 Visualization in the desktop environment

The DITAG Geomatics research group at the Politecnico di Torino has developed a specific software called LSR2004® to create this product. The *Solid Image* and its tools can also be used with common commercial software such as Adobe Photoshop, using a freely distributed plug-in.
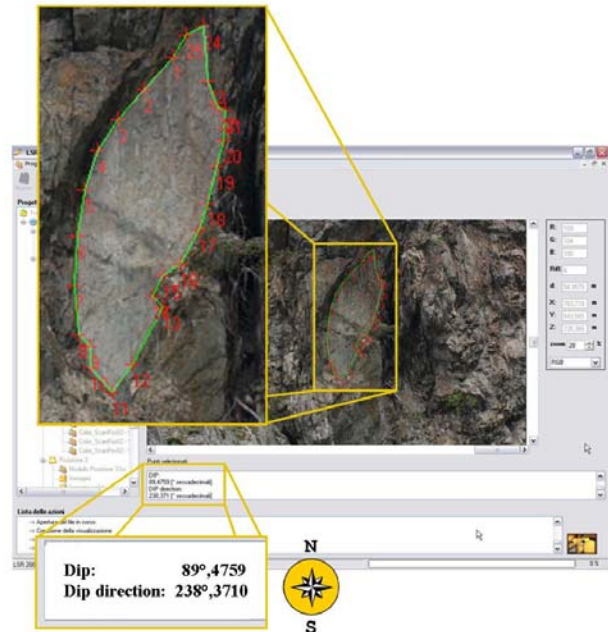

Figure 1. A *Solid Image* and its measurement tools: the determination of Dip and Dip Directions of rock fractures
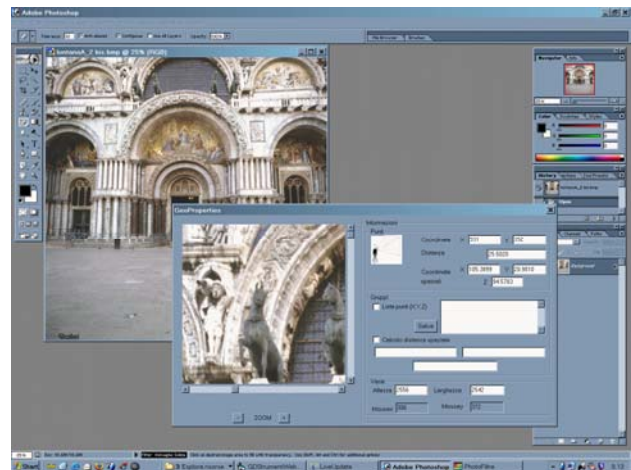

Figure 2. Fruition of a *Solid Image* using the plug-in

2. VISUALIZATION OF THE SOLID IMAGE IN THE WEB ENVIRONMENT

Considering the easiness of use and the completeness of information the *Solid Image* offers, it was believed that this tool could be of great interest for those who wish to present survey results. Exploring the possibilities given by this tool, tests were also made to integrate it in a GIS environment (Agosto, 2005). In a desktop environment, it is possible to use *Solid Image* and its tools by means of a link to one of the previously mentioned software packages that are not part of the GIS environment.

Developing a web-GIS application to communicate the results and products of a survey campaign in the Racconigi Castle park (a residence of the former Italian Kings which was inserted in the UNESCO world heritage list in 1997) the problem of using *Solid Image* was considered. LIDAR and photogrammetric surveys of the archaeological findings and of the park buildings had in fact been performed and *Solid Image* is one of the simplest ways of consulting their results.

Figure 3. The test site: the Fagianaia building in the Royal Racconigi Park

3D models are difficult to use on the web, due to their usual heavy dimension, therefore a tool that could speed up and facilitate the fruition of the 3D geometric model was necessary. When it comes to the fruition of *Solid Image* in a web GIS environment, a suitable architecture has to be chosen.

First of all it was possible to either develop a completely new application to both explore the common digital image, and use *Solid Image* tools (mainly 3D information access and then distance, plane and angle measurement tools) or it was possible to use already existent tools. *Solid Image* is an innovative tool, therefore it was possible to find some interesting products just to explore of the digital image.

2.1 Web environment and GIS approach

Many architectures and different solutions were tried in the development of a web visualization tool; a common feature of all these solutions is the fact they are all based on Open Source tools, in order to have the freedom of using and trying the most appropriate available tools, with the support of a flexible and scalable architecture.

For the visualization of the digital image, the fact that an image has its own reference system, connected to its matrix structure was first considered.

Starting from this point, it was possible to consider converting the coordinates of each pixel by rotating the reference system so that the X axis becomes horizontal.

$X' = n$
$Y' = MAX\_SAMPLES - m$

n being the number of columns and m the number of samples of the image.

In this way, it is possible to create a "dummy" georeferentiation for the image in a GIS environment, making it possible to view it correctly.

Figure 4. Digital image internal reference system (above) and dummy system used for the georeferentiation (below)

It was therefore possible to choose a tool to view the image on the web: a web mapping engine. The choice of the University of Minnesota MapServer prevented the necessity of developing a specific tool for the exploration of the digital image, and made it possible to navigate the image going through different visualization scales or using the pan tool.
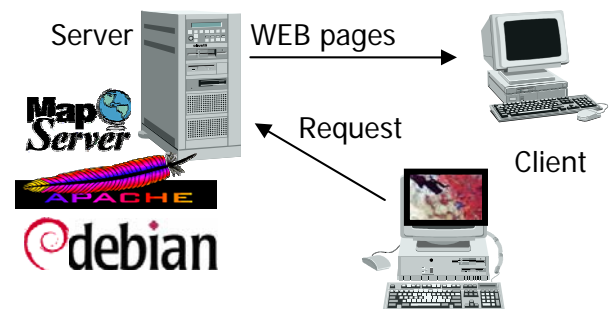

Figure 5. Architecture of the system

This tool is completely Open Source and offers a great flexibility in the development of a custom application.

In order to set up an application based on a web mapping engine, it is necessary to create an appropriate infrastructure: a server installed at least with a web-server is necessary. In the specific case, the server was a Pentium III 1GHz 512 Mb RAM, based on a Debian LINUX operating system, with Apache as

the web-server. All the chosen architecture is, in this way, made by Open Source tools.

2.2 Data structure: the solutions

Starting from this common base, different solutions were tried in order to find the best configuration to use the *Solid Image*. By "best way" essentially it is here meant faster.

Different solutions meant different ways of storing the 3D pixel coordinates, and consequently, different algorithms to retrieve them and different software architectures.

The solutions used to store the 3D pixel coordinates are:

1 – a common ASCII file;
2 – a binary file;
3 – a PostgreSQL database table;
4 – a coordinate image raster TIFF file.

In the first hypothesis, the 3D information of each pixel is stored in a common ASCII file: this means that all three coordinates associated to a pixel are written starting from a corner of the image, going towards the opposite one.

In this way, when the user queries a point on the image, the X', Y' coordinates are sent to the application, which is able to compute which three values have to be shown.

The advantages of such a solution are the ease of implementation and the simplicity of the used architecture: apart from the abovementioned tools, a customization by PHP scripting is also needed. The main disadvantage of this solution is that the answer time of the system depends on the position of the queried pixel in the image: if a pixel with 3D information stored at the beginning of the ASCII file is queried, a fast answer is obtained, otherwise the response is slow. This feature makes this solution unsuitable for an application but also because it often causes the server to reach its response-timeout.

An attempt was then made to convert the format of this "3D information file" into a binary format. This solution was an optimization of the previous one, as the architecture remains the same and only the reading of the data format was different in the scripts. This solution makes it possible to speed up the application performance, with just a few changes from the basic solution.

The next attempt was to use a database table to store the 3D information. A specific script was written in order to create a .sql file starting from the ASCII file. The instructions for the creation of the table and the insertion of the data in it, are inserted in the .sql file. The table has a very simple structure: apart from a GID, only the X, Y, and Z coordinates are stored. The conversion script is written in PHP. As it is easy to connect the queried pixel to the number of the table row, the GID table is indexed.

The query itself is very fast (less than 1 second) but the time necessary to transfer the information to the web page is instead considerable. First it was thought it was caused by the connection time to the database, but a checking of the execution time of the script excluded this hypothesis. If the\test had been positive a permanent connection to the database could have been established.

This database solution made it possible to have a homogeneous answer any queried pixel of the image; this was obtained by a more complex architecture: a database engine had to be installed beside the web-server and the mapping engine. As previously mentioned, a PostgreSQL database was chosen; the

scripting language used to connect the MapServer application and the information stored in the database was once again PHP.
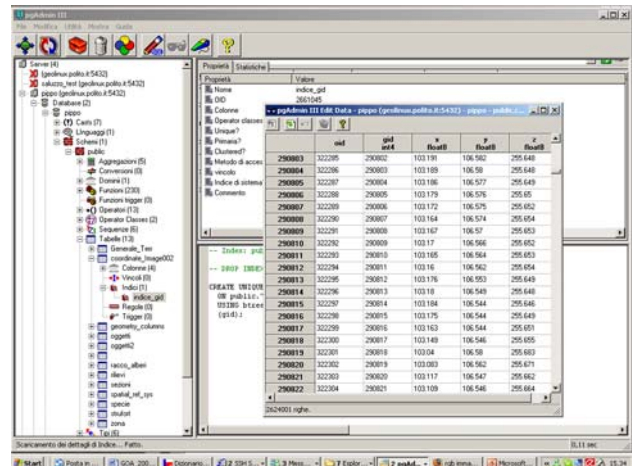

Figure 6. Structure of PostgreSQL table

The last explored solution consists in using a raster file to store 3D information. Observing common RGB raster file structure, the colour information of a pixel being stored in three different bands, one each fundamental component, an attempt was made to store the X, Y and Z data of each pixel in a common 3-band file: a sort of "geometry" image.

The connection between the photographic digital image and the "geometry" image is guaranteed in the creation process of the second image: a PHP script converts the ASCII file adopted in the first attempt into a raster format.
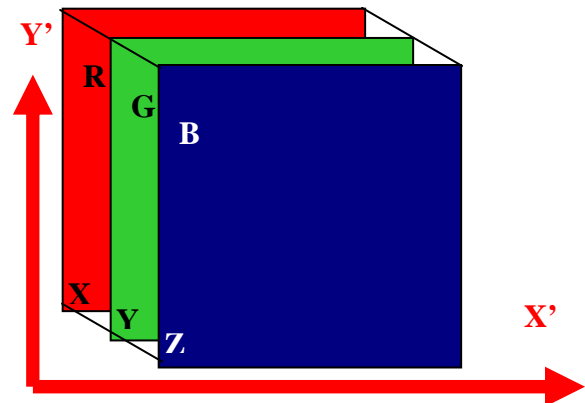

Figure 7. Structure of the "geometry" image

The request for the 3D information of a pixel by the users thus becomes a common web-GIS feature query. After a query, MapServer passes the band_1 [X], band_2 [Y] and band_3 [Z] values of the queried pixel to the answer page.

It is then the task of the application to use this information and display it. This solution combines the advantages of a light architecture and good application performance.
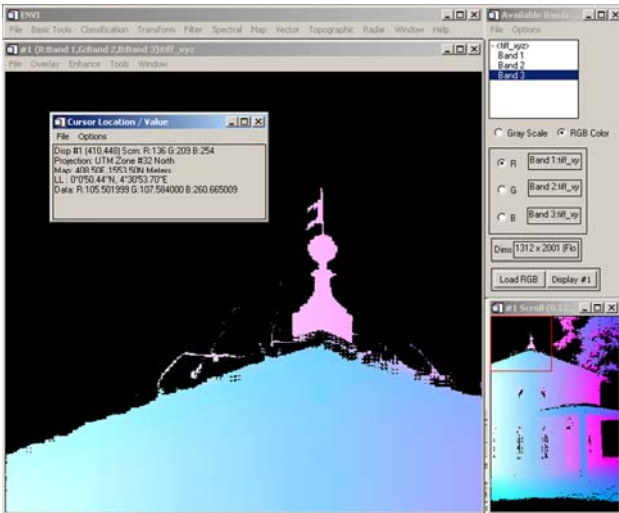
Figure 8. Visualization of the "geometry" image, by linking the X, Y, Z band to respectively the Red, Green and Blue channel

2.3 Benchmark

In order to choose the most reliable solution, a benchmark was set up. Once the data structure was defined, it was possible to project the application which consists of the GUI (Graphical User Interface) which allows an exchange between the user input and the system response. The interface was derived from the University of Minnesota MapServer demo application, by customizing it through the use of javascript.

Because of the different data formats, the implemented applications are different. Except for the "geometry" image solution, the applications are based on a PHP customization of a MapServer application.
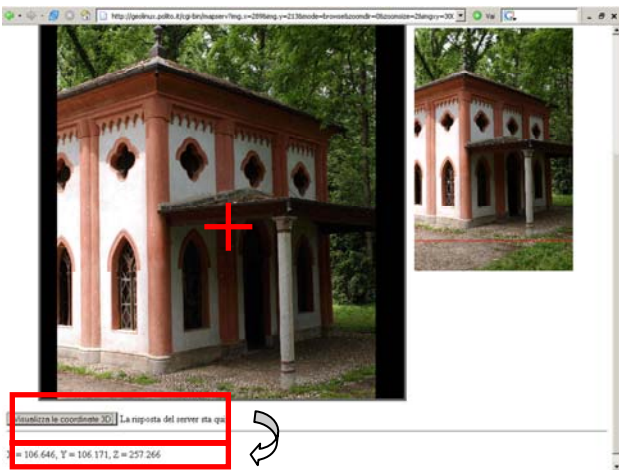

Figure 9. The AJAX technology only updates the coordinate area of the screen, avoiding the reloading of the whole page

After clicking a point on the image, the image is centred on the selected point, and it is possible to use AJAX technology to call a PHP script passing it the X', Y' position of the mouse-click: as a result, the 3D coordinates of the pixel appear in the specific area in the page, without the rest of the page being updated.

In the solution based on a raster file format for the storing of the 3D information, javascript functions provide the displaying of the 3 bands value of the queried pixel.

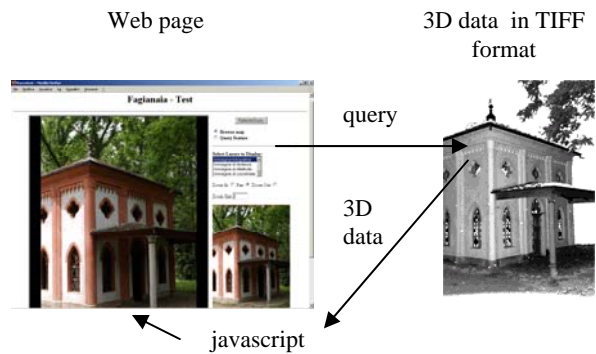The test showed the raster file solution to be the most suitable one.

Web page   3D data in TIFF format

Figure 11. The response to a query is managed and held by javascript
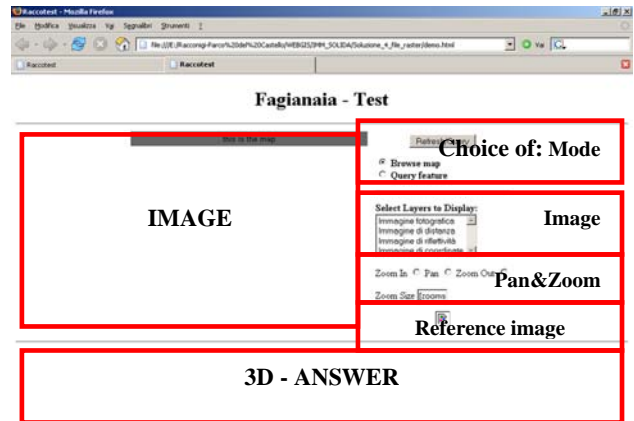
2.4 The visualization tool

Figure 12. GUI schema

The main part of the interface is reserved for the image display: it is possible to view the RGB image of the object, together with its reflectivity and distance from the taking position centre. The choice of which image has to be visualized can be made on the right part of the page, where it is also possible to chose the usage mode: users can decide whether to explore the image or query 3D information.

Having 3D points coordinates available, the tool allows the user to obtain distance information by selecting a couple of points; with the same procedure, it is possible to obtain other information such as angle measurements or plane equations.

Each click causes the 3D coordinates of the selected point to be updated; a 3D distance is also computed between the last two selected points, instead when three points are selected the angle measurement and the plane equation is determined.

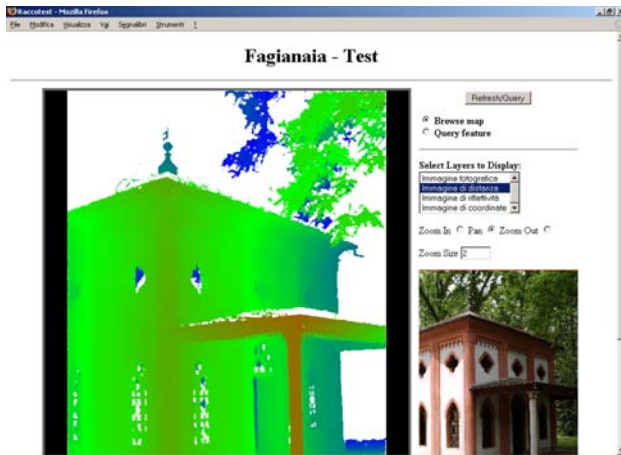A reference image is also displayed in order to facilitate the image navigation.

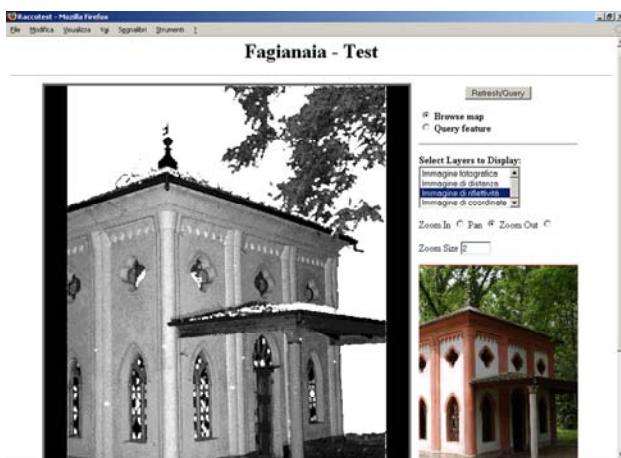Figure 13. Visualization of the distance from the taking centre position image

Figure 14. Visualization of the reflectivity image

3. CONCLUSIONS

Solid Image is a promising tool for the presentation of 3D information; it offers an interesting and user friendly way of using LIDAR and photogrammetric data, even on a web infrastructure.

Its most interesting feature is the fact it is an accurate survey product which can be used by anybody as it is also possible to use it via web, it increases the number of people who can interpret a *Solid Image* content. It is possible to consider scenarios where a survey campaign lead to a tool which could be analysed by different teams at the same time, each of which with different study purposes. In the cultural heritage safeguard field, where there are often problems in obtaining concessions to start survey campaign up or in data ownership, it could represent a solution which would guarantee the ownership of data, as it is kept in a unique and safe place, but at the same time offering possibility of carrying out an investigation to anyone who is interested.

Open Source tools make it possible to freely investigate the most appropriate solution in *Solid Image* displaying on the web. These tools were proved to be very flexible to integrate and use. UoM MapServer in particular proved to be capable of working outside a standard GIS environment it was designed for.

The utility of such a tool was greatly appreciated by users during its testing, therefore the Politecnico di Torino set up SIR

– Innovative Surveys Resources – a spin-off company in January 2006 with the aim of producing and marketing *Solid Image* based services.

The next step is to make it possible for users to gain vector elements of interest using the web *Solid Image* visualization tool: by selecting some points on the image, a 3D polyline is computed, as the geometric model is already known.

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