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1 Introduction

Road administrations all over the world are one of the main historical users of GIS application as they manage information which is mainly related to the use of land and the management of real elements that can be represented on maps.

Road administrations are the receptors and analysts of information related to the roads that they manage.

The main purpose of this paper is to show road administrations and GIS-related organizations that the virtual globes can be very useful for the management of road-related information.

This paper focuses on the management of road maintenance information rather than on road planning and construction issues. Application of virtual globes to the planning and construction of roads is beyond the scope of this paper.

2 Road infrastructures and data collection

2.1 Organization of road infrastructures and life cycle

Most of the countries have a similar road infrastructure management organization that can fit in the following schema:

- Central government authority: Responsible for the management (planning, construction and maintenance) of the trunk road network for the country.

- Regional government (state or province) authorities and local government (county or town hall) authorities. Both responsible for the same tasks as above, but related to the local roads.

Besides those above, there are some other authorities, as the Hydrographic administration or the National parks services that also manage (usually unpaved) road networks with more specific uses.

All those organizations have to do works related to the following issues:

- Planning: Decide where and when to build some new roads, and what should be the characteristics of these new roads; based on the traffic needs and the economical resources available.

- Construction: Define the detailed construction projects, and build what has been defined in the previous planning step to fulfill the need for improved road infrastructures.

- Maintenance: Do the small repairment and maintenance works (patching, crack

sealing, etc.) needed to keep the road network safely usable during the infrastructure life (20 to 30 years).

During the life of the road sections, all of the above issues are usually being reviewed to solve the problems that may appear when the built infrastructure cannot keep being used as it was supposed to, because several reasons (end of life, unpredicted traffic growth or any other).

In those cases decisions have to be taken to accomplish the necessary works to return the road section to provide the needed service. So these tasks are done in a continuous loop.

2.2 Decision making

In order to accomplish those planning, construction and maintenance tasks there has to be information collected on what the real problems on the roads are. With that information, the optimal management decision can be taken.

There are many information issues related to road management, and most of them are related to “geography and maps” of where the roads are. Samples of those can be:

- Topography related planning decisions
- Prioritization of preventive maintenance projects for a road network
- Traffic and pavement condition analysis projects
- Traffic signs inventory and maintenance projects
- Road related utilities (as gas stations) installation decisions.

The samples above show how information related to the road network is one of the main concerns that road administrations should have in order to be able to maximize the “overall profit” from their investments.

2.3 Information usually collected

All the stages of road management require the collection of information regarding the road and its environment to help the decision makers to choose the best solution.

Some examples of information that the road administrations need to collect in the maintenance area are:

- Pavement surface (measurements of road comfort and security for the user).
- Pavement structure (parameters measuring the remaining life of the road).
- Road geometry and road inventory elements (signs, barriers, structures).

Historically this information has been analyzed by means of database management tools

which allow the filtering of the information to detect which the main needs of road maintenance are.

2.4 Data collection of road maintenance related information

In order to focus the different scenarios of information related to road management, this paper describes how some of the information related to road management can be shown by means of the use of a virtual globe.

Among the information that road administrations use there are two sets that are going to be used as samples of what can be done with virtual globes to help on the visualization and understanding of the road reality.

2.4.1 Pavement status

There are several parameters that can be measured to help road administrations decide when and where to do maintenance works to reduce bad pavement “quality”:

- International roughness Index (IRI): It is an overall index that indicates how comfortable a road is (ride quality).

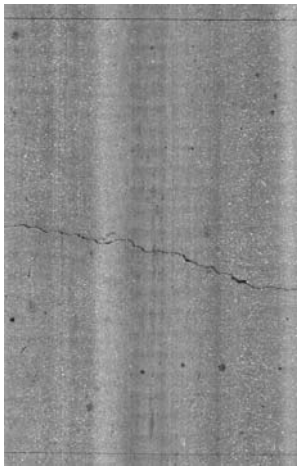
- Skid resistance: It indicates whether the road is dangerous because skidding mainly under wet road conditions.

- Pavement Deflection: It can be used as an indicator of the remaining life of a pavement.

There are many others as the rutting, crack indexes, lane marking retro-reflectivity, etc.

2.4.2 Road images

Besides the different indexes that reflect the status of some specific issue related to the road condition, lately there has been an increase in the use of images of the road to be able to “see” how the road looks like. Those images can go from the detailed pavement images to analyze the cracking of a pavement to aerial orthoimages to obtain a broad view of the road network and its surrounding.



Many of those images are usually obtained by the use of special vans configured with a modular setup of several high resolution digital cameras that can record images of the road every few meters.

These systems are mainly used to generate a road inventory of road related elements (signs, traffic lights, barrier, shoulder condition, etc.) and also to provide the road administrator with a detailed idea of how the road looks like and help in the decision making task.

With these systems the visual work is done directly from the computer, obtaining previous knowledge of road condition and to a great extent avoiding field work.

Most systems currently use digital technology to capture the images directly and store them on a hard disk. The digitized images usually have the location of the image, in linear or geographical coordinates that enable to reference the information in the image precisely. Usually these systems sample the video at regular intervals along the road, normally every 10 meters. This provides sufficient information for management purposes while not overloading the data storage system. In many instances video-logs are recorded in conjunction with other data. The combination of pavement data with the video image is very useful to confirm the true condition of the

road.

Usually these kind of video-logging vans provide not only the video but also some of the pavement indicators described before. For referencing the position of the images they keep recording these information sets (images and pavement related indexes) together with two methods:

- Measurement of the distance traveled from a reference point. This is usually done by means of a rotary encoder installed on one of the van wheels. With it, the collected data is referenced to an origin or to the previous milepost, by just knowing the distance traveled from that previous point.

- GPS/Inertial reference system to obtain geographic coordinates. It is very common to have equipment that integrates the results from a standard GPS unit with those from an inertial measurement unit plus the distance encoder in order to have coordinates even when the GPS coverage fails because of tunnels, trees, buildings.

As a summary, the information collected contains the following information:

- Parameters of the road status

- Road Images

- Coordinates from the items above

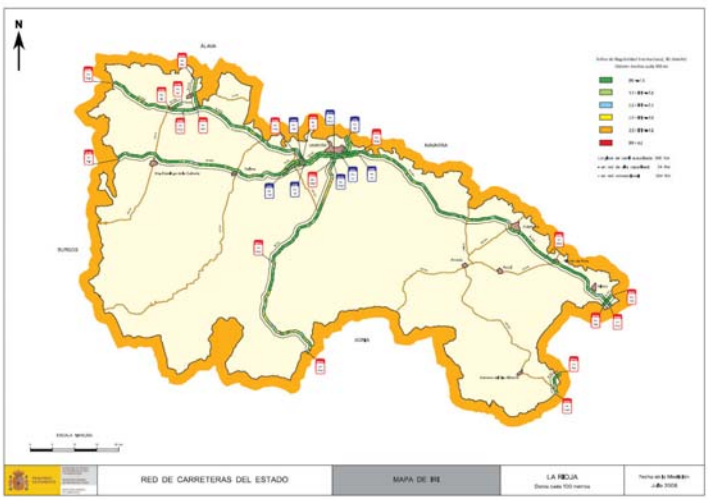
All that information is usually stored in a database (alphanumeric information) and on a file server (image information).

3 Historical use of CAD and GIS by road administrations

Historically different CAD and GIS tools have been used to show and manage the information related to the roads.

Since the beginning of CAD systems, they have been used in the processes of road infrastructure planning and also in the road construction project definition.

At present, many GIS tools are used for several tasks related to road management as for road planning and for visualization of information related to the road in a more visual way than the one provided by tables and graphs.



One of the most useful GIS uses for maintenance related information is the production of

ramp scale maps that indicate areas with some kind of failure on the road network as the one shown in the figure.

One step further, video-logging and GIS integrated solutions have become a common practice for departments responsible for road maintenance. It is a useful technology for identifying the location of roadside attributes and monitoring the road right-of-way and the road pavement.

4 Use of virtual globes to display road related information

These are some examples of what can be done to integrate the information related to road management tasks together with virtual globes

4.1 Sources of information

Apart from the information provided by the virtual globe software, we would be using the following road related data: Road images, Pavement status information, Signs and other road elements information.

All this information can be incorporated into virtual globes by at least two ways:

- Incorporating in the video-logging and data management application new modules that handle a virtual globe, and showing through this interface the already collected video logging and pavement status information.

- Using the virtual globes as the main entry point to get the information about the roads, and link the use of the legacy video-logging applications to the virtual globe.

The visualization of the information through the virtual globes can be made by means of graphics and videos incorporated directly in the virtual globe or by context information and reports that are pulled out when the user selects one feature along the road. These applications can also be mixed with video-logging functionalities to provide a broader view than the one provided by the current video-logging systems.

4.2 Traditional alphanumeric information

With all those information sets available from the road management world, there are many ways to visualize information by means of virtual globes. The following output can be produced:

- Geometry of the road from the GPS plus inertial unit.

- Incorporation of the graphs of the pavement condition inside the virtual globe along the road already drawn. This kind of graph improves significantly the maps

used by road administrations to have a general view of their road network (capability to modify scale and area of interest, to incorporate links to those “old” maps and so on).

- Generation of links to information reports (tables, graphs, images or even videos) related to the road generated dynamically from the information that is stored in the database, accessing to that information from inside the virtual globe.

4.3 Video logging images

In the last years there have been significant improvements in the resolution and number of images that video-logging equipment can obtain. That has been possible mainly due to the increase of the computer processing performance and in the computer storage capacity.

Usually the person responsible for the road management was only obtaining a narrow filed view of the road infrastructure. The systems for obtaining video logging images have moved from one right of view image with limited resolution to panoramic views with three or more high resolution images stitched together to get a broader view of the road and its surrounding.

This solution has been improved by using additional cameras to have a backward view or customized lateral views as well as detailed pavement crack images.

Video logging systems have also been improved to provide the functionality to measure in the images by using pairs of stereo images where the user can identify elements and measure them.

Joining all this information with a virtual globe enables the user to have much more information about what surrounds the roads: the intersections with other roads, nearby buildings, other infrastructures as railroads, etc. Virtual globes enable road management people to move forward in the knowledge of the environment that surrounds the infrastructure that they are managing.

4.4 Data logging and visualization system integration

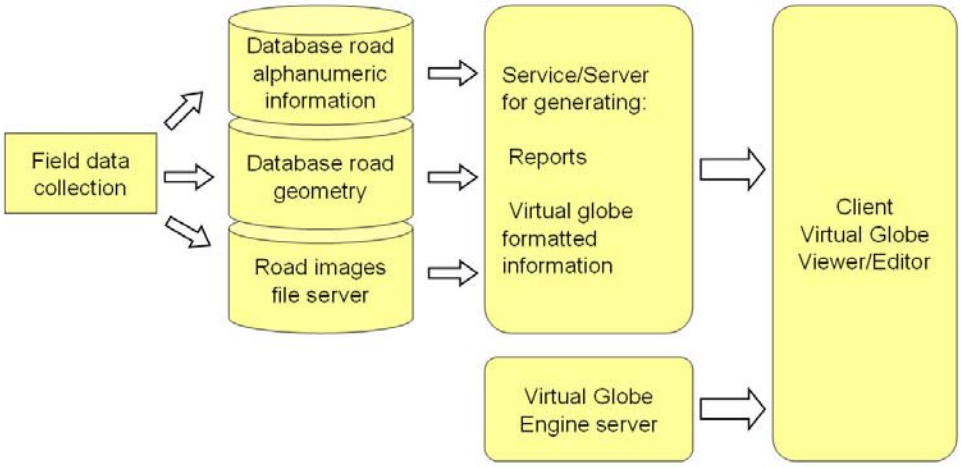
A typical setup for the collection and visualization of road data can be similar to the following:

- Collect field data by means of a multifunction van (pavement information + images + coordinates).

- Process field data and generate database with coordinates, alphanumeric information and fileserver with georeferenced images.

- Define what kind of information has to be available for the user: Report templates, graphs, images, etc.

- Setup the services to gather all that information together and provide it to the virtual globe system.



The examples developed for this document have been done by setting up an Apache web server that generates dynamically, by using several PHP scripts, the KML files that can be viewed from inside the virtual globe used (Google Earth for this example). This server also provides the reports defined as PDFs also generated dynamically from the road information database and the fileserver images. So the structure of the tools used is the following:

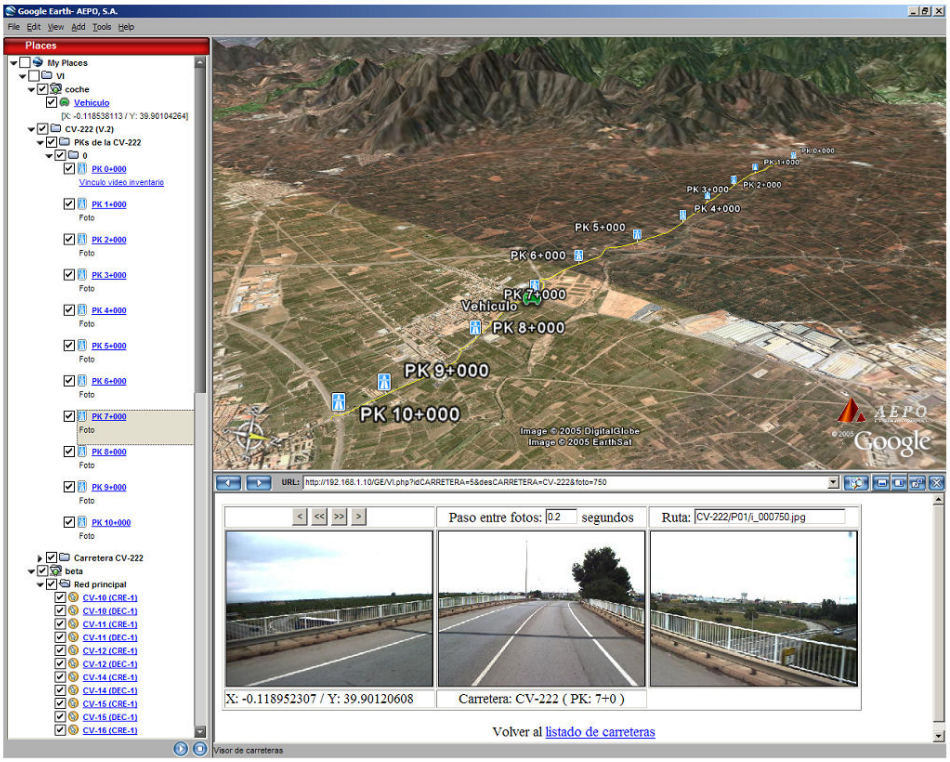
- A database with all the geometry and pavement status information for the road network.

- An image file server to provide the georeferenced images from the video logging system.

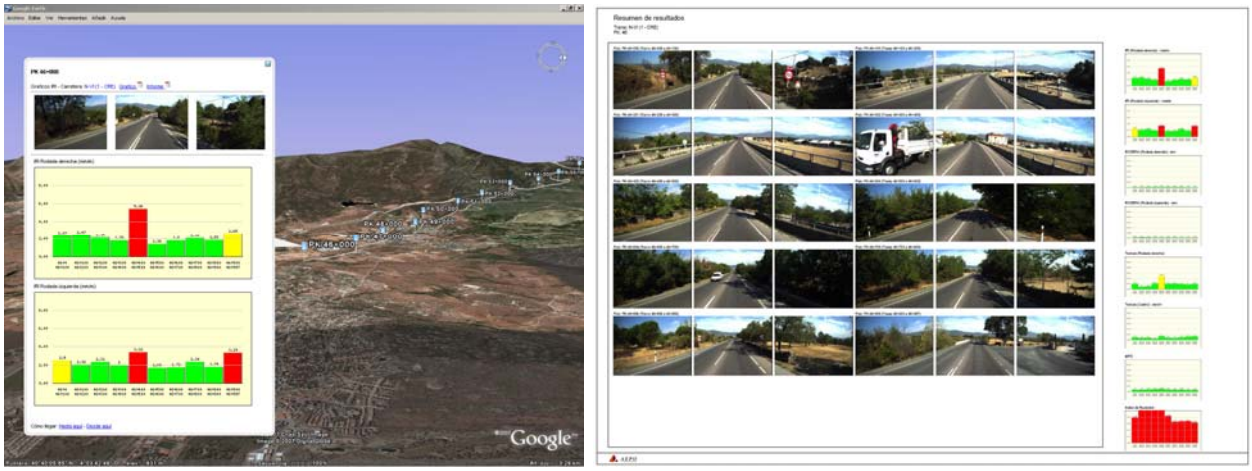
- A Web server with dynamic server side scripting to generate dynamically the corresponding files for its representation through the virtual globe software.

- Google Earth as the virtual globe tools on which the information can be presented.

4.5 Samples of accessing to road information sets with virtual globes



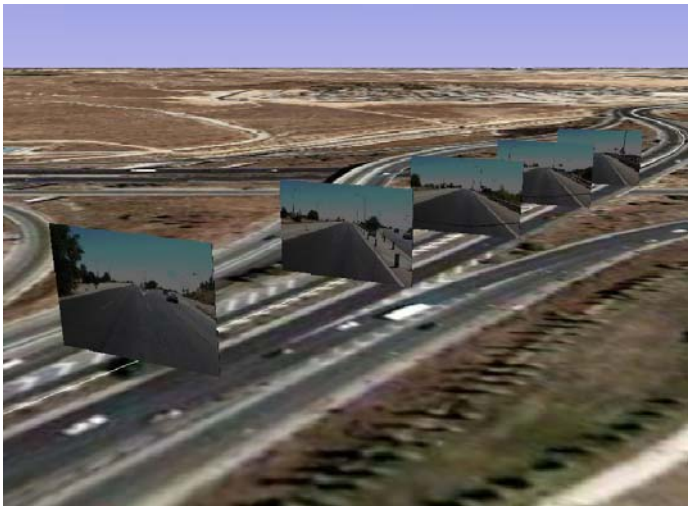
The figure above shows the integration of a panoramic video log of a road where the user can combine the control of movement of the images through a web browser with the linked map that shows the surroundings for the section of road that is being visualized in the video logging application. In the virtual globe window the real path along the road driven by the data logging vehicle can be seen, with the reference mileposts (kilometer posts in the image).



Over the virtual globe representation, several information sets from the alphanumeric database and from the image server can be shown in pop up windows. The sample shows a set of images forming a panoramic view of the road from the kilometer post, and also two graphs that show the ride quality for every hectometer of the selected kilometer.

There are also links to two custom reports. Those reports are just PDF files that are generated on the fly, the one shown in the sample shows a set of panoramic views of the road for every one hundred meters along the road, and a more detailed report of several pavement related indicators.

Going one step further would allow the integration of the road data through graphs directly inside the virtual globe as can be shown in the figure. The graph shows the value of a ride quality index for every hectometer of the road. The height of the bars are proportional to the ride index and the color also indicates the range for that bar so the user can easily recognize where the problem is and how it can be related to other inputs (as the road geometry or the topography of that road section). In a regular bar graph this could not be easily seen.



Using that same approach of immersing the information inside the virtual globe, the figure on the left shows how the set of georeferenced images obtained by the video logging van can be located on the virtual globe model and both the images from the virtual globe and the ones from the video logging van can be visualized together giving more information than the independent use of the video logging images and the orthoimages from the virtual globe.

4.6 Future ideas

Besides the current evolving functionalities that appear in the different virtual globes nowadays, there are other areas for future enhancements. For instance:

- Better handling of custom orthoimages (road administrations usually have their own high resolution ones for planning works).

- Implementation of dynamic segmentation or linear referencing (this technique generates point or linear geometry for database record events referenced by their position along a linear feature).

- Improvement of the integration of right of view and pavement images in the same 3D virtual globe visualization (this improves the information provided by the orthophotos and the digital elevation model).

- 3D reconstruction of the environment using video logging images as source. This can be done by integration of stereo images inside the virtual globe in order to identify features on both images and in this way identify elements and georeferenciate them.

- Static position video reproduction from inside the virtual globe environment. This can be done with videos from traffic cameras or other road related information.

Apart from the road functionalities shown, similar applications can also be implemented to several other linear infrastructures al railroad networks, power distribution networks, etc.