

HOW VIRTUAL GLOBES ARE REVOLUTIONIZING EARTH OBSERVATION DATA ACCESS AND INTEGRATION

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ABSTRACT:

The fusion of the World Wide Web and spatial technologies has led to the development of virtual globes which are increasingly serving as gateways to global geospatial data. Examples include Google Earth (originally Keyhole Earth Viewer), NASA's World Wind, ESRI's ArcGIS Explorer, Microsoft Virtual Earth, GeoFusions' GeoPlayer, Skyline Globe, ossimPlanet, EarthBrowser, and ESRI's ArcGlobe. These systems are revolutionizing earth observation data access and integration in two primary ways: 1) Democratization of access. The popularity of the openly accessible virtual globes extends far beyond the traditional professional communities engaged in geospatial science and commerce. The number of people interactively viewing and extracting content from earth observations such as satellite imagery is on a rapid upward swing as a result of virtual globes. For the technical users virtual globes have vastly reduced the overhead associated with accessing global archives of satellite imagery by eliminating purchase costs and effort required to stage and manage large image holdings. 2) Democratization of content contribution. Users are able to make links to their own earth observation data via web mapping services and insert site specific content (such as descriptions and photographs) which can be openly accessed by the broader community. This has made it possible to integrate earth observation data from diverse sources, enable increased productivity for individual projects and studies. Virtual globes are presently used extensively in areas including education, research/collaboration, and disaster response. The current wealth of technologies, expanding bandwidth, changing user expectations, and data available via the geospatial web are driving the rapid development of virtual globes. This paper presents a brief overview of virtual globes over the last decade, reviews the current capabilities and applications for virtual globes, and envisions what may be anticipated in the coming years.

1. INTRODUCTION

Advanced on multiple technological fronts have enabled rapid and open access to global geospatial data over the internet through systems commonly referred to as "virtual globes". As early as 145 BC, the earth was represented as a globe (The Planet Earth 1955) by Crates of Mallus and globes remain a popular representation of the earth to this day. The word globe, in this paper, is defined as "a three dimensional scale model of a spheroid celestial body such as a planet, star or moon, in particular Earth, or, alternatively, a spherical representation of the sky with the stars" (Wikipedia 2007). Virtual globes will be defined similarly; however, a virtual globe can represent a nearly infinite range of scales, is generated by some 3D software, and allows a user to move freely around the globe changing the viewing angle, position, scale, and data layers. Physical globes are true three dimensional models, however, current virtual globes are usually represented on two dimensional media such as one or more computer monitors. As of 2008 most virtual globes are not truly three dimensional, as they exist in a 2D environment; however they provide a representation of 3D or sense of '3Dness'.

Recently virtual globes have received a great deal of attention and Google Earth is probably responsible for much of this attention. "Millions of people across the world are zooming in

from space, flying across continents, and swooping over mountains and through cities, thanks to Google Earth, NASA's World Wind, and other free virtual globes" (Nature 2006). However, virtual globes were being developed for some time before the success of Google Earth. Despite over a decade of development, virtual globes are still in their infancy. Today the technology behind virtual globes is developing at an astounding pace. New virtual globes appear with a regularly and existing globes are frequently updated, forked (when developers take a copy of source code from one software package and start independent development on it, creating a distinct piece of software), or abandoned in favor of a new project.

Over the past several years virtual globes have revolutionizing access to earth observation data and integration. They have lowered the start-up threshold for access to global satellite data and opened up new possibilities for collaborative research and product generation. In this paper we review the benefits of virtual globes have brought to the geospatial sciences. In addition we speculate on some of the advances that can be anticipated over the coming years.

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2. WHAT IS CHANGING

2.1 Democratization of access

Prior to the advent of virtual globes our access to global coverage remote sensing data was limited to coarse resolution (1 km+) data from sensors such as NOAA's Advanced Very High Resolution Radiometer (AVHRR) or NASA Moderate Resolution Imaging Spectrometer (MODIS). Although higher spatial resolution imagery such as 30 meter Landsat was available, this data was packaged and handled as individual scenes covering relatively small areas. Few centers had a global collection of Landsat style imagery in their holdings and it was cumbersome to move from scene to scene. While high resolution imagery (1 to 4 meter) was available from, its use was referred to as "viewing the world through a soda straw" because each scene covered such a small area. Investigators would review the archive holdings for systems such as IKONOS and Quickbird to purchase a handful of images. Specialize software was needed to view and work with the imagery in a geospatial context. Clearly the old model of packaging and viewing individual scenes of imagery was a great obstacle to viewing and analyzing the globe.

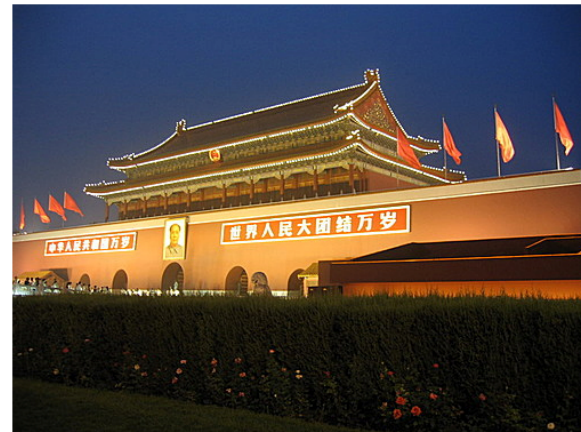
Virtual globes have democratized the access to global satellite imagery. Anyone can download the basic software for free and have open access to a full global mosaic of earth observation satellite imagery. While moderate resolution (~30 meter) forms the base, the quantity of high spatial resolution imagery is substantial and growing. The user can steer around the world with their mouse and zoom in to the full resolution imagery. The user is freed from the burden of reviewing, selecting, purchasing, receiving, storing and retrieving images. Virtual globes have expanded number of people who are routinely viewing and interpreting satellite remote sensing from the thousand into the millions.

2.2 Democratization of content contribution

The ability of users to contribute content provides a uniquely human richness to virtual globes. We are a social species and our ability to describe, document, and share finds a fertile field in the virtual globe. User contributions to Google Earth are made through KML files that have a tag-based structure with nested elements and attributes, based on the XML standard. The KML (and compressed KMZ) point to the data files, which may be widely distributed on servers around the world.

There are two key mechanisms for users to contribute content that others can access in a virtual globe. One mechanism is through the creation of vectors (points, lines, polygons) which record locations of specified features. The user can enter descriptive text or upload a photograph for each vector. The most widely used version of this is the place mark, which records a point. A formalized version of the place mark is the gazetteer, which provides the names of towns and places. Maplandia (<http://www.maplandia.com/>) provides a general gazetteer for use with Google Earth. Panoramio (<http://www.panoramio.com/google-earth/>) makes it possible for users to associate photographs with place marks and provide descriptive text (Figure 1).

Panoramio



TianAnMen Square night2

Photograph by CZ

In Beijing, Beijing (China)

[Misplaced?](#) | [Inappropriate](#) | [Comment it](#)

[Upload your photos »](#)

Figure 1. Sample photograph with annotation as available from Panoramio.

Individual or groups of users can generate their own place marks and share these with others and even the entire Google Earth community. Thus there are a growing number of specialty gazetteers, photographs and notations for places ranging from islands to restaurants.

The second style of user contribution is image data that can be viewed on top of the base imagery provided by the virtual globe. Examples can be found at <http://www.ngdc.noaa.gov/dmsp/maps.html>. This capability to link in images from outside of Google Earth has been extended with the 3-dimensional buildings available at: <http://sketchup.google.com/3dwarehouse/>.

3. APPLICATIONS

One only has to use your imagination to come up with ideas for using virtual globes in the conduct of geospatial studies. One type of application is in the collection of "ground truth". In the past when it was difficult to positively identify a feature using coarse to moderate resolution remote sensing data in a far away place the investigator wished that they could be on the ground – just for a few seconds to make a positive identification of the feature. It may have been impossible to travel to the location and in all likelihood there was no collaborator near the location to check the feature. Beginning in the year 2000 it became possible to order the collection of high spatial resolution imagery or perhaps find a high spatial resolution image from an archive. But this was costly if there were a large number of sites to check. With a virtual globe an investigator can enter a latitude / longitude and zoom in to see the feature in question. There may even be an annotated picture of the feature contributed by someone who visited the site.

We have successfully used Google Earth to confirm the presence and pinpoint the location of oil field gas flares identified in coarse resolution nighttime lights data from the DMSP-OLS (Elvidge et al. 2007). The coarse resolution imagery provides a high temporal resolution record that extends

from 1992 to the present, useful for tracking the gas flaring activity over many years. There were questions regarding the validity of our gas flare identifications. Our solution was to visit each of the identified gas flaring sites in Google Earth. In cases where high resolution imagery is available in it is sometime possible to see the flames and associated smoke pall at active flare sites (Figure 2). Using Google Earth we were able confirm the identity of hundreds of gas flares spread across sixty countries.



Figure 2. Digital Globe imagery available in Google Earth reveals two orange flames from active gas flares with an associated black pall of smoke. The high resolution image features confirm the presence and define the precise location for a gas flare feature identified with coarse resolution satellite imagery.

Another style of geospatial project that is enable by virtual globe can be termed a “collaboratory”. This is the term for a project or activity that is enabled by the internet by widely distributed participants. Since all the participants can view the same imagery and contributed material using the same front end interface it is possible to design and conduct large scale projects that are far beyond the scope that could be accomplished from one research team. As an example, consider Openstreetmap (<http://www.openstreetmap.org/>). This is a volunteer group that is creating an openly accessible digital database of streets and roads. The system is linked to a virtual globe. Participants can upload GPS traces collected of streets and roads. The system has a set of tools that make it possible for the GPS traces to be edited and annotated. It is even possible to digitize streets and roads off the high resolution imagery present in the virtual globe.

It should be noted that some virtual globes have restrictions on the use of the base imagery the present. In general, the use of contributed data is not restricted. Another consideration in the design of geospatial applications is whether the virtual globe allows for the development of customized viewers to perform specific geospatial analyses.

4. THE FUTURE

In the future we can expect that the openly accessible virtual globes will have more complete coverage with high spatial resolution imagery. One can also anticipate more frequent updates of the base imagery. It can also be anticipated that the quantity of openly accessible contributed data will increase.

One problem with the proliferation of contributed data is that they can quickly obscure the image features present in the base map. The image in Figure 3 shows the style of clutter that can develop as large numbers of people continue to contribute photographs, place marks and notations. There is also the question of how to review the large number of contributed items. But overall our assessment is that these are good problems to have when compared to the dearth of geospatial data that typified recent millennia.



Figure 3. TianAnMen Gate in Beijing as viewed from Google Earth with a large number of glyphs indicating the presence of contributed data.

As the number of scientific studies that use virtual globes increase, the scientific community will ask more and more from the virtual globe providers. The scientific community will ask for better metadata and the ability to develop customized analysis packages which can plug into virtual globes. The currently available geospatial capabilities found within virtual globes are rather limited. But over time it can be anticipated that the analysis capabilities will be expanded to resemble those found in a remote sensing software system or a GIS.

Thanks to virtual globes the number of people who are viewing, exploring and producing geospatial data is heading from the thousands to the millions and on towards the billions. We believe that the scientific community can ride this wave, producing more detailed, accurate, timely and meaningful geospatial products and analyses.

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