3D GEOINFORMATION FROM SATELLITE SENSORS

White Paper
January 15, 2015

The notion of "3D GIS" has been gaining momentum in the geospatial industry for a few years now. Realistic 3D vector data, Building Information Modeling (BIM), 3D terrain and imagery are all important components of building a GIS infrastructure that goes beyond two dimensions. The convergence of GIS, photogrammetry and remote sensing data, tools and methods has now matured to the point of making integrated 3D GIS applications a reality.

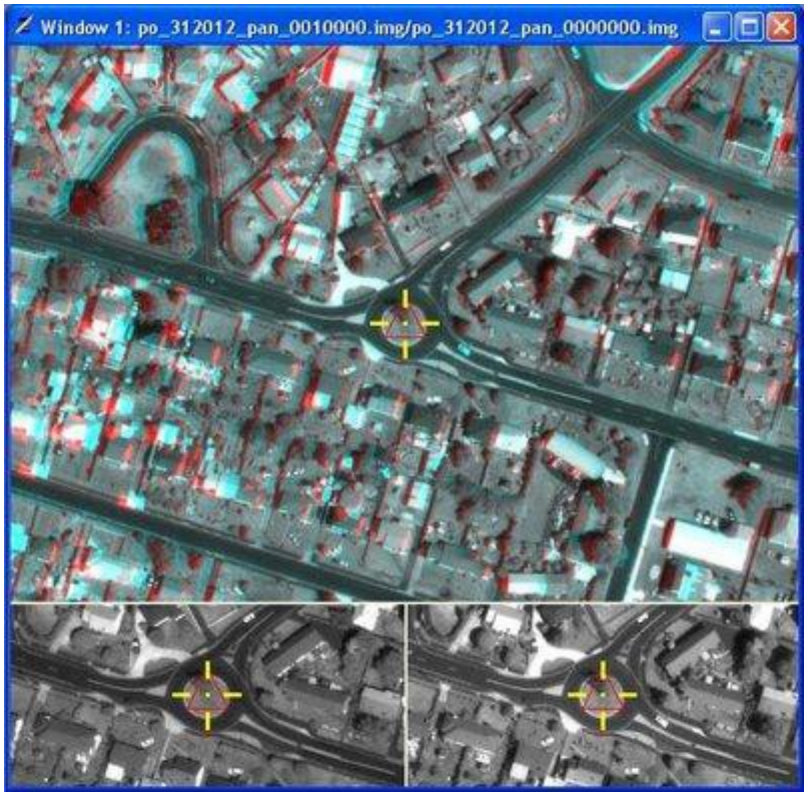
Stereo imagery has been a primary source of 3D geospatial data products since the advent of digital photogrammetry. Photogrammetric processing techniques can be used to create terrain models and capture 3D vector data, as well as produce digital orthophotos. These products are commonplace for many engineering, environmental, infrastructure planning and national mapping applications. To a large degree this remains a specialist domain within the broader geospatial community. Photogrammetric data production has remained a niche activity for a number of reasons, including the cost of data collection, the need for highly technical staff, as well as high-end hardware and software. Thus, the cost of data production can be quite high, and had traditionally been associated with very high accuracy (e.g. sub-meter) applications. However, both tools and data collection methods have been steadily evolving to reduce the barriers to entry, and while costs remain high for high-accuracy results, production costs for GIS applications can prove to be significantly less.

The benefit of stereo imagery is the value-added geospatial information that can be derived from it. This includes three specific data products: digital orthophotos, terrain models and 3D vector data. Digital orthophotos have become a standard component in base map data, and can be used for accuracy assessment, 2D vector digitizing and update, change detection, and a number of other applications.

Terrain data, which can be automatically generated via autocorrelation software, is a key component for orthophoto generation, and is useful for a wide variety of other applications as well. Another product is 3D vector data. One of the major benefits of stereo imagery is the ability to measure objects in X, Y, and Z and collect 3D vector data. Not only can the vector data be extracted in XYZ, but the objects can be accurately extruded down to the ground level. This provides a 3D object that can then be attributed, textured, and then fed into a variety of applications.

A key challenge to the widespread usage of stereo imagery is the lack of industry standards. Software vendors have developed proprietary solutions for storing image metadata, but this can cause problems, as the storage persistence models are often not transportable across systems. This also introduces challenges in the dissemination of data throughout the broader mapping community. Satellite data providers remain at the forefront of productizing stereo imagery and providing it as a solution for the market.

The GeoEye-1 earth imaging satellite, launched in September 2008, is one of the highest-resolution commercial imaging satellites. GeoEye-1 has both panchromatic (0.41 meter resolution) and multispectral (1.65 meter resolution) sensors. The workflow for producing the aforementioned data products in a softcopy photogrammetry environment is described below, and was documented during Intergraph acceptance testing of the GeoEye-1 sensor model implementation. The same workflow could also be applied to DigitalGlobe®'s WorldView-1 sensor, which was launched in September 2007 and features a 0.5 meter resolution at nadir.



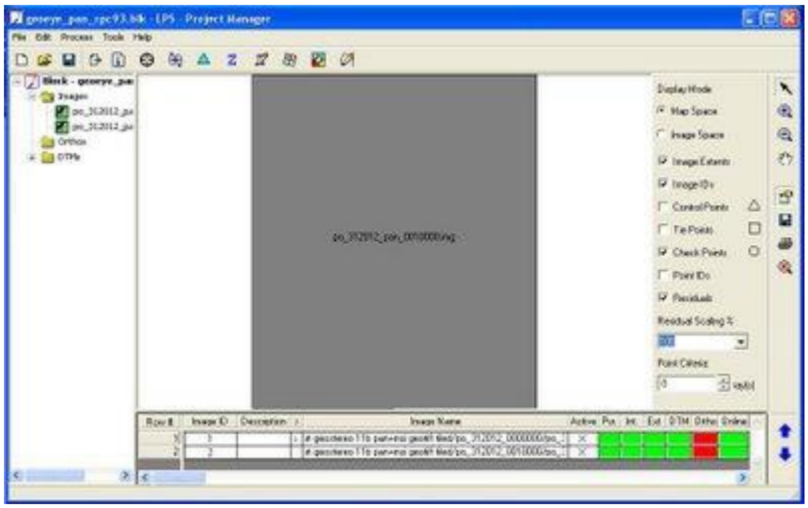
GeoEye-1 Stereo Imagery in IMAGINE Photogrammetry, displayed in anaglyph mode

In this case, the GeoEye-1 imagery is a single GeoStereo stereo pair with an RPC sensor model. This imagery has been partially processed by GeoEye® to remove high-frequency image distortions, making it amenable to a high-quality (sub-pixel) RPC fit. GeoEye's rigorous model metadata may not be available to the general public, so the replacement RPC sensor model is used. DigitalGlobe does release rigorous model metadata to the public (with its basic product if desired). Although the imagery is lower resolution than most airborne photography, one benefit is that the image footprint is much larger. For example, the orthophoto created from the stereo images in the workflow below measures approximately 210 square kilometres. This can decrease time and effort for certain parts of the workflow, such as seam review and editing during image mosaicking operations.

The workflow described below is for an urban project area with ground control points. The availability of accurate ground control means sub-meter accuracy can be achieved. However, it is important to note that one of the benefits of satellite imagery is that even without ground control it is possible to create relative stereo pairs which will have comparable accuracy to the original images, which can be less than 10 meters with the most accurate satellite imagery platforms, GeoEye-I and WorldView-I. This can be very beneficial for remote area mapping, and can dramatically reduce costs when meter-level accuracy is sufficient for project requirements.

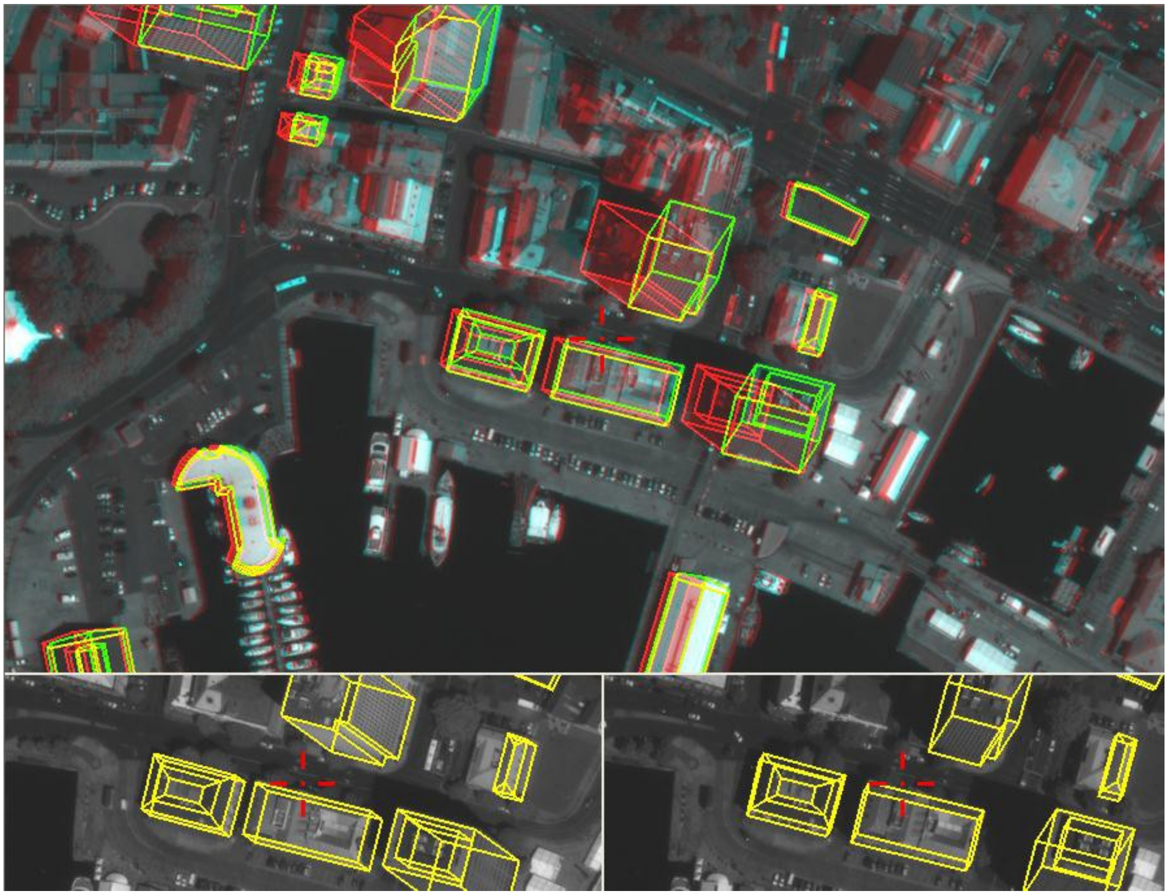
A softcopy photogrammetry system can be used to derive geoinformation products from stereo imagery. Hexagon Geospatial®'s IMAGINE Photogrammetry can ingest and process the imagery in a straightforward workflow. The process flow involves setting up the project, measuring ground control points, performing automatic point measurement, performing and refining the triangulation, generating and editing terrain and performing orthorectification. 3D feature extraction can come any time after the triangulation is performed. What follows is an overview of the workflow.

Project set up involves selecting the geometric model (GeoEye RPC/WorldView RPC) and then adding the images in the IMAGINE Photogrammetry Project Manager. At this point, processes like image pyramid generation can be performed as well.



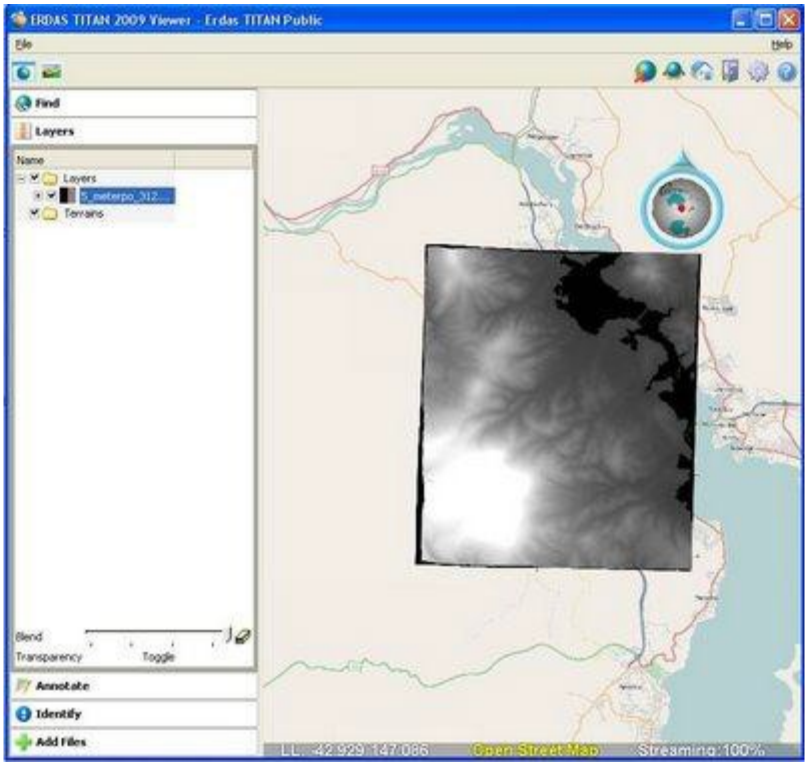
A GeoEye-1 project in the IMAGINE Photogrammetry Project Manager

After the block is set up, the next step is to use point measurement in either stereo or mono mode to measure the ground control points. This is where file/pixel coordinates are related to real-world XYZ coordinates from surveyed ground control points. Typically this can be a time-consuming step, but IMAGINE Photogrammetry has an "automatic XY drive" capability that puts the operator in the approximate area when you're ready to measure a point. After the GCPs are measured automatic tie point measurement can be run, which will generate tie points. Adding tie points may be necessary if there is insufficient ground control to solve the triangulation, and may also improve the quality of the solution regardless. If GCPs are unavailable, automatic tie points are required to create a relative stereo pair. Users have full control over the tie point pattern so there is a high degree of flexibility based on the project requirements. After generating tie points, bundle adjustment can be performed in IMAGINE Photogrammetry. This process involves running an adjustment, reviewing the results, refining if necessary, and then accepting the results once they are suitable. This is a critical step, because after triangulation the initial data product has been generated: a stereo pair. Stereo pairs are crucial for 3D product generation, because XYZ measurements can be made from them. That means 3D terrain products and vector layers can then be generated.



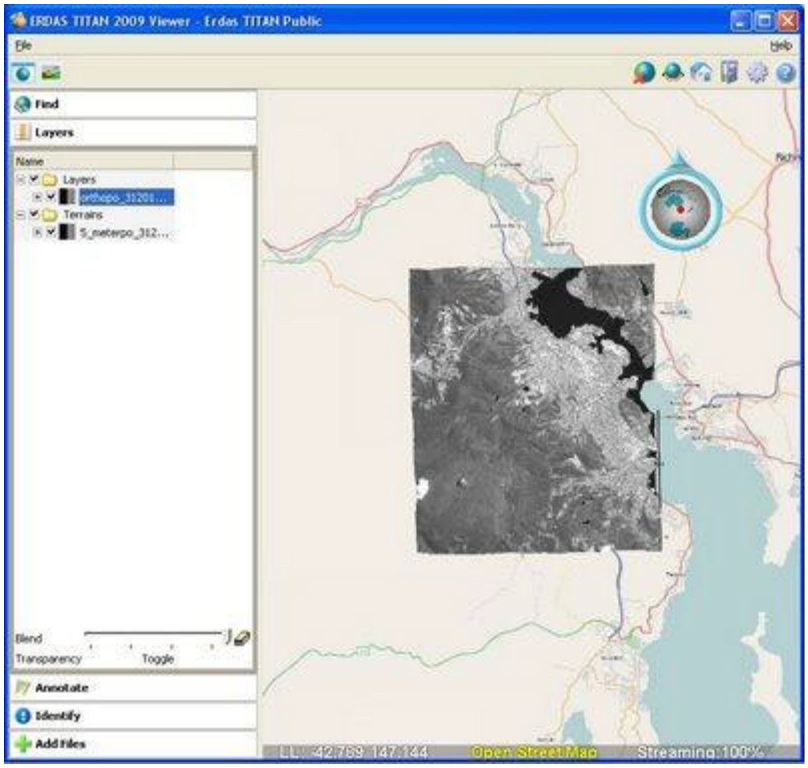
Stereo 3D Feature Extraction in PRO600 and IMAGINE Photogrammetry Stereo

The next step is to generate a terrain layer that can be used as a source during orthorectification, which may also be used as a product in its own right. The Automatic Terrain Extraction tool in IMAGINE Photogrammetry can generate a surface and allow a high degree of control in regards to post spacing, filtering, smoothing, and more. In this workflow a 5 meter grid was generated (displayed on next page).



Terrain displayed in ERDAS TITAN

After performing terrain editing with the IMAGINE Photogrammetry Terrain Editor to create a bare earth DEM, an orthophoto was created from a 0.5 meter panchromatic GeoEye image. Terrain editing is important because errors in the terrain can introduce horizontal error into orthophotos. The orthophoto is displayed on the next page.

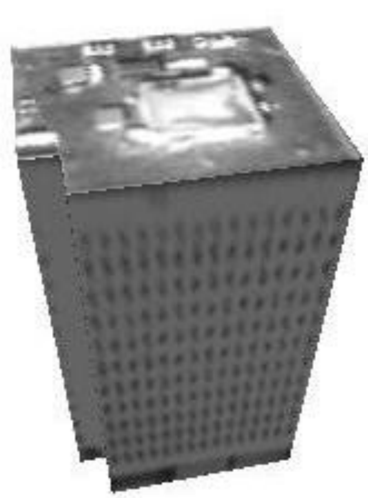


Digital orthophoto in ERDAS TITAN

With a 0.5 meter resolution stereo imagery, it is also possible to extract 3D features such as buildings. Stereo feature extraction software can be used to accurately measure objects in XYZ. An LPS add-on component called PRO600 Fundamentals was used to extract buildings as 3D objects. After extraction, the buildings were then exported to KML for display in Google Earth.

3D KML Buildings in Google Earth

Other tools may also be used for 3D feature extraction. Below, a building collected using Stereo Analyst® for ERDAS IMAGINE® is displayed, extracted as a 3D shapefile with texture applied. Note that this is not generic texture, but rather the actual texture from the panchromatic GeoEye-1 imagery. While it doesn't cover all facades, it does add a level of realism that enhances a 3D scene.



Textured 3D Building Model

In summary, the process for creating value-added geospatial data products from sensors such as GeoEye-1 and WorldView-1 imagery can be accomplished by following the steps identified above. While satellite imagery is often lower in resolution than airborne imagery, it offers an advantage in area that can be covered by a single image. Working with fewer images allows faster processing of certain steps of the workflow, such as triangulation.

Consequently, a variety of 3D geospatial data products can be derived that have value in a number of different applications. While orthorectified imagery is used as a base layer in many GIS applications, the additional 3D vector and 3D terrain information allow for analysis that goes beyond traditional 2D geospatial applications.

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