

## **Improving the Geospatial Data Extraction and Analysis Process Using Stereo Imagery Datasets**

**By**

Lonnie P. Hearne  
SimWright Inc.  
Middle Tennessee Office  
P.O. Box 682648  
Franklin TN 37068-2648  
1-615-497-0569  
[lonnie@simwright.com](mailto:lonnie@simwright.com)

Dan Matthews, C.P.  
SimWright Inc.  
93344 Navarre Parkway  
Navarre FL 32566  
1-850-939-8707  
[dan@simwright.com](mailto:dan@simwright.com)

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## Abstract

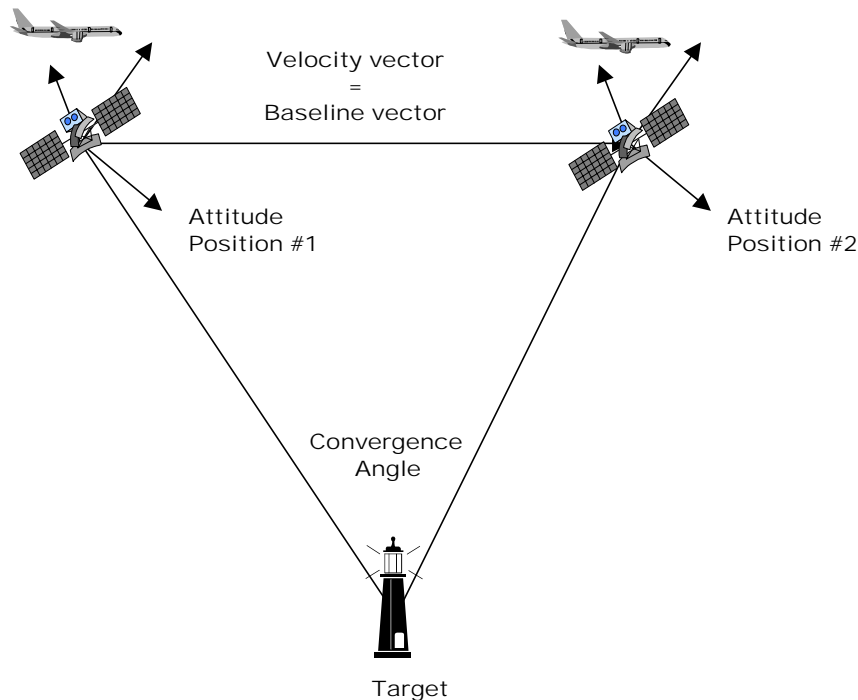
The rapid rise in the use of digital orthophotography (digital orthophoto's) has provided a quantum leap in the utility of aerial and satellite imagery for community geospatial applications. Production of accurate digital orthophoto's requires an accurate digital elevation model (DEM). Although LIDAR is increasingly being used to derive DEM's, the conventional method to produce accurate DEM's for digital orthophoto's is to derive them by applying photogrammetric processes to overlapping stereo image pairs. Generally speaking, once the DEM's and digital orthophoto's are produced, the photogrammetry firm retains the stereo pairs for use if further data products are required by the acquiring agency.

With the increase in computer processing power, it is now possible to view these stereo images three dimensionally on standard workstations with low cost stereo video cards. Even more importantly, these stereo pairs can be analyzed, measured, and have feature data extracted in three dimensions using desktop software. Industry has responded to this fact by producing an ever increasing number of applications that support geospatial data projects including stormwater management planning, linear referenced roadway feature extraction, survey assistance/augmentation for roadway planning and design, airport obstruction clearance assessment, 3D cultural feature modeling, and a host of other uses. Although industry has been fairly quick to react and produce tools capable of exploiting stereo imagery, most government agencies are only now beginning to adjust to widespread use of digital orthophoto's. As a result, the increasing numbers of inexpensive commercial stereo imagery tools are underutilized. These new tools allow desktop exploitation of stereo imagery to create products such as orthophoto's, digital elevation models, topographic contours, and 3D and 2D planimetric data extraction. They also provide for visual analysis of the imagery in stereo. A past president of ASPRS has referred to the use of desktop stereo photogrammetry as "photogrammetry on steroids". In order to use these tools, government agencies will need to change their aerial data collection projects to require the contractors to provide the stereo source data in the form of epipolar resampled stereo pairs when the initial data collection takes place. Generally speaking, the accuracy of stereo datasets is very good. Unlike digital orthophoto's that can have varying accuracy depending on the accuracy of the DEM, stereo imagery is characterized by uniform accuracy throughout the image.

A recent example of how such data could be used occurred in the city of Franklin TN. Imagery had been collected and all relevant data products including orthophoto's and contours had been delivered to the city. However, there were some questions as to accuracy of some of the 3D data and there was little available data regarding the quality control process that had been used to ensure overall data quality. Current stereo pairs from a recent Williamson County imagery collection were obtained for the city and this data was used to create geocoded stereo imagery datasets for the city and city Urban Growth Area (UGA). This provided imagery that could be overlaid in stereo with elevation components from the city GIS dataset. This allows for a rapid visual assessment of potential problem areas and also provides a means for exact measurement to determine the magnitude of any errors.

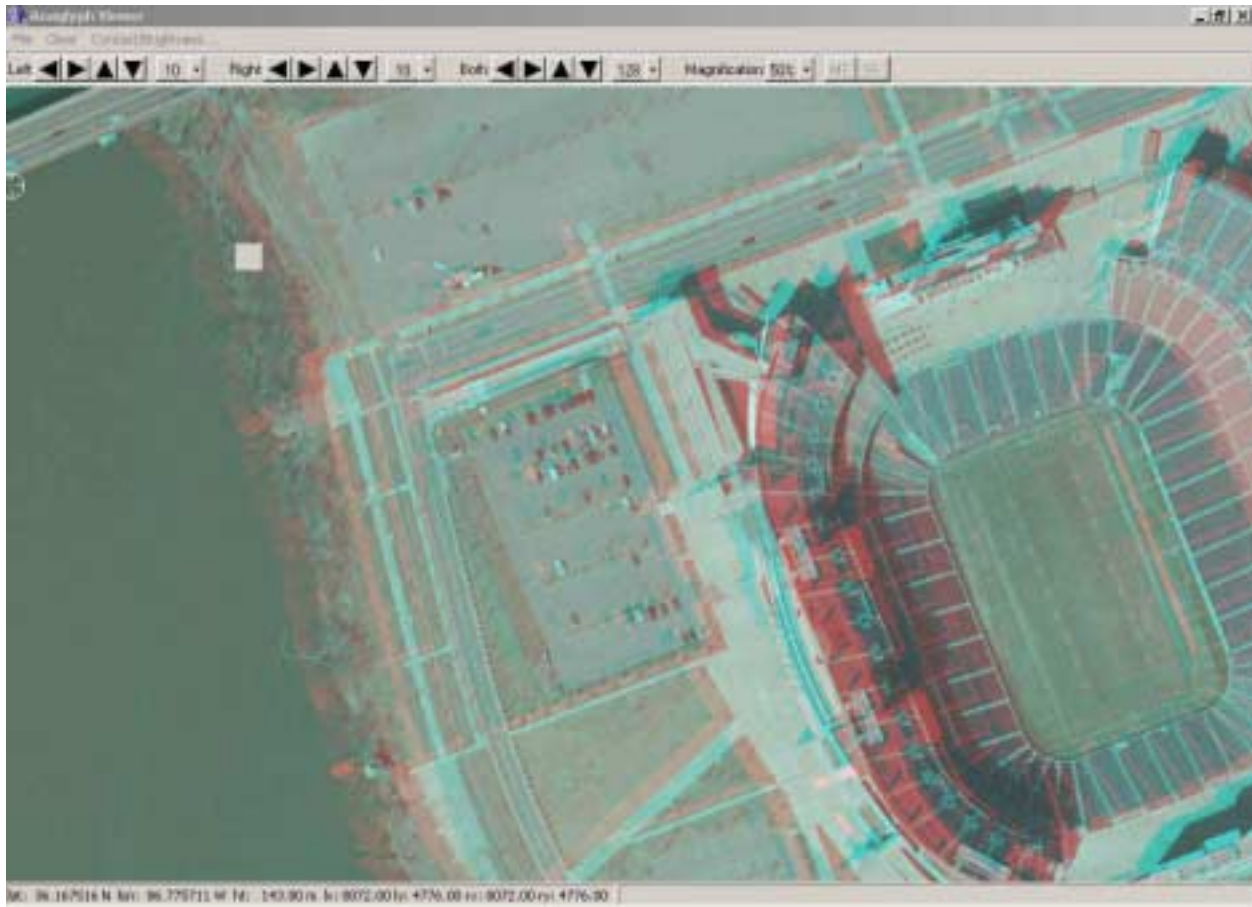
## Background

Controlled aerial photography has historically been used as the basis for most geospatial mapping efforts. Once aerial imagery has been collected, properly controlled and geospatially registered it can be used for both 2D and 3D geospatial feature extraction. Extraction of 3D feature data such as elevation's, contours, and 3D cultural feature data requires the use of stereo imagery. Stereo imagery is created by collecting the imagery such that sequential photographs along the flight line overlap by at least 60 percent.



**Figure 1**  
**Stereo-Pair Geometry**

In order to extract 3D data from this imagery, "stereo models" or "stereo image pairs" must be created using adjacent image pairs. This process consists of accurately geocoding each image so that each pixel is accurately registered in the x-y plane and also performing "epi-polar correction" to accurately align the imagery along the collection path so that it can be correctly viewed in stereo. Once this is accomplished, 3D data can be extracted from the image using a conventional stereo plotter or a softcopy photogrammetric workstation. Figure 2 is a red-blue anaglyph stereo pair produced from imagery collected by Nashville Metro at 6" pixel resolution (i.e. each computer pixel image represents a 6" square). Current processes for control and creation of stereo models generally yield image pairs with pixel accuracies of +/- 1 pixel resolution in the x and y axis and 1.5 times the pixel resolution in z. As an example, the imagery shown in Figure 2 is accurate to +/- 6" in x and y and +/- 9" in the z-axis. This accuracy has been practically demonstrated on aerial imagery sets having pixel resolutions as low as 3cm.

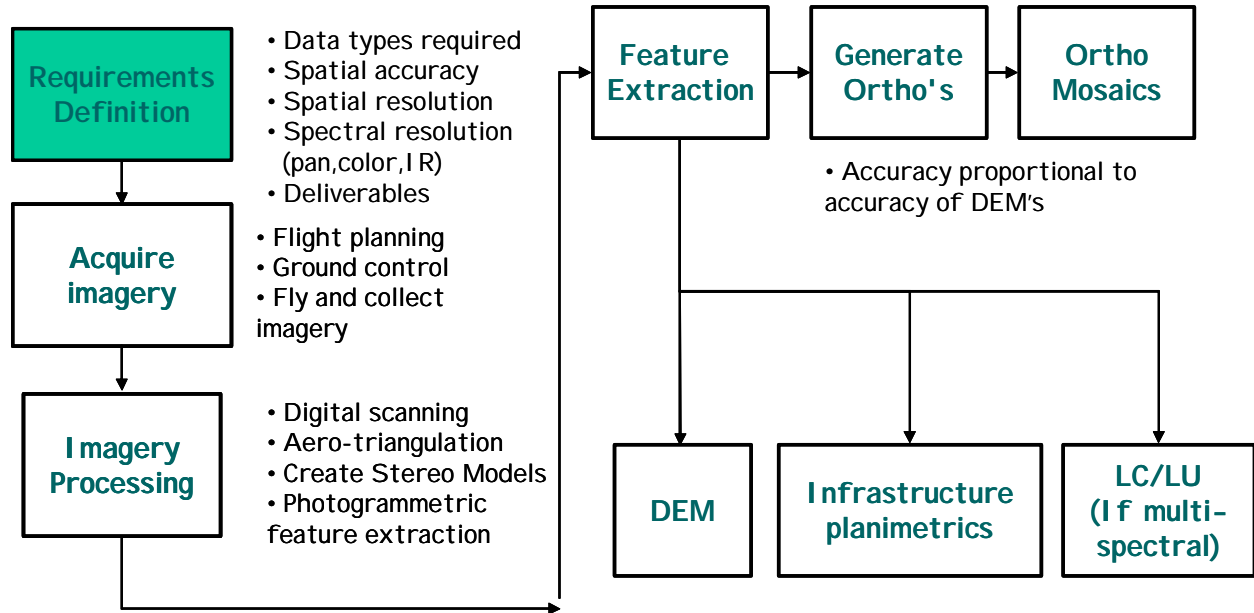


**Figure 2- Red-blue Anaglyph Stereo Image of the Nashville Coliseum (Source imagery courtesy of Nashville Metro and Kucera Inc.)**

The process of creating an orthophotograph involves processing an individual frame so that every point in the image appears as if you were looking directly down on that point. Ortho processing uses digital elevation data for the area in question in order to remove building lean and other features related to the camera angle. Orthophotographs are created using rigid mathematical processes in conjunction with the elevation data to geo-register the data into a 2D image. The accuracy of an orthophotograph is directly related to the accuracy of the underlying elevation data used to create it. One common procedure for creating orthophotographs is to use USGS 7.5 minute digital elevation data as the source for elevation data. USGS data is relatively coarse and sometimes inaccurate. This can introduce inaccuracies into the resulting orthophotograph. Another factor in the accuracy of orthophotographs is that induced errors may well be non-linear, i.e. accuracy may well vary in different points in the image. Precision orthophotographs are created using more resolute and hopefully more accurate data derived from the aerial stereo models. A current trend is to use elevation models derived using LIDAR to help improve the accuracy of the elevation data.

Photogrammetry or engineering firms typically use stereo imagery to prepare the contract deliverables but the stereo imagery is generally not requested or delivered to the agency. Agencies also do not typically require delivery of the original imagery from which the stereo models are derived. Deliverable outputs typically include ortho-rectified mosaic photographs, individual ortho-rectified photographic image tiles, digital elevation models in CAD or GIS formats, topographic contours and extracted geospatial feature data. These products are delivered in hard copy or digital form. The process of preparing the orthophotographs removes all 3D data from the resulting images. Because the 3D source data is usually

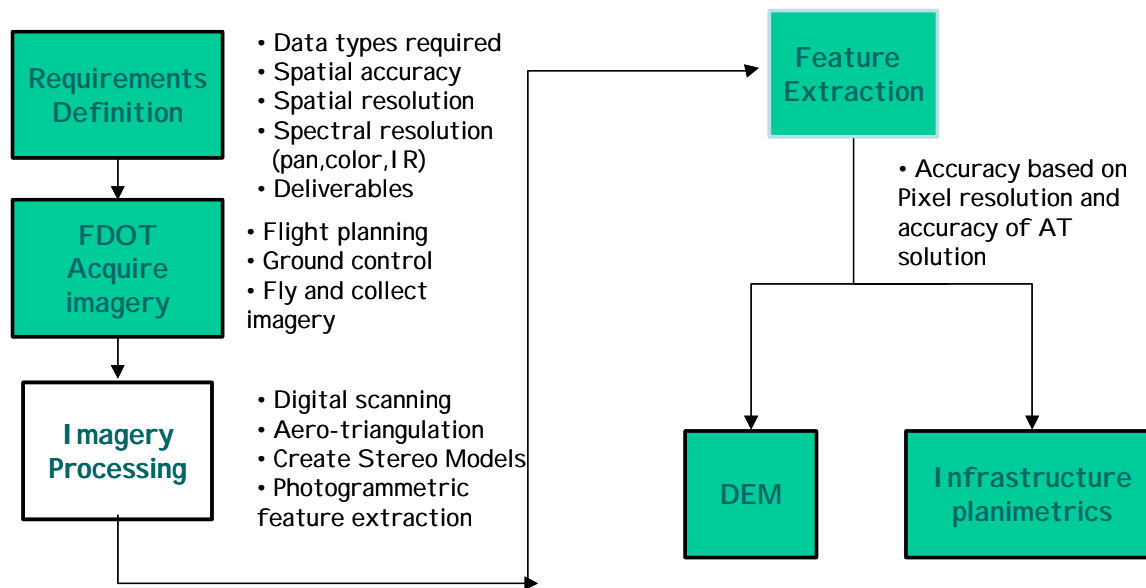
not a deliverable, if additional 3D data is subsequently required then the user must return to the original photogrammetry firm to acquire additional products from the imagery. Figure 3 depicts a fairly common approach to the process by which imagery data is collected to provide geospatial data.



**\*Shaded areas indicate govt. activities**

**Figure 3- Generic Feature Extraction Process**

Increasingly, agencies are looking at the direct use of stereo imagery for feature extraction. Recent developments in geospatial software and affordable hardware capable of processing, displaying, and manipulating stereo imagery now make it reasonable for an agency to consider desktop stereo photogrammetry as a capability. Once accurate stereo models are available, if the user has appropriate software tools they can create additional data products as needed. Properly controlled, georegistered stereo imagery also provides a valuable quality assurance function by allowing the user to overlay 3D vector data such as contours and elevation models and visually verifying their quality. Figure 4 depicts a notional process flow that has been evaluated for collecting and using stereo imagery for geospatial feature extraction.



\*Shaded areas indicate govt. activities

**Figure 4 Notional Feature Extraction Process**

Several benefits can accrue from increased direct use of stereo models for feature extraction. Representative current uses of this technology include:

- Use of 6" pixel resolution stereo data to extract roadway asset/feature data in Northwest FL. A feature of this approach is the ability to derive and compare linear referenced feature data with minimal fieldwork.
- Use of 3.4" pixel resolution color stereo imagery on the Gulf Coast for assessing coastal erosion and stormwater issues.
- Use of 3cm color stereo data by the Florida DOT to increase the number of data points available for design in roadway repair/resurfacing efforts.
- Use of 1m color Ikonos stereo imagery by ABC news for visual scene modeling of downtown Baghdad during the Iraqi conflict.
- Use of 9" pixel resolution panchromatic stereo imagery for visual scene modeling of downtown Franklin TN for planning and development efforts.
- Use of stereo imagery for direct assessment of airport vertical obstruction clearance and planning efforts in Addison TX, San Diego CA, Flagler County FL and elsewhere.
- Use of stereo imagery as the basis for an automated access management tool for FHWA.

Decreased production time and costs for stereo data make it a very attractive option for an agency seeking to optimize the return on investment for aerial data collection. As an example, quotations were recently received for a mid-sized city in the southeast U.S.. The costs for collecting 6" pixel resolution imagery, producing stereo pairs, and delivering the stereo pairs along with tools suitable for feature extraction were approximately \$54K. This would provide the data needed to accurately extract all the geospatial data normally required by an enterprise GIS. The additional cost for producing orthophoto's from 6" pixel resolution imagery of the same area was \$75K. These costs were both exclusive of feature extraction from the imagery. Feature extraction is usually quoted based on the price to extract the required data from one stereo pair or "model". These prices vary and costs can range from \$100 per pair up to \$800+ per pair depending on the imagery (urban, rural, etc.) and the types of data to be extracted. If an agency acquires

stereo data and they can request extraction of a minimum amount of data at the time the imagery is acquired and still have the flexibility for more rigorous extraction in the future. If the agency has the appropriate tools to exploit the data, they can extract additional feature data on an “as required” basis without having to go back to the original photogrammetry firm.

As with all new technologies, the increased use of stereo imagery in “desktop photogrammetry” applications is challenging the approach that surveying and mapping professionals take towards data extraction from imagery. The ready availability of desktop photogrammetry tools begs the question as to how best to ensure the quality and accuracy of data extracted with these tools. Proper control and geo-registration is obviously a critical element in ensuring the utility of the stereo models. Reputable firms engaged in the production of stereo datasets and the use of desktop feature extraction employ the services of ASPRS Certified Photogrammetrists and state licensed professional surveyor-mappers (PSM’s) to ensure the quality of stereo imagery models and the extracted feature datasets. Unfortunately, there is a lack of definitive guidance on how best to ensure and certify the quality of digital imagery datasets for use in desktop photogrammetry. This has led to inappropriate claims from some data producers and to wasted time and effort when collected data does not meet user requirements. The surveying/mapping communities and GIS communities are in a unique position to work together to promote these technologies and ensure the quality of data extracted using desktop photogrammetry. By actively working together they could help promote these technologies to create new uses and business areas that will ensure the growth and health of our professions while providing a higher quality of data to the end users.

**For further information contact:**

**Enterprise GIS Applications-** Dan Matthews, 1-850-748-5371, [dan@simwright.com](mailto:dan@simwright.com)  
**Transportation Applications-** Gay Smith, 1-850-324-3940, [gsmith@hsa.cc](mailto:gsmith@hsa.cc)  
**Visualization/Visual Modeling-** Lonnie Hearne, 1-615-497-0569; [lonnie@simwright.com](mailto:lonnie@simwright.com)  
**Airport Planning and Obstruction Clearance,** Kerry Christopher, 1-850-748-5370, [kerry@simwright.com](mailto:kerry@simwright.com)

For general questions or specific agency project contacts:  
Lonnie Hearne, 1-615-497-0569; [lonnie@simwright.com](mailto:lonnie@simwright.com)