

INNOVATION IN FLIGHT MANAGEMENT SYSTEMS USING REAL-TIME TOPOLOGICAL GIS ANALYSIS

David Hine¹, Gerhard Kemper², Frantsek Pivnicka³, Li Hongbo⁴

1: David Hine, Land and water Management, Mission Beach / Australia

2: Office for Geotechnics, Geoinformatics and Service, Speyer / Germany

3: TopoL Software Ltd. Prague / CZ

4: Big Map Ltd, Beijing / China

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ABSTRACT:

Digital data has replaced most paper maps for managers, aided by the increasing ease of transformation from raster to vector, and the capture of data in digital format natively. Some data will remain in raster format where it is intrinsically continuous, primarily remotely sensed data from satellite and aerial platforms. GIS has matured into a powerful tool for the storage, analysis and display of data from disparate sources. It is the central tool in our daily spatial data management.

There are about ten FMS (Flight Management Systems) in the marketplace, but only a few of them are GIS-based. In our paper, we highlight the benefits of GIS based workflows in the planning and execution of data capture, and a widening range of other, related, aerial tasks.

1. INTRODUCTION

Geographic information systems and the concomitant digital data have, over the past two decades, enabled the simplification of existing tasks, and the delivery of other innovative tasks. There exists a real need to have a GIS based application for aeronautics and avionic, mostly for planning and managing aerial photographs and also for scanning operations. GIS enables access to a range of tools that can be used for the planning and the navigation and project management parts of the process. Given the importance of interoperability, GIS enables data to be Easily imported or exported to other systems and data-exchange can be done to and from very different platforms. Such a solution is embedded into the geo-data-world and not a single solution or line of products. As most of the existing applications are made to integrate into complete solutions within one brand, the flexibility of the applications is small. They are limited in the range of sensors to which they will connect and also in the data-exchange formats that are part of the product.

Existing technologies seldom allow the operator to monitor the done work in real time. Rapid updating of sensor data and the use of software applications designed for cockpit environment enables higher efficiency and greater control over the results. The newly developed system aims to help companies and pilots to do effective campaigns in aerial photography or scanning (e.g. laser scanning/LiDAR). The system is based on software and hardware components including GPS, INS, cockpit-PC, GIS-application and real-time navigation with control-functions. A stabilized mount can be used to reduce rotation of camera axes. Through routines within GIS packages or in standalone applications, there are many options for the transformation of data between formats and between datums.

Since turn of this century, desktop computing power has been sufficient to deal with large amounts of data. The first achievement was to bring together the disparate paper based maps into one system; to display them as layers required the

development of systems to transform the map coordinates into one projection. It has become possible to reproject layers with different projections into one consistent projection and to do so on the fly. In addition to the continuous gradient of raster data was added topology enabling analysis of adjacency and connectedness etc.

2. BASIC GIS FEATURES

GIS is a tool widely used for mapping, planning, navigation and data-analysis. While some GIS software was initially developed as either raster or vector based, hybrid systems that use raster and vector data have become the standard. Displaying of raster-data e.g. orthophotos, satellite data and scanned maps, is common for most of them. Some however offer additional capabilities as transformation, mosaicing or raster analysis. All GIS use vector data with attached database. Vector-data are hierarchical and in some systems also topological. Dealing with different vector formats either by Open GIS rules or via import or export-filters is standard nowadays. Reading of the wide range of raster formats is also well developed.. Modern GI-Systems are used for mapping in combination with GPS live time as navigation solution. This feature was used for AeroTopoL FMS that is based on TopoL GIS. It is particularly important where the three dimensional component of the feature is important. For example, purely raster based GIS applications cannot retain their position when a vehicle passes through a place where roads are in layers one above the other. Similarly, elevation of the terrain is important in photogrammetry.

AeroTopoL has all features that TopoL GIS, the base on which it was built, has. Basic functions are classical vector and raster-operations and database management. Besides various filters for the import or export of vector data, digitizing and editing of blocks or shapefiles can be done within TopoL and software derived from it. Various formats of georeferenced rasters can be loaded and displayed in the map-window, including geotiff, .ecw and jpeg 2000. Depending on the version, there are also

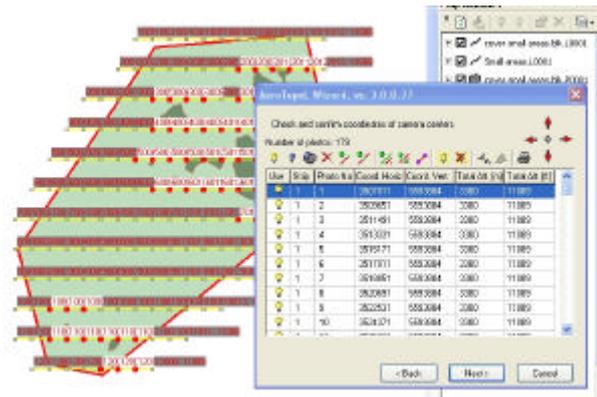


Figure 4: automated disabling of planned images by GIS Boolean operations via a second layer

3.3 Stabilising strips

From photogrammetric point of view it is recommended to add strips perpendicular or at least freehand to the block for stabilizing the Aerotriangulation process. Sometimes this is also suitable in case of difficult shaped areas to add a run non-parallel to cover the area more economically. For that, a free tool is available to draw a run where the release points are computed in same scale and overlap. This line can be moved and edited independently to the normal block, there can be even add parallel ones to it e.g. to create a second block with correctly sidelapped runs.

3.4 Terrain model

In the workflow for planning a mission, a terrain height has to be predefined. If this height corresponds with the average terrain height, scale and overlaps also are in average. If the entered value corresponds with the maximum terrain height, the predefined scale is the maximum only at the highest elevation. At lower elevations the scale will be smaller, and the overlaps may not be sufficient for use.

Only in some cases particularly in flat terrain, the use of average terrain height gives a convenient solution. A better adjustment to the terrain can be done in two ways. During the project planning and in particular with the flight direction, the terrain should be taken into account. It is strongly recommended to plan as closely as possible parallel to the contour lines. It makes no sense to fly perpendicular cross a valley. If the terrain is well structured and the terrain below the runs has a relatively homogeneous height, the single strips can be adjusted easily with an editing tool.

A more professional solution is the adjustment via a terrain model. AeroTopoL needs the DTM for that in ASCII Grid format already in a projected coordinate system. Again, GIS assists in creating this format from any 3D data in any supported coordinate system. It will create an internal DTM format and then to write the ASCII Grid in the target datum. SRTM data, which is frequently used for this purpose, can be re-projected e.g. from WGS84 to a local projected datum (ETRS/UTM). A button in the planning dialogue starts the adjustment using DTM. The algorithm needs beside the path and name of the DTM one information, which is the range of scale. As a standard value is set 80%-120%, which meets the standard conditions for tenders, however the user can edit it.

First operation of the module is to change the photographs rectangle to a polygon by inserting three vertexes on every side. Finally, the footprint is defined by a perimeter with 16 vertexes. Highest priority is to keep the overlap within minimum values,

keep the scale in the defined range and to adjust the various altitudes of the runs as bundles.

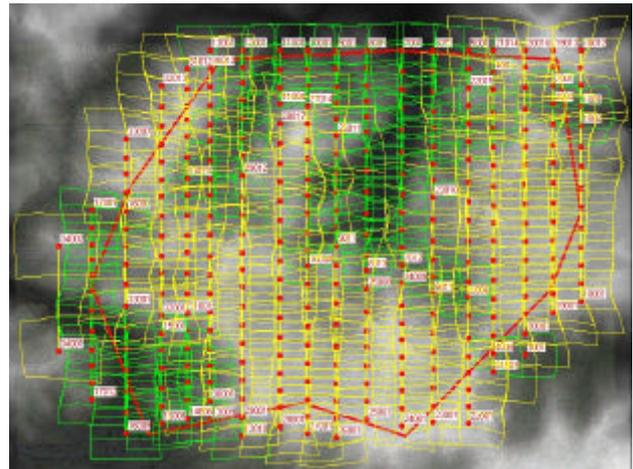


Figure 5: Planning over DTM causes interesting footprints as presented with an example with high relief

The footprints with their sixteen corners are used to compute the right overlaps in flight and the sidelap to neighbour runs. After validating the scale range, it carries out an adjustment of the height of the run. The user may also choose to cut a run and create three or more lines out of it on different altitudes.

When this interactive process is complete, the new footprints, lines with altitudes and all other information are shown in the map-window.

A new feature enables the user to export the data to Google-Earth to visualise the footprints and the planned projection centres as shown on figure 6. This workflow assists in communication with clients, especially those not familiar with GIS.



Figure 6: Reobservation of the DTM based planning in Google earth

3.5 Data-Exchange, Planning reports

The planning process is now complete, and the user can select from various export functions. The plan can be saved into a topol block with full featured database. It includes the project area, the runs and the release points.

A special export is possible of the points into ASCII including datum transformation, which can be used to create waypoints in an autopilot.

A typical GIS feature is the creation of an overlap layer. Topological analysis routines are used to detect parts of the project area of containing sufficient overlap to satisfy the requirements for the GCPs. Effective placement reduces the numbers of GCPs needed in the costly exercise of getting ground control

4. MISSION NAVIGATION

When the FMS is built around GIS capability, the user has the benefit that data from GPS are handled properly and displayed immediately on a moving-map window and/or to virtual instruments. The moving map functionality using rasters and vectors as well as the real time computation of the real measured footprints are compelling benefits to survey pilots, providing an intuitive and easily scanned interface for information from the system and some guidance to flight operations. The position and rotation of the camera can be used and calculated to adjust to the terrain, ensuring proper coverage and overlap in the project. If some areas seem to be badly overlapped or covered, manual imaging can avoid the necessity of additional flights.

Mobilisation for data capture can only be done when weather conditions are suitable and is expensive in addition. Confirmations of the status of the mission, the certainty of image capture are critical to effective mission execution.

4.1 Camera-definition and Auto zooming

In many cases, the camera is properly defined during planning as a frame camera in either landscape format or portrait format. This is essential for a proper mission plan. In the navigation is the possibility only to rotate the camera by 180 degree. This will conform with the mission plan but not with the kappa angle of the image. The orientation of the camera can be defined here and will be taken into account during writing the report files.

For control of the mission and the navigation, moving map function is used to display raster and vector-data, the planned runs and release points and the own position with orientation. Typically, the project area is distant from the starting and landing point. It is useful to have the virtual instruments as a navigation guide, assisted by the auto-zoom function as the plane approaches the project area. The zoom levels can be defined (minimum scale, maximum scale) and the rate of refresh levels.

4.2 Sequencing and catchments

Automatic shutter release is achieved by calculating the distance from the target to the true present position of the camera. The refresh rate of the position typically is 10 Hz due to the speed of the GPS/IMU. 2 snap-circles are defined as inner and outer buffer. The inner buffer starts a release when the GPS position is detected as inside this buffer; the outer buffer monitors the nearest position of the aircraft to the planned release centre. The sequence of the runs and their direction can be preset which reduces any interference during flight. Some additional functions can be set up, especially if a stabilizer is used and a full heading compensation is required.

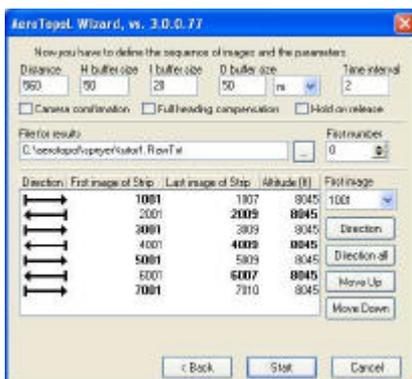


Figure 7: Setup of the run-sequence and the snap parameters

4.3 Navigation and control

The heart of the entire system is the carefully developed combination of software and hardware. The avionic hardware consists of synchronized GPS data with INS information. Rapid update and event based additional position and attitude information is handled by the FMS. It is recommended that the setup include a rugged notebook and a monitor for the pilot. The pilot-display is important; it should be visible even under daylight conditions, small enough to be mounted in the cockpit along with the other instruments and in easy view of the pilot.

The control of the camera via the hardware uses both the release signal from the software and the event signal returned from the hardware as confirmation.

The entire communication between FMS and Hardware/camera is managed by one serial cable only, using high-speed bidirectional serial communication.

The incoming data is, on datum WGS84, the commonly used datum in GPS applications. They are transformed on the fly into the user-selected datum of the map window.

Instruments placed in a control panel show the pilot an artificial horizon, a track-guidance with the offset parameters and the heading and a target-assistance to catch the snap-point in 3d. Besides these instruments, the pilot sees his position, represented as a aircraft symbol over the raster and vector data. The orientation of the aircraft is shown by the coordinate differences during moving.

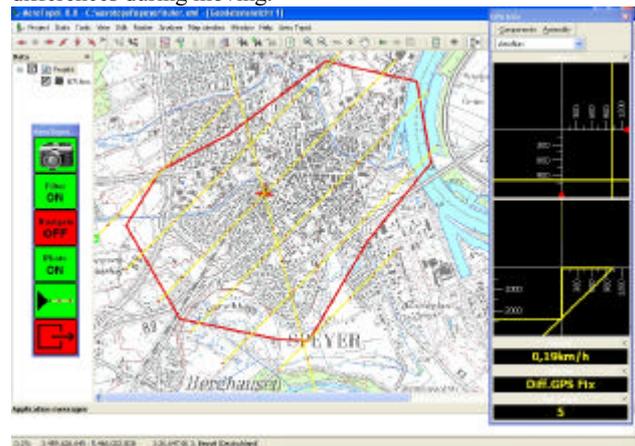


Figure 8: Moving map and virtual instruments support a precise navigation

The auto-zoom function always assists in navigation to the first navigation point. Beside that, the software always computes on a high priority task the distance to the next release-point. The software enables only the image that is next in the strip, or next in the project. The virtual instruments guide the pilot to the next snap point. If the outer snap radius is reached, the system is enabled to release the photo and tries to detect the closest point to the inner snap-circle. If the computed distance starts to become bigger, the system fires the image while the software sends a command to the port. The camera releases and creates an impulse to the sensor, which informs the software again to store the data (y, x, z, roll, pitch and heading). AeroTopoL calculates by these values an actual footprint that is shown on the map with the real projection centre in the middle.

In this way, the coverage of the data can be monitored easily. If all images are taken, analyses over the correct overlap can be done immediately to see, if additional photos are needed. This function is the same as at the planning part, just there are used the real measured values of X,Y,Z, Omega, Phi and Kappa for the footprints.

Since all data of the GPS/IMU data for each camera release event is stored in a database, a project can be flown over two or more days when required. At the end of the mission, all projection centres with their rotations, already saved in photogrammetric values, assist in speeding up the processing workflow. The vector data can be delivered directly to the customer as a first report since all relevant information (Date, time, Image number...) is stored in the point database.

During the mission, user level decisions such as whether to use auto-zoom, whether to abort a mission due to cloud etc, are all available through large buttons on a floating toolbar and suited for rapid and easy use on a touch screen.

5. OTHER APPLICATIONS

The FMS capability can assist in with a range of tasks. Aerial survey with frame cameras is just one application that was managed by GIS, it can be applied equally for LiDAR scanners. A rather new application in aerial survey is oblique imaging which is now possible with AeroTopoL FMS. The application of fertilisers for agriculture and forestry is a different domain, but uses the same principles and technology. The creation of zones and buffers is important in this task. Drop-speed and wind drift are additional parameters that have to be taken into account. A third domain is the control of power lines where the database access is of high importance. Errors on the cables or pylons have to be registered and the history recorded in the database has to be accessed automatically– a task that can be managed only using GIS.

5.1 Oblique imaging

The main difference to nadir viewing images is the offset of the flight line with the image centres and that images must be taken from 4 sides to cover an area. Rotating and tilting must be computed and the image centre computed. From that it must be back calculated to the projection centre. The flight direction is now fixed since the camera is facing relatively to the aircraft always in same direction. The footprints become trapezoids and the overlap is computed by the axes through the image centres. This finally is a rather difficult task but is already implemented using the GIS based software.

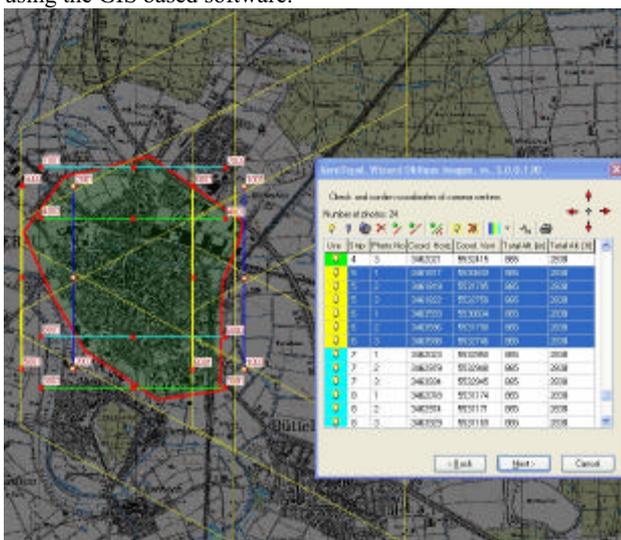


Figure 9: Planning of oblique imaging is a much more complex task for FMS.

Oblique imaging can be done also for synchronised cameras as well as sequentially handled single camera solutions. The tools

are under developing for those special issues. Systematic Oblique photography is a strongly growing market with focus on two different customers. One who really needs photogrammetric accuracies to measure building facilities especially for security reasons, and others who need image coverage for internet-applications or data for city planning and monitoring without needs for a precise measurement.

5.2 Laser Scanning

Most FMS use normal imaging tools for guiding the aircraft. However planning a scan over DTM is of high important more than that, the monitoring of the coverage is essential for a successful and economic mission. There are possibilities to get information of the scanned extremes. In combination with the GPS and IMU information, the borders of the scan carpet can be displayed in real-time.

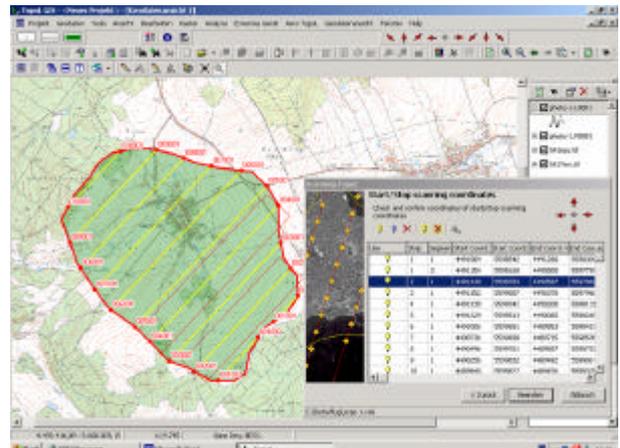


Figure 10: Planning for scanner missions in combination with aerial imaging is a challenge in modern FMS.

5.3 Broad Scale Aerial Application of Lime in Forestry

In Europe and world wide, the forests are damaged and their ecological integrity compromised because of air pollution such as SO₂ emissions which are cleaned from the atmosphere by rain but disastrous consequences caused by this acid rain, notably the acidification of forest soils. Forest management institutions and state government bodies undertake liming campaigns to address this problem. The lime is generally applied by helicopters. Every year in Germany, several thousand hectares are treated with lime applications.

In the framework of ISO 9001 (the process standard for environmental management systems) and upcoming European rules, such applications must be documented by the institutions. A system, based on GIS, GPS, sensors and avionics, has been developed. The heart of the system is a data logger built using the AeroNav technology. In addition to logging the rate of lime application, the Aerologger sends a modified NMEA-string to a cockpit computer to navigate the pilot to the forest project sites. The software is able to start, stop or interrupt the lime application system, map its work and display the result directly on the monitor. An event on the lime distribution unit sends a signal to the Aerologger and to the FMS/lime application software, which is recorded and used to determine the state of the application.

For the planning team, the most important details are the project areas. They may have been provided in vector format by the forest organisation or they have to be developed in house by digitising onscreen in the software. It is very likely that the

contract will require variable applications according to soil pH and other factors. There may be protected areas, where lime must not be applied. To support both requirements, buffers can be defined around these features.

The software for the flight itself must meet very complex requirements. To compute the drift of the lime on its descent, and its eventual swath of deposition a range of variables is required. This includes the wind speed, the wind heading, the average drop speed of the lime and either a value of the flight altitude over ground or (preferably) a digital terrain-model both for swath estimation and for pilot guidance. With this information AeroTopoL continuously shows the position of the helicopter on the moving map and a bar where the lime will come to rest. Either manually or automatically the emitting starts. This application can be adapted to other fields, including ground application by tractor or truck of lime or fertiliser, pesticide applications and many others.

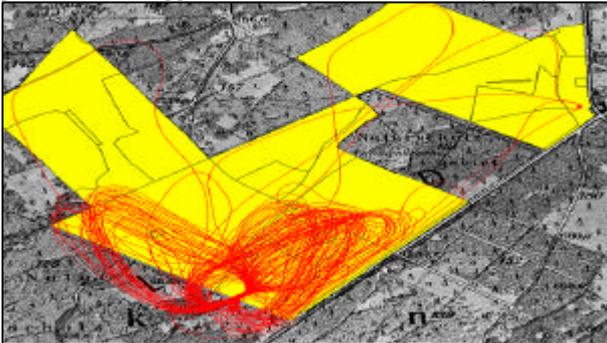


Figure 11: Typical track of the helicopter used for forest chalking. Without a FMS a homogeneous coverage is nearly impossible

5.4 Aerial inspection work

Helicopters are frequently used for the management and maintenance of power lines, pipelines and other sensitive installations. All these applications require very precise navigation; the costs of an error are very high. This application is the most near to classical GIS but with even simplified and easy to use menus. Differential GPS is used for precise navigation and vector data capturing, using predefined database fields. Special features like length-splitting, intersection and others are used for this work. As pipelines are often buried, the exact determination of their location is critical.

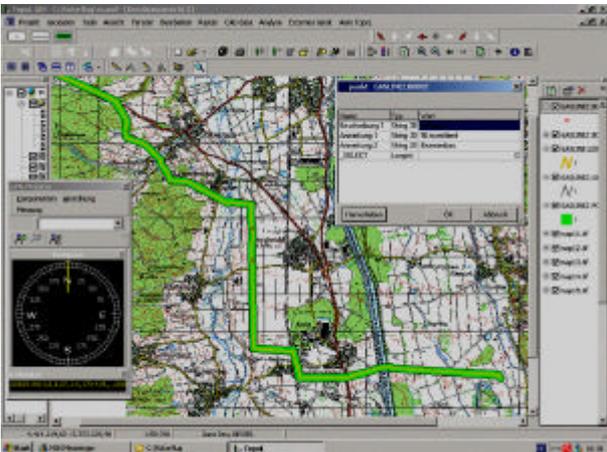


Figure 12: Application for Corridor Monitoring, here the observation of a GAS pipeline where a Database with History is very important.

In Germany already gas pipelines are controlled by such a GIS based-system. Electric power lines easily can be seen, but often several lines are going parallel and here an exact navigation with 1 m accuracy is needed to detect problems on the correct line. With a GIS based system, it is feasible to record text data for later analysis and to update the information on each inspection point. By developing a record for each point, computer analysis of the electrical or gas transmission system is enabled, utilising existing database technology.

It is only by use of a GIS based management and maintenance system that all data collection, utilisation, and analysis can be integrated.

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