THE INTEGRATED WORKFLOW AND SOFTWARE SYSTEM FOR GIS DATABASE UPDATE BASED ON GEOSPATIAL IMAGIES

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ABSTRACT:

Although the image-based update strategy is becoming one of the most desirable choices in keeping the up-to-date state of GIS database, now in China, the traditionally adopted workflow and arts for update are still scarcely affected by the current advanced technologies and methods, which is quite inharmonious with the high demand for fast data update. Considering the current technical and financial feasibilities in practical applications, this paper studies on the design aspect of the efficient software system for GIS database update based on geospatial images, in which the operation mode of integration is emphasized; next, a brief discussion of the system function architecture also is included; finally, the integrated software system *Geomapupdate* for national 1:50000 GIS database update based on geospatial images is introduced, as a typical case study. It is a platform exclusively servicing the current GIS database update businesses of our country and supported by National Geomatics Center of China (NGCC) and designed by the research group of State Key Laboratory of Information Engineering in Surveying Mapping and Remote Sensing (LIESMARS) Wuhan University. Practices manifest that *Geomapupdate* is a successful case study attempting to realize the highlighted integration concept for GIS database update; and it is able to improve the traditional update efficiency by more than 20%, which has been witnessed in the 1:50000 GIS database update business of China recently and laid a base to achieve rapid updating GIS data.

1. INTRODUCTION

The up-to-date state is the key factor that evaluates the utilization value of GIS databases, which becomes the focus in the application field of GIS at both home and abroad nowadays (Speren 1996; Dowman 1998; Fritsch 1999; Jiang and Chen 2000; Chen et al., 2004; Dekker 2004; Bouziani et al., 2007). In china, construction of the national fundamental geospatial database has been completed in the past “tenth five-year plan”, and the primary task has turned to the geographic database updating aspect in the new “eleventh five-year plan”, during which State Bureau of Surveying and Mapping enlarges the capital, material and labour input, planning to organize the domestic surveying and mapping departments to jointly complete the updating mission of the national 1:50000 GIS database, mainly through the approaches of image-based integrated interpretation and surveying or map generalization. Under the new circumstance, many spatial data producing departments gradually transfer the traditional collecting-oriented data producing mode into the updating-oriented data refinement mode, during which continuous explorations and achievement are made to the advanced methodologies for spatial data update. The quick and sustainable GIS database update is closely linked with the continuing up-to-date data sources and efficient mechanisms for update. With the rapid development of airborne and spaceborne sensor technologies, now it is easy to acquire the real-time or near real-time high-resolution images of land covers; meanwhile, the intelligent combination of imaging sensors with various additional sensors also contributes to the gradually automated and intelligent data processing technology. All of these developments indicate that the image-based updating strategy is a most desirable choice for GIS database update, due to the abundant up-to-date information it provides (Gunst and Hartog 1994; Knudsen and Olsen 2003; Holland et al., 2006).

However, in China, the update workflow in traditional operation mode is fixedly followed by three main steps: image interpretation indoors, field validation and supplement, data revision indoors. Such a serial workflow is unsuitable for the fast GIS database update command due to the long updating cycle induced by the disjointed indoor and field working mode. The current field validation and supplement mode is scarcely renovated by the contemporary electronic technology and almost continues to adopt the traditional analogized photo or printed map based surveying and revision pattern, incurring disharmony and inconvenience in operation consistency and information sharing between the work indoors and in field. Besides, there is a vacancy in the integrated software system exclusively provided for the current image-based data updating business, so much so that the accomplishment of workflow has to rely on combined operations on software from different specialized fields, e.g. ArcInfo, MapInfo, Photoshop etc., without a uniform criterion for professional operators to comply with, which to great extent increases the operation complexity and discontinuity. All of these limitations have been exposed during carrying out the traditional GIS database update business based on geospatial images. Considering the problems from both efficiency and quality aspects, reformation of the traditional image-based update methodology relies on the full realization of the integrated workflow and software system based on which the update process is carried out.

Regarding the technical and financial feasibility in practice, the second chapter of this paper explores on the design aspect of the efficient image-based software system for GIS database update, in which the operation mode of integration is discussed in detail;

and then the architecture of the system function is designed in the third chapter; in the fourth chapter, the integrated software system *Geomapupdate* for national 1:50000 GIS database update based on geospatial imageries is introduced as a typical case study. It is a platform exclusively servicing the current GIS database update businesses of our country and supported by National Geomatics Center of China (NGCC) and designed by the research group of State Key Laboratory of Information Engineering in Surveying Mapping and Remote Sensing (LIESMARS) Wuhan University. The whole system is efficiently organized with several functional modules in which the integration concept has a detailed embodiment. It is a successful case study for the practice of the integrative updating concept emphasized above, which has been witnessed in the 1:50000 GIS database update business of our country recently.

2. THE OPERATION MODE OF INTEGRATION

In surveying and mapping industry, the essence of geospatial images based GIS database update is: with the up-to-date multi-source geospatial images e.g. aerial or satellite Digital Orthophoto Maps (DOM), Digital Raster Graphics (DRG), stereo image models of photogrammetric block, etc. as the major information sources for update, cooperated with various subordinate datasets such as the vehicle-collected GPS data of road network, data of place name, data of territory border or some other thematic information in the fields of irrigation, electricity power, communication, transportation and land use etc., to accomplish the topographic database update mission based on the existing Digital Line Graphics (DLG) data through the technical approaches such as image-based information integration, interpretation and mapping indoors, field validation and supplement and so on.

It is well known that the indoor working task such as data preparation, image interpretation, data revision, etc. and the outdoor task including field validation, supplement and filling out are both indispensable to accomplish the whole work of geospatial images-based GIS database update. As mentioned previously, the traditional operation mode is quite defective and can not keep up with the current fast update command any more, due to the disintegrative procedures and working tools still equipped with. Therefore, it is of great importance and significance to consider the brand-new operation mode when the integrated workflow (see Figure 1) and software system for the geospatial images-based GIS database update is to be designed. As a whole, the integrated software system for GIS database update should not only be cost-effective, practical, customized and with high integration degree from the system module design aspect , but also be characterized by some distinguished features described in subchapters as below.

2.1 Integration of indoor work and field work

Relative to the disjointed indoor and field working mode, the operation mode of integration first of all should embody at the integral whole operation of indoors and field, i.e., to make a homogeneous operating environment where the data acquired indoors and outdoors can seamlessly exchange with each other. In order to make this concept applicable in practice, two aspects should be considered in system design.

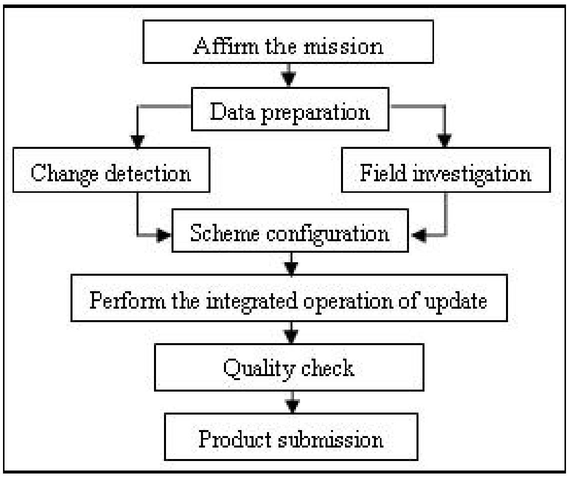

Figure 1. The update workflow with the operation mode of integration

Full digitized workflow: The software system for image-based GIS database update needs to work in the full digitized mode, which means totally abandoning the outdated analogized field validation and supplement mode. The rapid development in the field of computer engineering, modern communication science, embedded techniques and mobile GIS technologies provides many approaches to realize such an integrated operation mode. For example, the PDA (Personal Digital Assistant), as shown in Figure 2 (a), is a considerable device for field investigation in terms of its localizability, portability, outdoor manoeuvrability and data transmissibility as well as its powerful programmability. The efficient outdoor working strategy can be derived to be a replacement of the traditional by developing a PDA-carried, GPS signal detectable function module for field investigation and filling out in pure digital from. With the internal industry updated, it can be imported into PDA-based field surveying and mapping subsystem, through the GPS navigation to do the field work verification and filling out.

Applicable without need of the professional equipments: The system should also integrate the registration and editing with no need of the professional equipment; as we know, the traditional photogrammetric workstations such as Intergraph, VirtuoZo, JX4 are all unexceptionally special systems which need professional equipments e.g. hand wheels and feet wheels to support the data input; besides, these equipments are somewhat expensive and importable, which can not meet the fast data update requirements. Therefore, to put the integral whole operation of indoors and field into practice, it is really necessary to provide the more flexible working mode, that is, the designed software system should support some accessory apparatuses which are both economical and convenient to operate, giving a full consideration to the equipment portability. With the update software installed on a portable computer, as to image interpretation in stereo mode, at present, the operator just needs a 3D mouse (Figure 2 (b)) or common mouse with trolley (Figure 2 (c)) and a pair of stereo-glasses (Figure 2 (d)) to carry out the stereoscopic observation and measurement; to a certain degree, it also decreases the operating difficulty for non-professional operators, such as the traditional field workers who are unfamiliar with the operation of indoor workers.

Figure 2. (a) A typical PDA ;(b) the 3D mouse; (c) regular mouse with trolley; (d) stereo glasses and radiator

Undoubtedly, such kind of integration benefits the information exchange and sharing between image interpretation indoors and investigation in field, and thus evidently reducing the complexity and redundancy in the traditional update process. Besides, it brings much flexibility in the workflow adjustment and optimization aspect, making a transition from the traditional serial workflow to the more efficiently collateral mode. For instance, after the data integration during which pre-warning change analysis is carried out either through automatically image based change detection or field exploration, the update procedures can be flexibly adjusted and configured. Commonly, image interpretation indoors finishes most of the geospatial data collecting and editing work, which effectively releases the labour intensity in field and shortens the whole update cycle; besides, the work assigned to workers indoors and in field is no longer rigorously divided as before. In the collateral working mode, field workers are in double harness, on one hand, they work in field with PDA; on the other hand, they can timely download the field data recorded by PDA to the portable computers taken with them, and then the field data is integrated with the indoor data based on the functional modules installed on the portable computers. As a result, the process of data revision can be performed timely, which guarantees the correctness and up-to-date state of the final results. Overall, the operation mode of integration brings immense innovations to traditional serial workflow, also considered to be an effective exploration to the full digitized work tendency for field validation and supplement in future.

2.2 Integration of multi-source information

Inferred from the essence of image-based GIS database update described in the second chapter, data preparation is the prerequisite step for update which refers to the projective management and uniform process of various useful materials, primarily including the existing DLG data and multi-resolution multi-temporal image datasets, either spaceborne or airborne, either in single or in stereo; meanwhile, the multi-scale topographic map and other thematic data from relevant areas and etc are sometimes included as accessory. The purpose of data preparation is to make multi-source data more efficient and utilized for update.

Format transformation and data importation: the up-to-date spatial images, the existing DLG and other information to be used for update are in various data format. For geo-referenced images, the format can be Geotiff, Tiff or BMP; for DLG with the corresponding scale, which are stored with the separate map sheet and named according to the map sheet encoding standard, there also exist various formats such as ESRI Shapefile, Arcinfo coverage, Arcinfo e00, Geodatabase and etc; for other materials like place name database and GPS-collected road net also have specific formats. Data in different formats are inconsistent in terms of organized structure, datum and unit, so one of the most important missions for data preparation is format transformation, where DLG in various formats are uniformly transformed to the inner designed vector format of the system; besides, DOM, DRG, DEM, etc. are also integrated into the respective inner supported format, i.e. data is homogenous in format within each dataset. The designed inner formats here are compatible with the indoor working environment in which the integrated vector and raster datasets can be loaded and registered in convenience.

Block management: the image-based GIS database update not only relies on the up-to-date orthoimages for registration, collection and update, but also integrates photogrammetry with GIS for DLG、DEM、DOM and 3D Model update. With the development of various airborne and spaceborne imaging sensors, block management is also regarded as an important aspect for data preparation. Here, the fulfilment of block management mainly includes organization of the block data, generation of stereo models and seamless stereo orthoimage pair (Wang 2004) as well as orthoimage in single mode. The prepared block then is loaded to the indoor working environment, and stereoscopic observation and update can be carried out on the selected stereo models or stereo orthoimage pair.

Data registration, fusion and change analysis: it is commonly known that the image-based GIS database update is interpreting change information from various geo-referenced images, based on which the existing DLG is updated. Therefore, data registration here primarily concerns about the registration between different images, or between images and DLG. Generally speaking, there are mainly two approaches for data registration: one approach is adjusting the geo-reference information of image dataset through semi-automatic human interactions with multi-layer overlapping; the other routine is much the same as image rectification, through automatic feature extraction and matching of images and DLG, thus accomplishing the data registration process finally. Besides, spatial registration of multi-temporal or multi-sensor images is required for many applications in remote sensing, such as change detection, the construction of image mosaics, DEM generation from stereo pairs and orthorectification. Once registered, the images can be further fused or combined, in a way that improves information extraction.

2.3 Integration of scheme throughout the update process

For GIS data collection and update, it is a prerequisite work to configure a comprehensive scheme. Theoretically, a scheme is a database file which is preliminarily integrated with the indoor working environment while the update performance is carried out, actually there is no definite restricts for the type of the database. All in all, the purpose of scheme configuration is organizing various meta-information for GIS data update into an open database. In summary, the update scheme mainly constitutes the following contents: it firstly manifests the hierarchical structure of the updated data, according to the relevant industry standard; next, the scheme establishes the corresponding relationships between the exiting GIS database and the new one, such as the reference of old and new feature code, the reference of old and new attribute field, etc. In addition, the configured scheme includes the meta-information of each category, layer and feature from the perspective of database setup, update and mapping. For database setup and update, the meta-information primarily concerns about the geometry and attributes, while for cartography, it refers with the line and the filled colour, the line width, the symbol pattern, the placement angle of the point symbol, etc., which is useful for map displaying and printing out. In other words, the scheme can be regarded as a data dictionary.

As to the selection of the database type of the scheme, there are mainly two aspects in need of consideration: one is the operational flexibility and simplicity for scheme maintenance, while the other cares about the convenience of interoperability between the scheme and the indoor working environment. Commonly, one of the most considerable strategies is to organize the scheme in the form of an Access database file, a simple small database composed of several relation tables which are interrelated and linked with each other, and within such a database are all the meta-information organically contained. A visualized tool for scheme configuration is recommended to be designed and applied in practice, to make the maintenance more visible, direct, reliable and easier to handle with. Overall, the scheme configuration is an independently preliminary work due to important role of the meta-information it records. While the image-based GIS database update work is carried out, the scheme is synchronously linked and integrated to the indoor update procedures with relevant database techniques. For a designed update system, most of the procedures need the scheme to finish the operation regularly, such as (1) Creation of the graphic and attribute template of indoor working file; (2) Structure reorganization of the exiting GIS database; (3) Collection, editing of terrain and relief data; (4) Layer management in both geometry and attributes; (5) Process quality control and data check; (6) Product exportation; (7) Mapping and printout and so on.

3. CASE STUDY

Geomapupdate is an integrated software system exclusively servicing the current GIS database update business of our country and supported by National Geomatics Center of China (NGCC) and designed by the research group of State Key Laboratory of Information Engineering in Surveying Mapping and Remote Sensing (LIESMARS) Wuhan University. It is a successful case study for the practices of integrative updating concept emphasized above, which has been witnessed in the 1:50000 GIS database update business of our country recently.

3.1 System application environment

The system application environment is: (1) Hardware: common personal computer with stereo display card; (2) Stereo model observing equipment: stereoscopic glasses or red-green glasses; (3) Import equipment: common mouse with trolley or 3D mouse; (4) Operating system: Microsoft Windows 2000 or above; (5) Indoor update working environment: MicroStation V8.

3.2 System framework and realization

The image-based update is not simply a digitized process based on the reference images, which is more or less different from the pure process of data collection and editing (Ramirez 1997). It puts more emphasis on data integration and the incremental update; therefore, several key issues should be concerned in constructing the system framework. In terms of the function aggregation, the designed system is organized with six modules respectively servicing for: (1)data preparation, (2)indoor collection and update, (3)field invalidate and supplement, (4)quality control and check,(5)product export, and (6)scheme maintenance, each of which consists of many related functions; in terms of the implementation environment, the whole system is generally composed with three subsystems: (1) the data preparation subsystem, (2) the indoor update system and (3) the field investigation subsystem. They transfer, share data and information seamlessly with each other, by which the very sound capacity of function interoperability is gained for the whole system.

Data preparation subsystem: It is independently developed under the Visual C++6.0 IDE (Integrated Development Environment) with technologies of COM (Component Object Models) and other ActiveX controls, and the main user interface is as Figure 3(a). Apart from the uniformly projective management of various datasets, the subsystem also fulfils the settlement of the environmental parameters, the multi-data conformity as well as change analysis. Overall, it provides a comprehensive framework of datasets for the subsequent indoor update and field investigation.

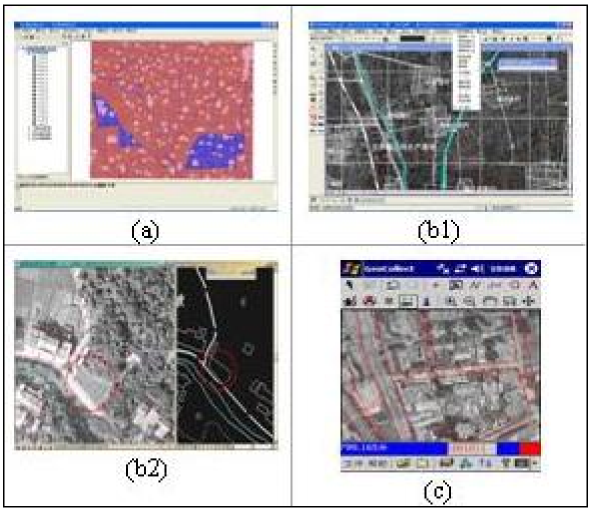

Figure 3. The main user interfaces of the three subsystems

Indoor update subsystem: it is developed based on platform of MicroStation and constitutes the core part of the entire system for update, which aggregates powerful and efficient function modules, such as the module of indoor updated data collecting and editing, the module of layer management of the working file, the module of attribute information administration, the module of quality control and check, etc. As one of the currently mainstream CAD (Computer-aided Design) software systems, Bentley Corporation's MicroStation is an innovative CAD platform used by teams of architects, engineers, contractors, and GIS professionals to integrate work on buildings, civil engineering projects and geospatial information (http://www.bentley.com/en-US/Products/MicroStation). Its powerful capabilities in aspects of drawing, symbol making, data manipulating and program developments continuously expand the application fields including GIS in recent years (Schutzberg 2003). Therefore, the indoor update subsystem is subordinately constructed on MicroStation V8 system platform. Since the function modules of the subsystem can be flexibly configured and developed with MDL (MicroStation Development Language) and VBA (Visual Basic for applications) developing tools of MicroStation V8, the developing workload and the time cycle for implementing the system have been decreased distinctly; besides, the reliability and robustness of the subsystem can be ensured to a large extent.

Field investigation subsystem: with PDA as the hardware platform, the subsystem is developed under the Embedded Visual C++ environment (WinCE3.0), and is the combination of embedded GIS, mobile communication, GPS and other advanced techniques. The main user interface is shown in the Figure 3(c).

3.3 System workflow

Generally speaking, the technical routine of the system *Geomapupdate* is mainly as follows:

Scheme configuration: with the scheme configuration tool, configure the database file of the update scheme; then generate the MicroStation DGN seed file, in other words, set up the indoor update environment, according to the configured scheme.

Multi-source information integration: this is finished with the data preparation subsystem, at first establish the project of map sheet with the corresponding scale; and then data preparation and integration work including data importation, format transformation, block management, data fusion and registration, etc. is carried out until an uniform framework of multi-source datasets is constructed; finally, link the update scheme with the current project.

Perform the indoor pre-update: in the MicroStation-based indoor update subsystem, firstly reorganize the integrated DLG data of the current project into the DGN working file, according to the linked scheme. Then pre-update the DLG data in the 2-D image-interpretation–based updating environment (Figure 3 (b1)), or alternatively in the stereoscopic measurement environment (Figure 3 (b2)).

Integration work of indoor update and field investigation, data refinement and quality check: as the expenditure of the in-field operation is relatively higher, it is uneconomical to completely finish the data refinement and quality check work in the field but after the field investigation instead.

Product generation and submission: transfer the DGN working file to the objective GIS format (such as ERSI Geodatabase) according to the production submission command.

3.4 System characteristics

In summary, the system *Geomapupdate* is characterized with the following features:

1) The system is successful in handling the CAD/GIS interoperability, where the indoor update subsystem based on MicroStation perfectly realizes the seamless integration of CAD and GIS for data collection, editing, quality control, check and data output.

2) It is flexible to customize modules for update according to specific user requirement, based on the powerful secondary developing capabilities of MicroStation, as well as techniques of Component Object Model (COM) and other ActiveX controls.

3) It is a portable, applicable and cheap system to carry out the integrative mode of indoor work and the field work, from both the hardware design and the software design aspects.

4) The system integrates modules for photogrammetric data process with GIS for DLG、DEM、DOM and 3D Model collection and update, able to meet the various requirements of data collection and update as soon as possible.

5) The system accomplishes data collection and update with the process unit of map sheet, which is propitious to keep the data integrate and decrease the map joining complexity of the adjacent models thus improving the update efficiency.

4. CONCLUSIONS

This paper studied on the design aspect of the efficient software system for GIS database update based on geospatial images, where the operation mode of integration was definitely emphasized. As a specific software system for national 1:50000 GIS database update based on geospatial images, *Geomapupdate* is introduced as a study case in this paper with detail. It is an integrated platform for GIS database update, achieving the integration of indoor and field work, the integration of data collection and editing, the integration of quality control and quality check, and the integration of database setup, update and mapping. It has improved the operational efficiency by 20% with such kind of integration in collaboration with the integrated stereo registration and editing method provided by full digital stereo photo mapping system. Overall, it is a successful study case laying a base to achieve rapid updating GIS data.

However, some issues are still required to be solved or further improved for the current updating software system to achieve a much more efficient operability, such as how to automatically or semi-automatically detect and extract the change information from the multi-temporal remote sensing images with less human interaction, how to manage the multi-version incrementally updated data more regularly, etc. In the future, the system will be developed and perfected towards an automation and intelligence direction by further exploration.

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REFERENCES

Bouziani, M., K.Goïta, D.C.He, 2007. Change detection of buildings in urban environment from high spatial resolution satellite images using existing cartographic data and prior knowledge. *Geoscience and Remote Sensing Symposium,* 2007. pp.2581-2584.

Chen, J., Z.L.Li, J.Jiang, Z.R.Zhao, 2004. *Key issues of continuous updating of geo-spatial databases*. Geomatics World, 2(5), pp.1-5

Dekker, R.J., 2004. Object-based updating of land-use maps of urban areas using satellite remote sensing, *Proceeding of the 12th International Conference on Geoinformatics*, University of Gävle, Sweden, pp.13-19.

Dowman, I., 1998. Automated Procedures for Integration of Satellite Images and Map Data for Change Detection: The Archgel Project. *International Archives of Photogrammetry and Remote Sensing on GIS-between Visions and Applications*, 322 B4[C], pp. 527-532.

Fritsch, D., 1999. GIS Data Revision-visions and Reality. Keynote Speech in Joint ISPRS Commission Work shop on Dynamic and Multi-dimensional GIS. Beijing: NGCC.

Gunst, M. E., J. E. Hartog, 1994. Knowledge-Based Updating of Maps by Interpretation of Aerial Images. *Pattern Recognition Vol.1-Conference A: Proceedings of the 12th IAPR International Conference on Computer Vision & Image Processing*, pp.811-814.

Holland, D. A., D. S. Boyd, P. Marshall, 2006. Updating topographic mapping in Great Britain using imagery from high-resolution satellite sensors. *ISPRS Journal of Photogrammetry & Remote Sensing*, (60), pp.212-223.

Jiang, J, J. Chen, 2000, Some Consideration for Update of Fundamental Geo-information Database. *Bulletin of Surveying and Mapping*, No.5, pp.1-3.

Knudsen, T., B. P. Olsen, 2003. Automated change detection for
updates of digital map databases, P*hotogrammetric Engineering &Remote Sensing* 69(11), pp. 1289–1296.

Ramirez,J.R., 1997. Revision of Geographic Datasets: Development and Implementation of a New Solution. *GIS/LIS '97 Annual Conference and Exposition Proceedings*, Cincinnati, Ohio, October 1997, pp. 65-75.

Schutzberg,A., 2003. "CAD/GIS Integration-modern technology merges the best of both worlds". http://www.geoplace.com/gw/1998/0698/698mrtch.asp (accessed 28 Sept. 2007)

Speren, A., 1996. Digital Updates at the Dutch Topographic Service. *International Archives of Photogrammetry and Remote Sensing*: XXXI[C],pp.891-900.

Wang, M., 2004. A New Approach for Generating a Measurable Seamless Stereo Model Based on Mosaic Orthoimage and Stereomate. *XXth ISPRS Congress*, 12-23 July Istanbul, Turkey Commission 3.