

EXPERIENCES WITH THE WILD SYSTEM9-AP AND ITS STEREO IMAGE INJECTION SYSTEM

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Abstract

The Institute of Photogrammetry and the Institute of Microinformatics of the Swiss Federal Institute of Technology of Lausanne (EPFL, Switzerland) have developed, in collaboration with Wild Heerbrugg Company, a graphical injection system for photogrammetric plotting. The system is conceived as a peripheral device coupled to the Wild System9-AP, the new Wild analytical plotter, and working according to GKS standard extended to 3D. The main innovations of this system are **full editing** and **stereo superimposition** in order to allow full geometric control. This article gives an overview of the S9-AP and its injection system, and describes our first experiences under operational conditions.

Sommaire

Les laboratoires de Photogrammétrie et de Microinformatique de l'Ecole Polytechnique Fédérale de Lausanne (EPFL, Suisse) ont développé, en collaboration avec la Maison Wild Heerbrugg, un système d'injection d'image pour la restitution photogrammétrique. Ce système, conçu comme un périphérique travaillant sur la base du standard graphique GKS étendu à 3D, a été intégré au nouveau restituteur analytique Wild System9-AP. Par rapport aux systèmes concurrents, ce système de superposition d'image offre une **injection stéréoscopique** de la carte digitalisée dans le restituteur et la **possibilité d'éditer** interactivement ces données. Cet article donne un aperçu général sur le système d'injection d'image ainsi que le S9-AP, puis décrit la mise en œuvre pratique de cette station de restitution et les premières expériences réalisées.

Zusammenfassung

Das Institut für Photogrammetrie und das Institut für Mikroinformatik der Eidgenössischen Technischen Hochschule Lausanne (EPFL, Schweiz) haben, in Zusammenarbeit mit der Firma Wild Heerbrugg, ein interaktives graphisches Einspiegelungssystem für die photogrammetrische Auswertung entwickelt. Dieses System arbeitet mit auf 3D erweiterdem GKS-Standard und ist als eine Peripherie zu der neuen analytischen Auswertestation Wild System9-AP konzipiert. Es bietet, im Vergleich zu herkömmlichen Systemen, eine **Stereoeinspiegelung** der digitalisierten Objekte in das photogrammetrische Modell und die Möglichkeit zur **interaktiven Editierung** der vorhandenen Daten. Vorliegender Artikel gibt einen allgemeinen Überblick über die Auswertestation S9-AP und das Bildeinspiegelungssystem, und beschreibt im folgenden die Inbetriebnahme der Station und erste Erfahrung in der Praxis.

1 INTRODUCTION

Parallel to the development of Geographic Information Systems (GIS), photogrammetric data acquisition has fundamentally changed during the last years. While in the past the main purpose of photogrammetric plotting was to produce graphical output in the form of maps or plans, today's requirements demand a numerical product integrated in a Geographic Information System. Although the graphic output is still an important option in this new kind of data handling, it will lose its deterministic role. Furthermore, the user of spatial information will no longer be satisfied with a single graphic product, but will rather ask for product independent databases, being usable for performing different applications and representations. The development of a completely new generation of instruments and of new photogrammetric plotting techniques resulted from these new requirements.

The instrument industry has developed during the last years a new generation of photogrammetric stereoplotters which satisfy these new requirements to a great extent. An important aspect of this new generation of instruments consists in the communication between an interactive graphical workstation, the database management system, the photogrammetric workstation and the operator. The Institute of Photogrammetry has contributed substantially to this development by the conception of a stereo superimposition system, a project which was realized in close collaboration with the Institute of Microinformatics and the Wild-Company.

Parallel to this development, Wild has conceived its System9™ and the S9-AP photogrammetric workstation which is fully integrated in the global concept of this system. The System9 family consists of four different workstations performing several tasks of data acquisition and data management :

- System9-E : Editing station
- System9-D : Digitizing station
- System9-AP : Analytical plotter station for photogrammetric data acquisition and editing
- System9-S : File Server station

The central part of these stations consists of an interactive Sun-3™ graphic workstation and the Empress™ relational database management system (see [CHA87]). Several System9 workstations can be interconnected in a local area network.

The Institute of Photogrammetry disposes for about one year of the new S9-AP analytical plotter, and in the meantime a user-friendly software was available. This allowed us to acquire first practical experiences under rather operational conditions.

This paper presents a first report on the experiences made with the new S9-AP analytical plotter; the stereo superimposition system, as the direct contribution of the Institute of Photogrammetry, will be its main subject. The first part consists of a technical description of the superimposition system and analyzes both its performance and architecture. The second part gives first a description of the System9-AP functionality, before showing how to initialize the workstation and analyzing the first practical experiences. In this way it becomes evident that the transition from a classical analytical plotting system to a photogrammetric workstation integrated in Geographical Information System causes thorough modifications. Only by assuming these modifications can the user take advantage of the new particularities offered by this new generation of instruments.

2 GENERAL ARCHITECTURE OF THE SYSTEM9-AP

The System9-AP photogrammetric workstation is based on a multiprocessor design and consists of **three main parts** interacting with each other : the main computer, the stereoplotter and the optional stereo-superimposition system. Figure 1 illustrates this general architecture.

The System9 **main computer** is a Sun-3 workstation, based on the Motorola™ 68020 μ processor (32 bits, 16 MHz); its main memory and disk storage may be delivered in various sizes. Standard delivery includes a 1152 x 900 pixels color graphics screen, a keyboard, a mouse and a 60 MB cartridge-tape drive. Available options are floating point accelerator, graphic coprocessor, Ethernet™ local area network interface, etc... The main-computer role is to support the Wild System9 GIS software and other applications. For the S9-AP and S9-D stations, Wild has developed a special input device called CIS (Command Input Screen) : a touch-sensitive screen for entry of commands by finger selection from graphic menus.

The measuring unit of the **stereoplotter** takes up elements from its predecessors, the Wild Aviolyt™ AC1 and BC1/BC2 analytical plotters. The driving system of the picture carriers is separated from the measuring system which uses glass scales; the resulting precision should be in the order of 1-2 microns. Other main components of the stereoplotter are : high-resolution optics (completely redesigned for stereo superimposition) with a differential zoom system for continuous change of magnification between 6 and 25 times, different sizes of color luminous dot-shaped (25, 35 and 50 μ m) or ring-shaped (diam. int/ext 100/120 μ m) measuring marks. Picture carriers, in the format of 254 x 254 mm, are controlled by an independent Real-Time Processor (RTP) based on the 16 bits Intel™ 80286

μprocessor (with its 80287 floating point coprocessor and a 80188 servo-controller). The operator can move within the model with X-Y handwheels and Z footdisk at 3 different speed ratios, or move quickly using fast motion switches. So as to measure profiles, he has at disposal an additional profiling-speed control «throttle». A coordinate display and a measuring mark indicator (where the current position is shown by a light-spot on a paper copy of the right-hand photograph) are also available. Other components are : special knob for Y-parallax elimination, double function recording footswitch (start/record and stop) and an additional snap/connect footswitch. A X-Y freehand guidance device is optional.

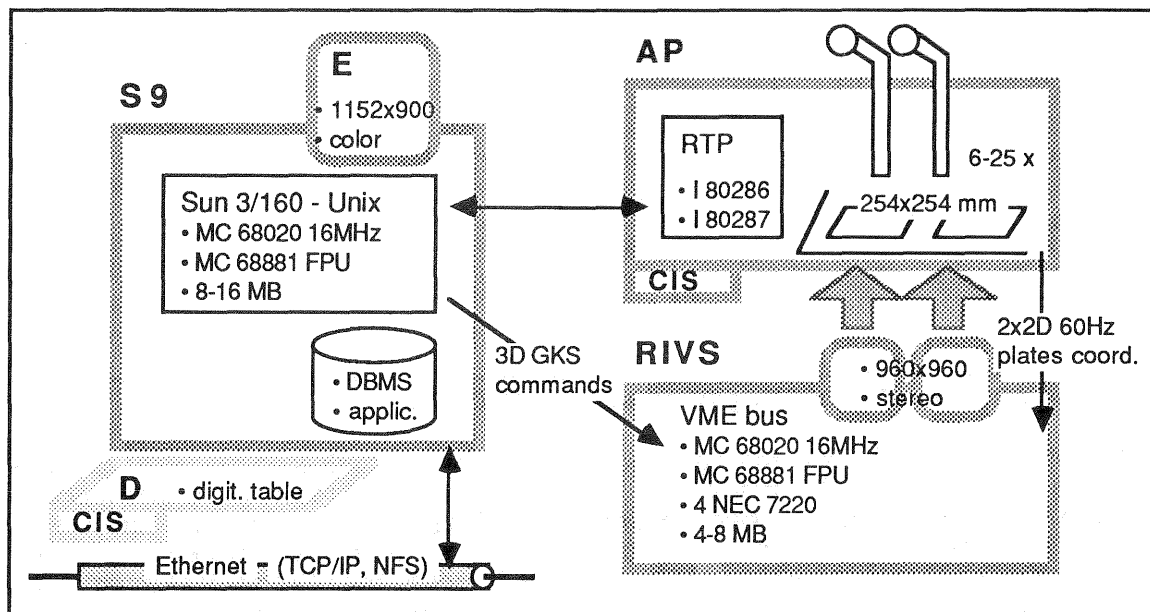


Figure 1: Multiprocessor architecture of the System9-AP workstation including the RIVS stereo-superimposition option. A minimal System9 configuration consists of a S9-E (Editing station) made up of a Sun computer and its graphic monitor. Adding a digitizing table would result in a S9-D (Digitizing station), or adding a stereoviewer, a S9-AP workstation (Analytical Plotter) having its own Real-Time Processor (RTP). All these stations can be interconnected together by an Ethernet local area network and share data under NFS™ and TCP/IP protocols.

The **stereo-superimposition system** can be considered as a «verification system» which explains its name RIVS : Raster Injection Verification Subsystem. It consists of two high resolution monochrome raster monitors (100 x 100 mm for 1'024 x 1'024 pixels), optical components for the injection of screen images into the stereoplotter optical system, and the RIVS real-time processor. This system is based on the 32 bits 16 MHz Motorola 68020 μprocessor, its 68881 floating point coprocessor and 4 NEC™ 7220 graphic controllers. The standard memory, 4 MB, is sufficient for handling photogrammetric models up to 200'000 vectors. The superimposition system comes as an option to the System9-AP.

3 RASTER INJECTION VERIFICATION SYSTEM - RIVS

The superimposition system RIVS allows the operator of the analytical plotter to observe simultaneously the photogrammetric model and the line map of the captured data projected on both photographs (see Figure 2). This enables the operator not only to check the **completeness** of the work in progress and of the geometric content of the System9 database, but also the **precision in planimetry and altimetry**. Therefore, elements recorded or edited during the data-capture loop are shown without any delay on RIVS. Furthermore, data acquisition and editing are facilitated by special highlighting and rubberbanding capabilities.

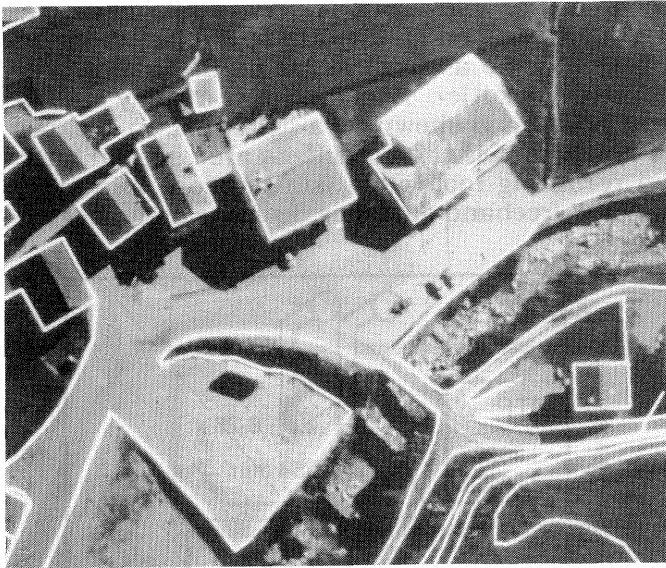


Figure 2: Illustration of the superimposition principle by a photograph taken through one of the S9-AP oculars.

3.1 Principle of a stereoscopic image injection

As for the observation of a stereoscopic model where two homologous photographs are needed, the stereoscopic observation of vector information requires a perspective deformation of these vectors on **two screens** according to the perspective projection equations of the corresponding aerial photographs. Then, so as to superimpose the vectors on the stereo-model, the two screen images have to be **injected into the optical path** of the analytical plotter as illustrated on Figure 3. In order to assure that the content of the screens and of the photographs will closely coincide, screen images have also to be brought in perfect position in relation to the picture carrier motions. Consequently, the original orthogonal map content to be superimposed has to undergo the two following transformations : **projective transformation** of the database objects from 3D space into 2D photo plans (requiring Z-information for all object points) and **real-time translations** of the screen images in order to follow measuring mark movements (respectively X-Y picture carriers translations).

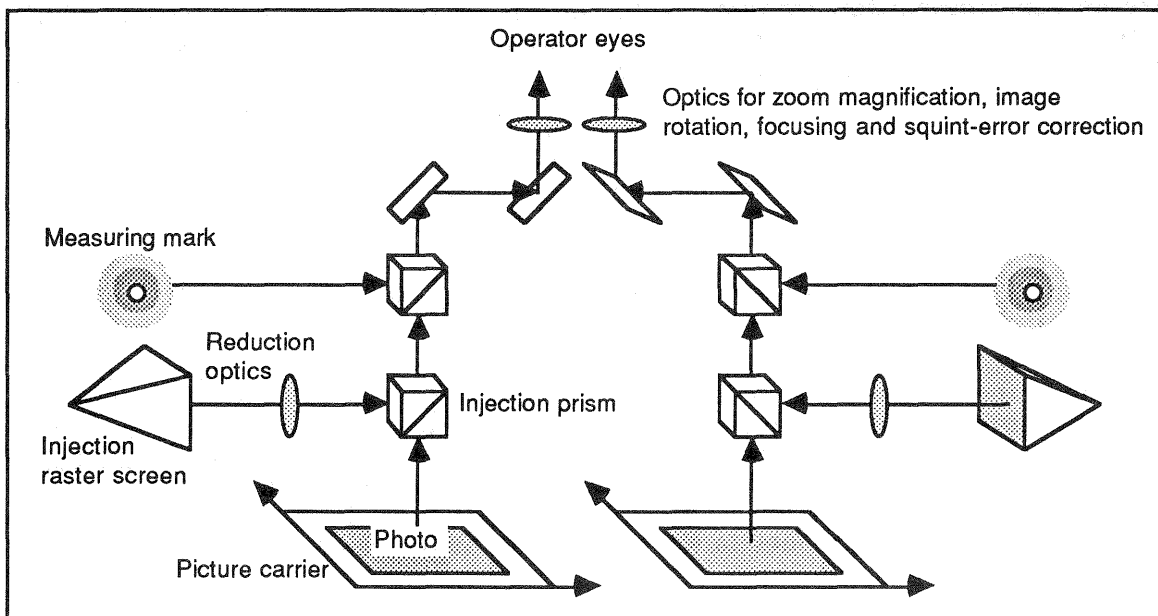


Figure 3: Principle of the stereo superimposition optics of an analytical plotter. For stability reasons, screen injection is made, on the S9-AP, near the picture carrier (thus before the zoom optics) rather than on the ocular level.

3.2 Performance requirements

The concept of an image injection system has to take into consideration the performance of the stereoplotter optical system and the quality of aerial photographs. Assuming that for data acquisition a standard optical enlargement of 15x is used, which gives a field of view of about 10 mm, and that actual image quality is in the order of 30 lines/mm, we have about 300 line pairs for the 10 mm field of view. So, choosing a raster screen of about 1'000 x 1'000 pixels injected on the field of view, the resulted **resolution** is :

$1 \text{ pixel on injection screen} = 10 \mu \text{ on photo} = 1/3 \text{ line pair}$

This relation between screen and field of view on the photos also defines the apparent line width as seen in the oculars and the precision of their location. Lines shown on the screen with 1 pixel width should then be on the limit of perceptibility when seen through the oculars. Such fine lines can however be obtained only when screen light intensity is strongly reduced because at normal intensity pixels are smeared out and have a line width of nearly 3 pixels. But an advantage of stereo superimposition lies in that very fine injected lines can still be well detected whereas monocular image injection requires much heavier lines and more brightness.

Furthermore, to provide possibilities to change the enlargement from the screen to the photographs in order to take into consideration eventual variations of the magnification factor, the injection optics of the S9-AP allow to choose two discrete values, 10 and 5 times, for **screen image reduction**. Resulting resolutions are 10 μ and 20 μ . It should give optimal conditions for superimposition by working with a zoom system of 6-25 times.

3.3 Architecture and functionality of RIVS

The described reduction rate between screen and photographs leads to a **model** size of about **23'000 x 23'000 pixels** for photographs of 230 x 230 mm. But currently available hardware (memory chips integration) has allowed us to design maximal **2'048 x 2'048 pixels** wide **physical bitmaps** for the left and right image. How is it then possible to move in real-time through the whole photogrammetric model ? Our bitmaps are conceived as cache-images of the model, and the whole selected graphic database content is locally stored in RIVS in a **vector form** (more compact than raster form). We have then developed a new graphic architecture which is specially designed to offer a very fast vector to raster conversion performance and panning capabilities (see [BEE86] and [BEE87]). Of each bitmap, an area of **960 x 960 pixels** is displayed on the injection raster **screens** and refreshed at a 60 Hz non interlaced cycle. To follow the picture carrier motions, the screens are able to perform pixelwise shifts within physical bitmaps (smooth **scroll**) at the 60 Hz refresh rate.

As the photogrammetric model is much larger than the physical size of the bitmap, we have defined the concept of a **virtual bitmap**. Figure 4 illustrates these 3 different image levels : screen, bitmap and model. Depending on screen shifts, updating of the bitmap content for subsequent display takes place for still invisible portions of the bitmap. For this purpose, data to be displayed (2D display lists) are organized in **256 x 256 pixels facets** according to their geometric location. The physical bitmap is updated by regenerating those facets which are likely to be displayed in the next moment. When the screen viewport is «going out» of the physical bitmap, the bitmap is considered as a cylinder closed in horizontal and vertical directions, and the screen will then come back on the opposite side of the bitmap. The bitmap refreshing procedure is then conceived to guarantee the image continuity of the virtual image displayed on the screen.

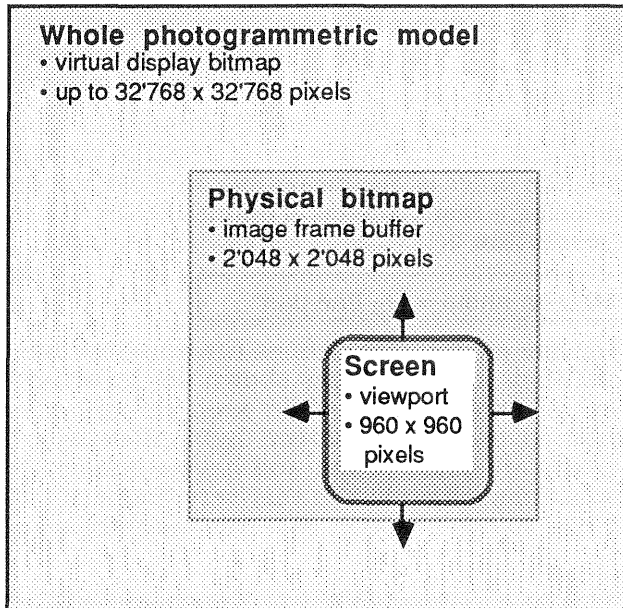


Figure 4: Illustration of the 3 different image levels: the whole photogrammetric model (vectors projected according to the photo geometry and managed as a virtual display bitmap), the physical bitmap (raster graphic memory) and the screen (corresponding to the section of the model currently observed through the ocular). The hardware permits pixelwise and real-time (60 Hz) shifts of the screen within the physical bitmap (scroll), and a mechanism of updating the bitmap graphic information by facets allows the screen to move through the whole photogrammetric model. This concept is duplicated for the left and right superimposition screens.

The **architecture** of the injection system is based on the industry standard VME-bus and consists of 5 boards (see Figure 5) :

- the **CPU** board runs all the injection system firmware (down-loaded from the System9 at startup time) : 3D objects handling from System9, coordinates projection according to the orientation parameters of the photos, clipping and insertion of the projected vectors into the left and right 2D display-lists, sending display commands to the graphic controllers, reading 60 times per second the current location of the picture carriers and sending the corresponding image shift commands to the graphic controllers
- the **I/O** board has serial and parallel lines for communication with the System9 computer and for real-time acquisition of the AP picture carrier displacements
- the **RAM** board is used to store the 3D vector-list and the two facets-structured 2D display-lists (capacity of up to 200'000 vectors for 4MB RAM)
- the **two** left and right intelligent **graphic controllers** each contain memory for the 2'048 x 2'048 pixels bitmap and two graphic processors for simultaneous vector to raster conversion and screen refresh

The graphical **GKS standard** has been adopted for the communication between the System9 and RIVS, and has been extended for handling 3D objects and real-time operations. The logical graphic data structure of RIVS is based on graphic **primitives** like polylines and polymarkers, and on **segments** (collection of primitives). Thus, data editing is possible at the segment level : a segment can be picked up, visualized, highlighted or eliminated in real-time.

The storage mode in vector form makes the system sensible to the effective number of vectors which must be treated within a photogrammetric model. Various estimations have shown that a map section corresponding to a photogrammetric model might include 50'000 to 200'000 vectors. Generally, such numbers are reached when curved lines or contour lines are plotted. The requirements for the **synchronization** of the two screens are of special importance for stereoscopic image injection, as delays between left and right image could quickly create X and Y parallaxes and thus disturb the observation of the injected image or create errors in altitude.

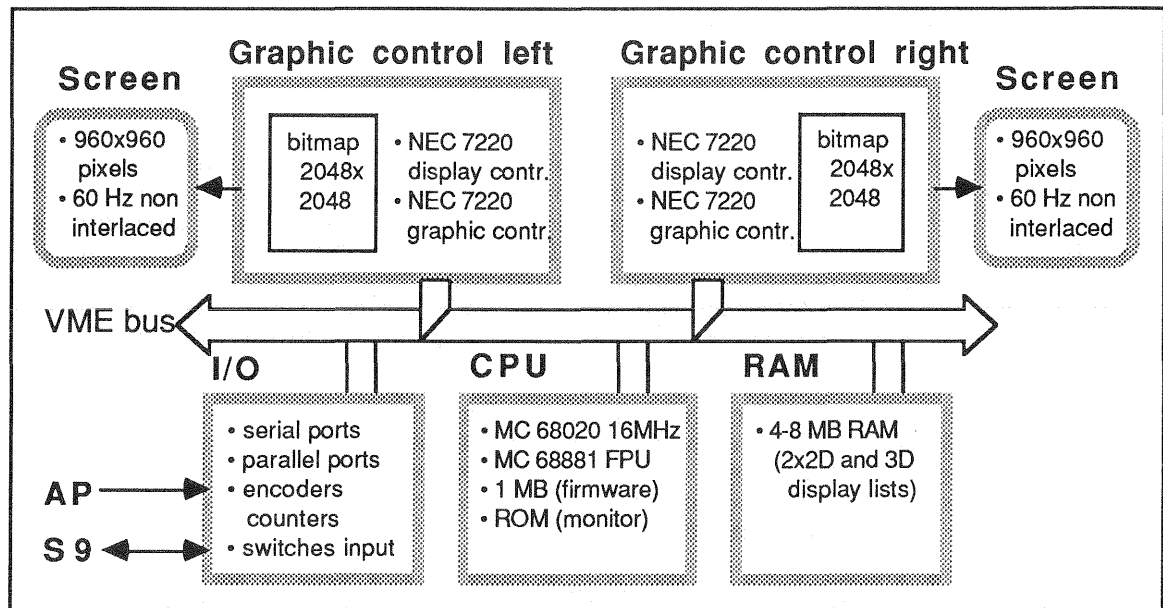


Figure 5: General architecture of **RIVS** (**R**aster **I**njection **V**erification **S**ubsystem). The system is based on a multiprocessor architecture around the VME bus. The main components are: the **CPU** board driving the system, the two **graphic** boards (including bitmap memory) and their associated left and right **screens**, a **RAM** board for local storage of the display lists, and an **input/output** board for communication with the System9 and the AP.

4 FUNCTIONALITY OF THE SYSTEM9-AP

The photogrammetric workstation System9-AP is not only a digital mapping system which allows the user to digitize points and lines. It is primarily designed as a 3D digitizing and editing device fully integrated in the global System9 concept (see [SCH87]). Moreover the S9-AP also supports all other photogrammetric applications like data capture for DTM or aerial triangulation, and the set-up of the photogrammetric model. The standard S9 software-package used on all workstations provides the following functionality:

- **project management** to define and maintain the feature classes, their attributes and the relations between different feature classes. A feature class is a logical group of objects of one topologic type and with the same structure of attributes, such as houses or roads. The topologic type can be from node, line, surface, spaghetti or TIN (triangle for DTM)
- **graphic transforms** to define the relations between the geometric data and their graphic representation
- **display functions** to open and close graphical windows on the screen, to select feature classes and attributes for the display, to zoom in and out within the partition and to pan across the partition display
- **data capture functions** for the digitizing of features and complex features. **Geometrical functions** like rectangularisation of polygons, parallel line functions and tangential connections are available for this purpose. Already stored primitives can be used as **shared primitives** in order to define new features
- **topologic checks** to verify if the captured data are conform with the topologic requirements of the feature class definition, e.g. surfaces must be closed
- **attribute handling** to enter, indicate, check and modify attributes during the photogrammetric restitution

- **COGO-functions** to allow the definition of geometric primitives and features by coordinate based computations
- **editing functions** to correct, delete and replicate any primitive, feature or complex feature (logical group of feature classes)

All data recorded on the S9-AP workstation are stored in the System9 database and can be therefore processed by every other S9-station. On the other side, data collected with every other S9-station, field survey data or information transferred with **Data Interchange Modules (DIM's)**, can be used directly on the AP. DIM's are available at the moment for the Intergraph SIF (Standard Interchange Format), the Ferranti System, the Wild GeoMAP and BC1/BC2 systems, the english MOS-package, the Ordnance Survey format, and the Wild CIP digital terrain model. For other systems, Wild offers a library of input/output routines giving the user the possibility to write his own interface for his special purpose.

All S9-AP applications utilize the System9 **user interface**, which is based on the multiprocessing (UNIX™) and multiwindowing (Suntools) of the Sun workstation. Interaction with the system is based on menus; different applications, functions and parameters can be selected with the cursor and the mouse, with the CIS touch sensitive screen, or by means of an alphanumeric terminal.

5 IMPLEMENTATION OF THE SYSTEM9-AP AND FIRST EXPERIENCES

Until today, photogrammetry's main purpose was to produce graphical output in the form of maps. The recent development of analytical plotters using digital mapping techniques did only optimize the quality and performance of these graphical outputs. But today the introduction of Geographic Information Systems (GIS) in photogrammetric data acquisition offers more flexible, powerful and complete solutions with quite more possibilities (see [HEG86]). But in this way, also the preparation, the management and the organization of those restitutions change. By the means of a few test-projects we have made some experiences about these changes.

5.1 Database creation

From now on, data are no more stored in a map or in a simple file, but in a database which represents geometrical information and non-graphical elements (attributes) from our environment. So, the first step must be the creation of this database which is achieved in the case of System9, with the aid of the application-package **project management**. By the means of this package, we define our **project** by its spatial extent (x_{min} , y_{min} , x_{max} , y_{max}), by the **feature classes** included in the project, by their **topologic types**, by their **attributes** and by the relations between feature classes. In the project management, we create and initialize all the project-databases and logical structures without presence of any data.

The project definition should not only be usable for the restitution of a set of photogrammetric models or even a single model, but should rather satisfy all actual and further requirements of the enduser of the information stored in a global modern Geographic Information System. For this reason, except in the case of special restitutions, the project definition must not only take into account the needs of photogrammetric restitutions or of only one enduser, but also all other information required by other users at the moment and, as far as possible, in the future. Of course modifications of an existing project are always possible, but so as to keep the data homogeneous it should be considered as an exception. It is possible to create new feature classes or to add attributes; otherwise what would happen if a feature class already containing data had to be changed fundamentally because it did not respond to all requirements? For this reason, all the different experiences and knowledge of operators, endusers of data, responsible persons and project managers should be considered during the project definition.

In Lausanne, because of the above reason, we first have worked on several representative test projects. On the basis of the experience collected with them, we are now working at the creation of a project applicable to the whole of Switzerland and containing several System9 themes which are usable for different purposes like classic topographic plotting, mapping for land register and so on (see Figure 6). A System9 **theme** contains a logical group of selected feature classes and attributes defined in the project; one feature class can be

the definition of several themes. In the themes definition, we have also integrated the directives for the further coming REMO (REnovation de la Mensuration Officielle) concerning the creation of a multi-purpose land information system in Switzerland.

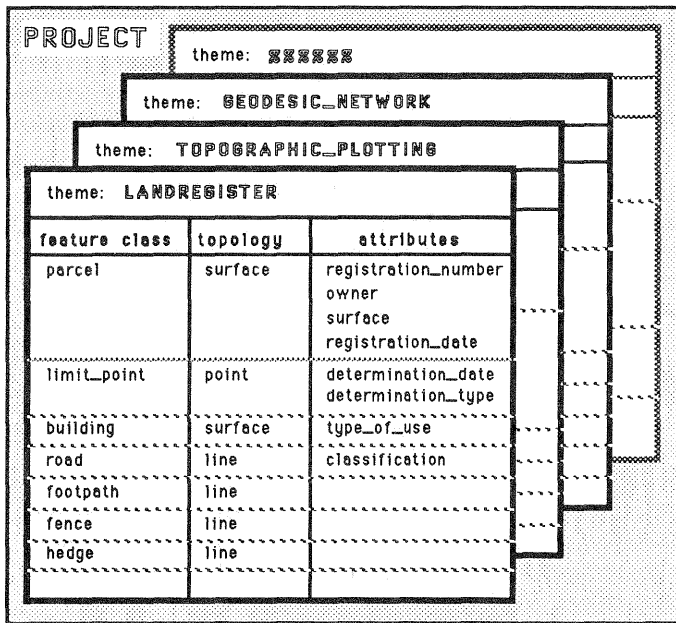


Figure 6: A System9 project contains several different themes defined by logical groups of feature classes and attributes taken from the project definition. In determining the contents of themes, it is recommended to define one theme for each application.

The real working area of the restitution has to be defined in the **partition management**, an application of the project management, as a physical and logical **partition** of the whole project. A set of one or more themes is to select, and the spatial extent of this working part (x_{min} , y_{min} , x_{max} , y_{max}), which can contain several photogrammetric models, is to specify (see Figure 7). After this definition, the partition has to be **checked out** from the project, that means that a partition database will be created and the working data will be extracted from the project database. From one project, several independent partitions can be checked out for data capture and editing at the same time. But it is not possible to work with the same datasets simultaneously on several partitions, because the datasets of all checked out information are locked in the project database. When the work is completed in one partition, the current partition database has to be **checked into** the project.

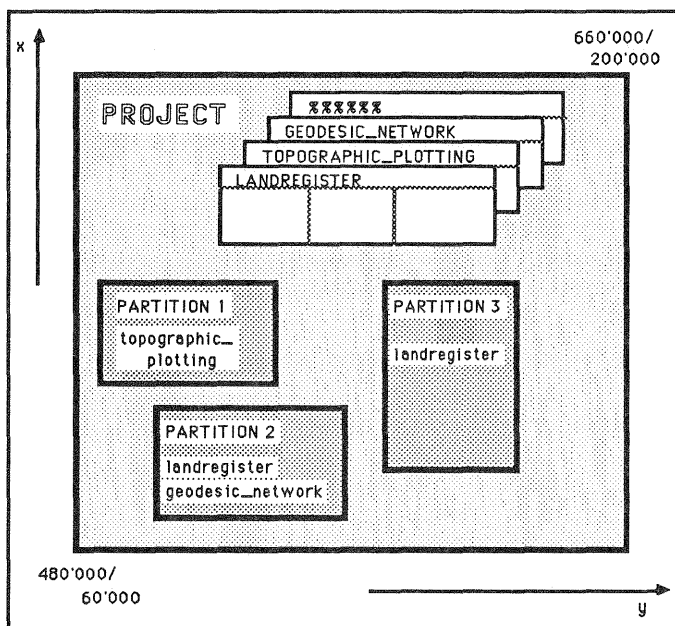


Figure 7: A System9 partition is a working copy of the project database. It is defined by its spatial extent and a set of one or more themes selected from the project. This subset of the information contained in a project is extracted into partitions by the checkout function. From one project several independent partitions can be checked out at the same time.

The graphical representation of objects and elements must be defined in the **graphic transform**, where we have to specify in details how the features and attributes have to be displayed. This representation is stored separately from the database and is only attached to a theme. This offers the possibility to create, for one theme, several graphic transforms related to different requirements and scales. Concerning graphical outputs in form of maps, other representations than for the output on the screen can be foreseen. Herewith System9 offers the user a solution to the problems of having very often different drawing instructions for one type of objects from different customers, and of being generally unable to represent information in different scales with the same kind of graphic representation and with the same content.

Working with such a system like S9 which offers lots of possibilities makes the separation between **operator** tasks and **project-manager** tasks unavoidable. The third independent task on the S9 is the **system-management**, but it can be assumed in practice by the person in charge together with the project-management. Once a project is defined for the most of applications and requirements, the main tasks of the project-manager will be, in partition-management, the selection of suitable graphic transforms and the allocation of **access-rights** for the different users.

5.2 Setting up of the photogrammetric model

The software which performs the photogrammetric model set-up, the **photogrammetric procedures**, is fully integrated into the S9-AP basic functions. It allows the user to carry out the calibration of the stereoplotter, to manage the control points and to establish a photogrammetric model by executing the inner and outer orientations. To protect the consistency of the whole S9 database, all photogrammetric data on the AP are also managed by a database system, the **photogrammetric database** (see [EXL87]). The practical advantage of this solution, in comparison with other stereoplotters, is that all photogrammetric information with a common structure is stored for one project in one table. This gives the user more flexibility, he has no file sizes restrictions, no problem with points numbering, and book-keeping of the control-points has become an easy task this way.

For the operator establishing a stereomodel, a helpful facility is offered by the **graphic user interface** based on the Sun multiwindowing system. During the whole orientation, the current position of the measuring mark is displayed on the screen : during the inner orientation in relation to the image coordinate system, and during the outer orientation together with a graphical overview of the control-points.

5.3 Data Capture and Editing

The Data Capture and Edit (DCE) package of the System9 is provided for interactive spatial data acquisition and manipulation of already existing object-information. Selected sets of feature classes can be displayed at the same time on several graphic windows, and superimposed by RIVS on the stereomodel. Captured lines and points are displayed in real-time on the screen as well as in the two oculars of the stereoplotter. They can be immediately integrated in the database and modified by using the editing functions. This ability to use the whole S9 functionality during the photogrammetric data acquisition offers a lot of new possibilities for photogrammetry; but while working with several test projects, we were also confronted with new requirements concerning the organization of those restitutions.

Generally, a session for photogrammetric data collection on the S9-AP consists of the four following phases :

- a) initialization
- b) collection loop
- c) feature assembly
- d) data editing

During the **initialization**, we make use of the **display functions** to select feature classes from the partition, to open and close graphical windows and to view selected areas of the partition. The operator first has to select the feature classes to be displayed in an overview window and on RIVS. After this selection, he can create additional views by selecting subareas of the overview and setting feature classes to be displayed in these subwindows. He

can also zoom in and zoom out all these views and pan across the partition. Using all these functionalities, an operator has to be very careful to only select absolutely required information for his restitution and to make an appropriate selection for the display in the different views. Otherwise he might have quite too much information on his screen or in the stereomodel and could only be heavily disturbed. But respecting this advise, he will make good use of all the display management facilities. He can observe at once on the screen an overview of the partition, a smaller working area and a detailed view of an object (see Figure 8). During the data capture the content of all the windows and of RIVS is actualized in real-time. This is a considerable help for the restitution and, above all, for the editing of complex objects, like for example old built-up areas in centers of villages or towns.

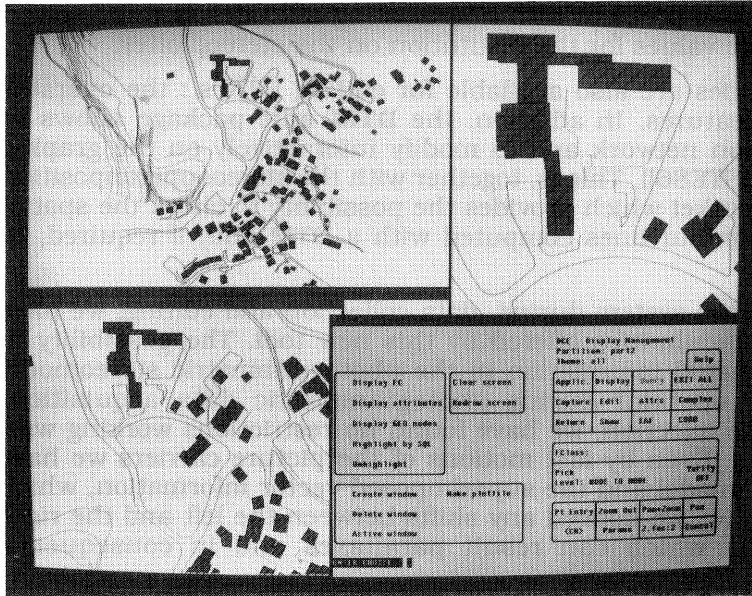


Figure 8: With the means of the display functions, an operator can view up to 3 different windows and select different feature classes being displayed on the screen. On the figure one can recognize an overview of the partition, a working area, a detailed view of an object and, in the lower right corner, the display functions main menu.

The **collection loop** starts with the selection of the feature class to be recorded and the specification of the parameters controlling the data acquisition. Then the operator sets the stereoplotter measuring mark on a required point and presses a footswitch or a button of the freehand guidance device to record this point. For the geometrical definition of an object, the operator can also use primitives already stored in the database as **shared primitives** by selecting them with the cursor or the measuring mark. Therefore, he has not to digitize one primitive twice or even several times. During the restitution the operator can continuously regulate the brightness of objects injected by RIVS from zero up to maximum value; the brightness of injected objects should not be too high in relation to the pictures. For contouring, it can be, according to our experience, suitable to measure without real-time superimposition and to inject the lines only at the end of the data capture, in order to check their completeness and spatial precision, maybe to modify them or to put annotations.

In the **feature assembly** following the collection loop, the primitives will be ordered and the features will be created according to the feature class definition. Each feature created during the feature assembly is displayed, and attributes may now be requested. The topology will be checked and errors will be marked in real-time on the screen and on RIVS with symbols, the Error Attention Flags (EAF's). For example, if buildings are defined as surfaces, all the buildings not closed will be flagged with EAF's. The operator can now correct immediately all these errors, or store the EAF's together with the objects in the database. Whether the photogrammetric operator should execute this correction or not depends on the complexity of the task, on the project definition, on the equipment and on the merit of the available personnel.

For errors correction, the operator makes use of **data editing** functions which support the modification of features or primitives. Those editing capabilities must exist in a geometric information system. Errors made during data collection must be corrected, some kind of information must be interpreted by taking other sources and added later; one must also keep in mind that geographic information evolves and must be updated. The data editing facility offered by the S9-AP together with RIVS is a unique possibility for updating this geographic information. Up to now, this information was stored in maps and, as an example taken from the land register in Switzerland, in a lot of cases was neither up to date nor complete. Now with the System9 family, we have the possibility to digitize the old maps on a S9-D station and to integrate the whole information in a database-system. Then the old situation can be injected in the S9-AP, compared with the new photo-information and in this way updated in the database. The problem with non-existing altitudes is to be solved with the introduction of approximate values for the restitution on the stereoplottter.

All standard System9 editing facilities are also available for editing DTM's : the operator may add, modify or delete input features. In addition, the **DTM edit** package allows to optimize the calculated triangulation network and to modify interactively on the graphic screen the computed contours (see [STE86]). This is, together with the stereosuperimposition of the S9-AP, the only tool on the market which provides the possibility to check the spatial precision and the correctness of contour lines computed with a DTM and, if required, to modify sections of these contours.

Working with the RIVS image injection system during data collection and editing, we have been very satisfied by the new particularities offered by this new tool. The possibility to check immediately the collected spatial information in the photogrammetric stereomodel is a very helpful facility for the operator during photogrammetric data acquisition. Concerning the quality of the image injection, we have found no restrictions working with huge models up to 100'000 vectors. Even by fast motions of the picture carriers we have found no delays between the stereomodel and the superimposed vector information, which can disturb the operator. Neither have we noticed any shifts between the left and the right superimposed vector images from which can result parallaxes and in consequence altimetric errors.

6 CONCLUSIONS

The concept of the System9-AP has been largely confirmed by our experiences on this instrument. A powerful superimposition system is required when connecting a photogrammetric stereoplottter to a modern Geographic Information System. By this means, the operator has the possibility to control efficiently the various operations of data acquisition; a better quality of the captured information is resulting and the operator is no more losing time by consulting external graphic devices (drawing table or workstation screen...).

The stereo superimposition system with high resolution raster screens has proved its efficiency. The practical work showed that also the spatial precision can be controlled efficiently by this device. It was however of great importance to design a high performance architecture in order to assure that the injected information coincides completely with the photographs during the scanning operations. The operator has thus the impression that the vector information stands completely still with respect to the photograph when moving the floating mark.

A high processing speed is also necessary to show without any delay the injected elements on the superimposition device during the data acquisition. A delay would slow down the work because the operator might be tempted to adapt his working speed to the performance of the injection system. On the whole, experiments with the new superimposition system have been very positive, but further tests will be necessary to acquire more practice.

Furthermore, integration of an analytical stereoplottter in a Geographic Information System offers new functionality unused until today which will extend the field of activities of the photogrammetry and increase the quality of the captured data. In this way, project management aspects are also of special importance for photogrammetric data acquisition, and a well defined project is necessary to improve all the new facilities offered by a GIS.

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