CONTEXT AND INTEGRATION OF PHOTOGRAMMETRIC PRODUCTION LINES

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Abstract:
Integration of photogrammetric components into larger entities is considered in a broader context and with emphasis on information structures and communication. The context pertains to issues such as the wide-area GIS networks, the state of the art, and the information production environment. It addresses the relationships between the quality of information and the economics of its production, the determinant factors for structuring information and data, and the definition of the production lines. Integration implies collective optimization of the production lines. Hereby the structure of the knowledge base and of the image base, and the local area communication are most significant. The production means, which can be analogue, analytical or digital, should reflect the requirements emerging from the integrated production lines.

Introduction

This paper addresses the context of present and anticipated integrated photogrammetric systems and some basic aspects of the integration itself. The context establishes a frame of reference for the integration. Significant contextual factors include the wide-area network of geo information systems, the interrelationships between performance of information and corresponding production economics, the classification models for structuring information and data, and the realm of the photogrammetric production lines.

The integration process implies optimization of the overall production system. It concerns: hardware and software; information and data; procedures for operation, support and quality control; and communication. Most of these constituents of integration are strongly interrelated. The predominant factor in integration is optimization of the production lines. The structures of information and data and the local-area communication are thereby most influencial.

Photogrammetric production lines can imply analogue, analytical or digital techniques, and they can be optimized both individually and collectively in a given production environment.

The basic pre-requisites for integration are:
- Knowledge of the context of the system to be integrated and of the relationships between the system and its context (broad professional insight);
- Comprehensive knowledge of the system components and techniques that will be involved, and understanding of their interactions (expert knowledge);
- Acquaintance with the methods of integration (information systems engineering);

- Realistic projections of the system's capabilities and its compatibility with the future environment (professional vision).
- Familiarity with the problem solving models in the users' domains.

The concept of integration addresses different levels of a system hierarchy: the sub-system (or component) level, the individual production line level, the collective production lines level, and the broad (external) system level. Successful integration provides higher performance and reliability, lower production cost, balance between automatic and interactive operations, better quality control and faster responsiveness to the users' needs.

As the title of this paper implies, we are concerned with both context and integration of production lines.

II. Context

1) General

Despite the considerable effort towards more clarity, the realm of system integration appears still to be fuzzy and disordered. An essential pre-requisite for an orderly approach to integration is knowledge of the context of the anticipated system. There are some significant contextual factors that emerge from different, virtually unrelated perspectives. These include:

- The multi-user, multi-level (hierarchical wide-area) distributed networks, with photogrammetric systems included;
- The relationships between performance and production economics;
- The classification model(s) for structuring information and data;
- The environment of the photogrammetric production lines.

In the following, consideration is given to each of these factors.

2) Multi-user, multi-level distributed network

Photogrammetric systems or components are involved in three hierarchical levels:

- Broad (geo) information system level;
- Photogrammetric integrated system level;
- Photogrammetric sub-system (or component) level.

The lower levels are embedded in the higher levels. The sub-system level will be bypassed here; the corresponding information can be found in photogrammetric textbooks.

a) Broad information systems

A country-wide distributed network of geo information centers can be represented by a matrix of the users' categories against the hierarchical levels of the geographic-administrative regions (figure 1).

The crosses in figure 1 indicate individual information (sub-)systems participating in the hierarchical multi-user network. Several sub-systems can share common objectives, information and data, software, and expensive hardware components.

- Each hierarchical level in figure 1 (i.e., a horizontal section) represents a matrix of the users' categories versus the specific areas of geo information application (figure 2).

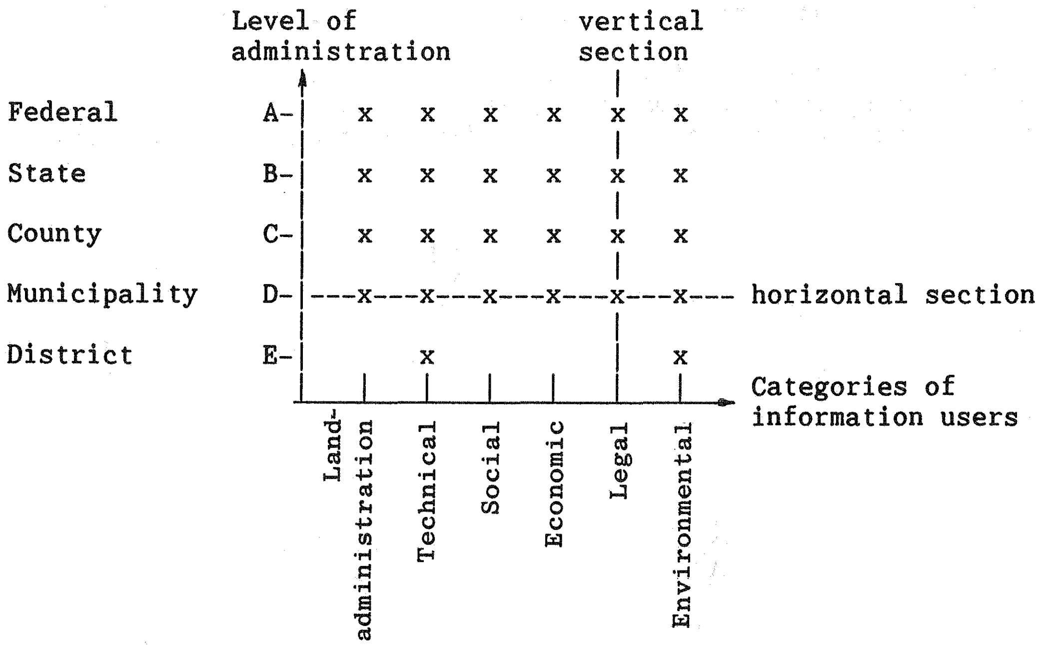

Fig. 1: Categories of users versus administrative levels

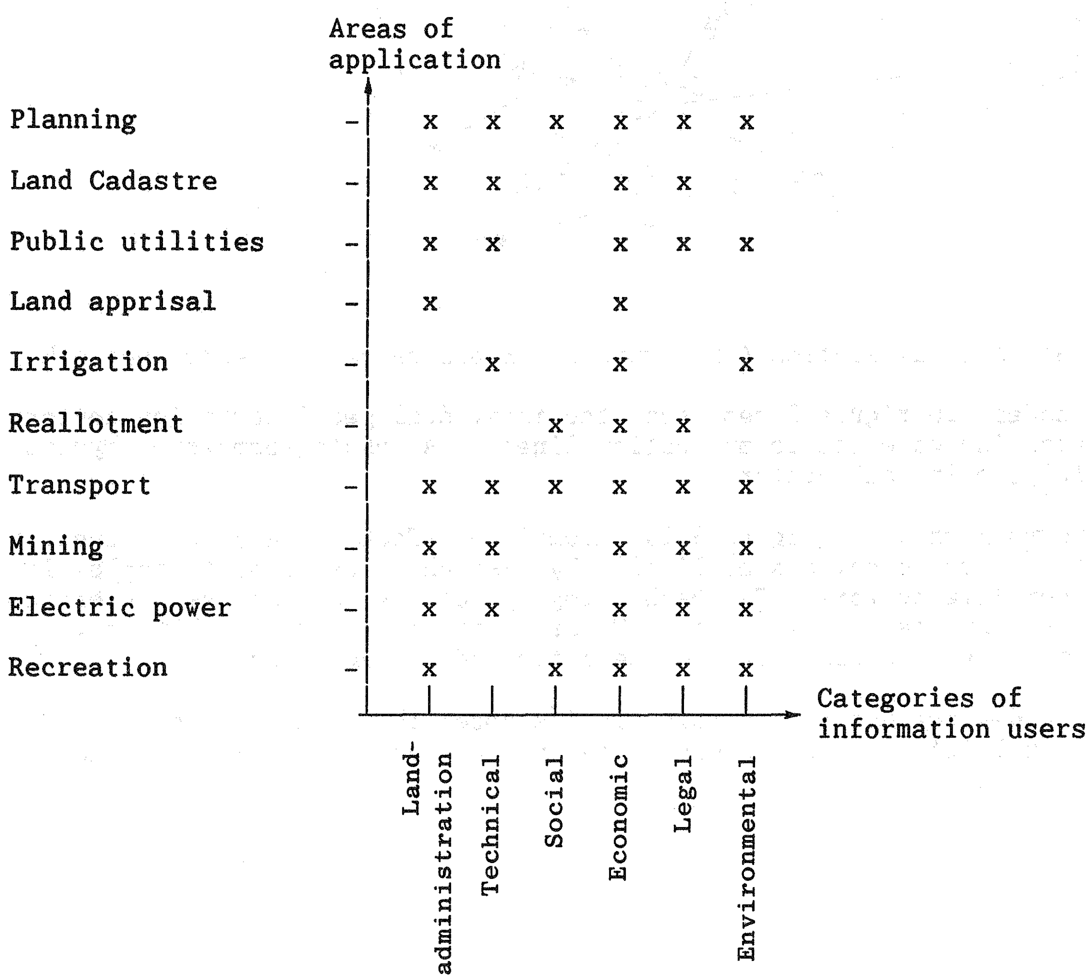

Fig. 2: Horizontal section: Users' categories versus applications

Both lists, users'categories and applications, are open ended and liable to change.
Each <u>vertical section</u> in figure 1 represents a country-wide domain of a specific user category participating in two or more hierarchical levels. The corresponding wide-area network is configured accordingly (figure 3).

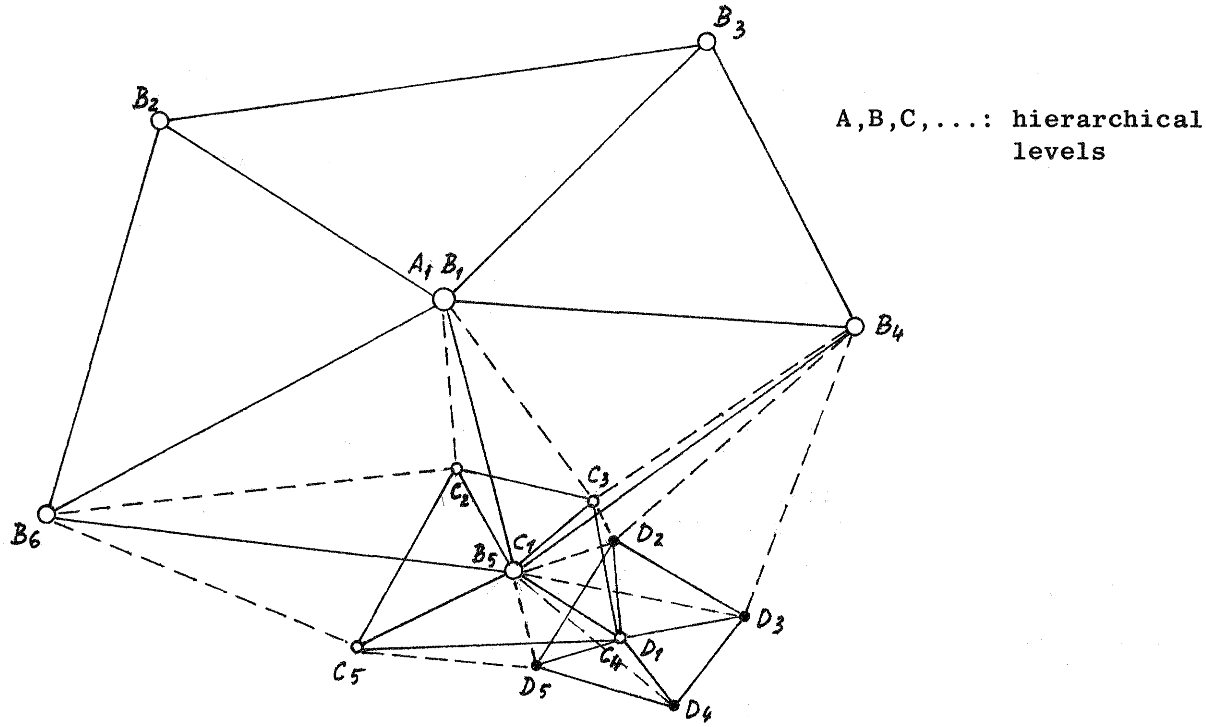

Fig. 3: Vertical section (in figure 1): Hierarchical wide-area network

The nodes in figure 3 represent the individual geo information centers and the arcs indicate the communication lines. A photogrammetric system can participate in each center.

The network shown in figure 3 is incomplete. Each hierarchical level (A, B, C,..) is represented symbolically by just one cluster of triangles instead of a complete network. For each category of users, another hierarchical network can be constructed. These different networks, however, overlap considerably, and can therefore be optimized collectively.

Each wide-area network contains in its nodes the local-area networks of the individual information centers. The internal and external networks should be compatible.

b) Photogrammetric systems
Integration implies optimization, which includes the interfacing and compatibility of the components involved. Special consideration should also be given to the structures, balance between interactive and automatic operations, and to the engineering of the photogrammetric production lines.

- Structures concern the hardware and software, and the information and data. These structures are interdependent and should therefore be optimized collectively (figure 4).

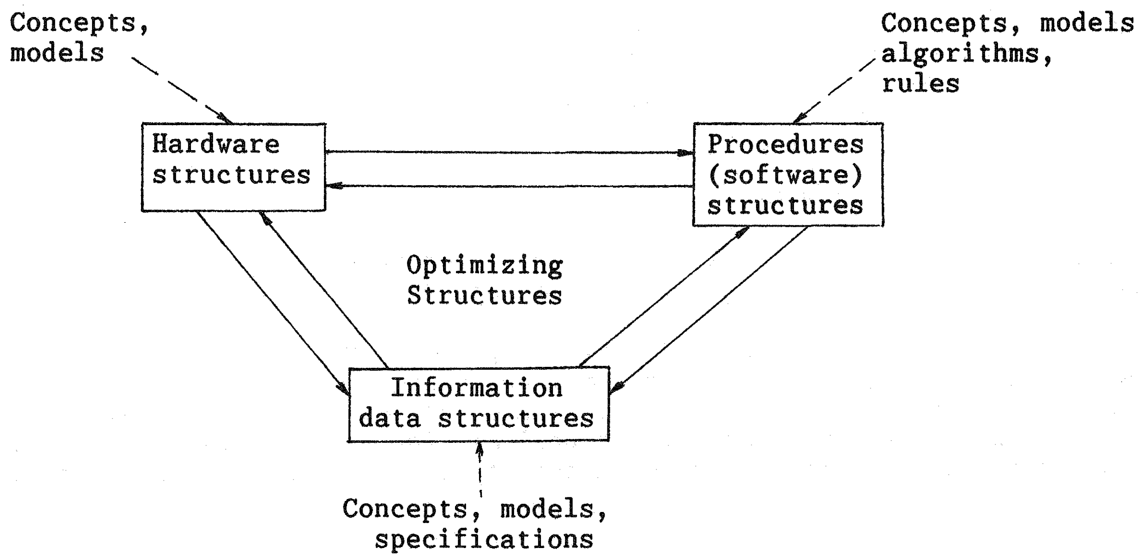

Fig. 4: Interdependent structures

The advance in information technology has also effected the structures, e.g., new developments of hardware may call for alterations of the software and/or in the information structures.

The structures and their interaction should be intelligible, possibly even simple, and transparent. To provide flexibility for change, a differentiation seems useful between the variable and invariable (or slowly changing) parts of each structure.

The balance between the interactive and automatic techniques should reflect the state of the art. The fast-changing information technology, however, tends continuously to destabilise this balance.

Automation concerns digital and analogue components and their interfaces (figure 5).

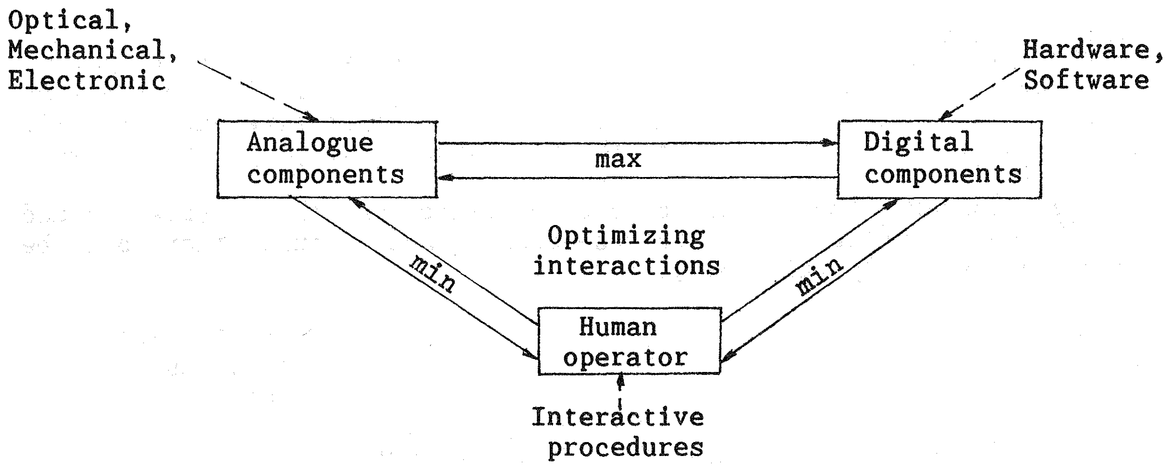

Fig. 5: Interfaces in a system

The human interface with digital and analogue components should be devised and tuned with care, by giving consideration to all significant ergonomic factors.

A proper definition of photogrammetric production lines is essential for successful integration. First, the individual lines need to be identified and delimited. Then the structure and flows of information and data must be defined for each line individually, as well as for all lines collectively. The optimization of the production lines is discussed in section III of this paper.

3) Performance versus production economics
Performance and economic considerations have a dominant impact in system integration. An optimal system provides a balance between performance and economy. Performance pertains to semantic and geometric domains. These two performances form, in conjunction with production economics, the optimization triangle shown in figure 6.

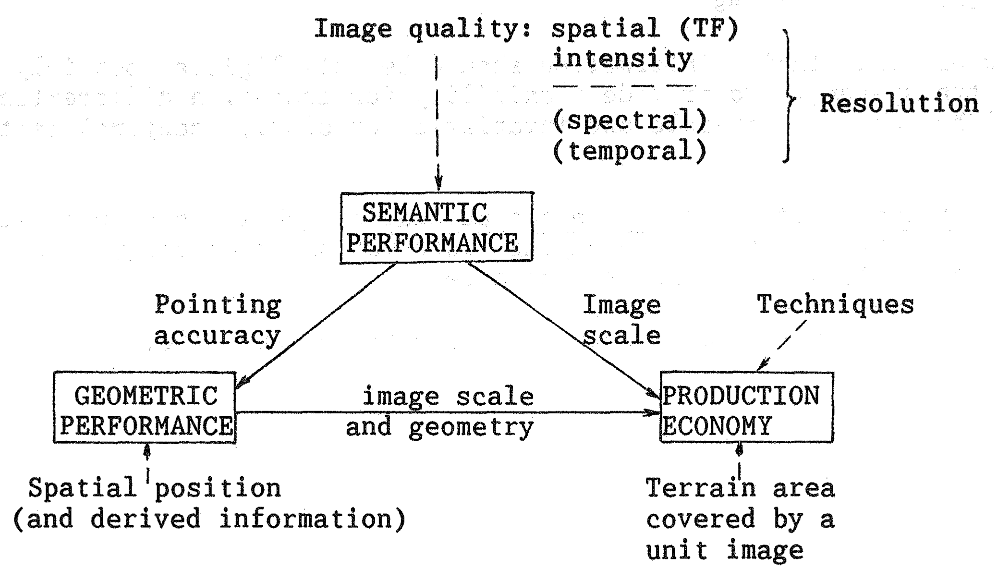

Fig. 6: Optimization triangle

The optimum state is attained when the image quality is maximum, the geometric accuracy meets the specification (for the required information product) and the terrain area covered by a unit image (e.g., a frame) is maximum. If one or more of these conditions are not met, the production engineering is not satisfactory.
Examples of sub-optimal imaging systems are listed in table 1.

Image	Spatial resolution (in terrain)	Geometric accuracy	Terrain area covered by unit image	Limitation
Satellite	low/medium	low/medium	super-large	low semantic content
Panoramic (air)	medium/high	low	large/medium	poor/medium geometry
Small format (air)	high	medium	small	economics

Table 1: Examples of sub-optimal images

4) Classification models for knowledge base
Knowledge and images to be represented in a data base need to be structured for both operation and communication in an integrated system environment. To this end, suitable classification models are required for the knowledge base (figure 7).

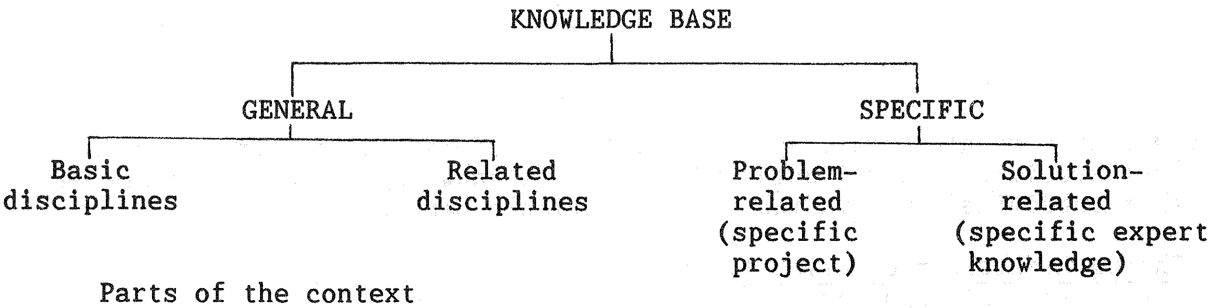

Fig. 7: Classification model for knowledge

The knowledge base is composed of general knowledge and the domain-specific knowledge; each of these is further differentiated.
- General knowledge concerns the basic disciplines, providing input for system integration, and related disciplines, using similar techniques as the system under consideration. General knowledge is a part of the broader context.
- Domain-specific knowledge comprises two parts, one is problem-related and the other is solution-related. Problem-related knowledge addresses the input and output of the (information production) project or program under consideration (figure 8). It contains the basic information.

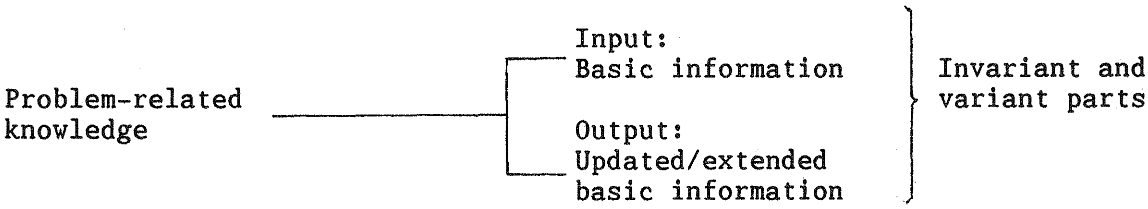

Fig. 8: Classification model for problem-related knowledge

To attain flexibility for implementing changes and upgrading, the problem-related knowledge can be differentiated according to the variable and invariable parts.

The solution-related knowledge is domain-specific and it comprises control data. It can be classified according to input, output and procedures; the latter providing the link between input and output (figure 9). Procedures imply the overall strategies, specific algorithms and rules.

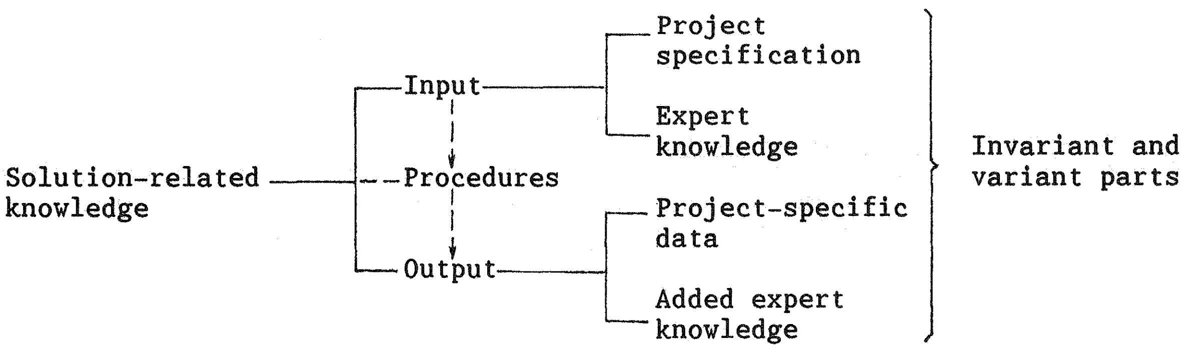

Fig. 9: Model for solution-related knowledge

The solution-related knowledge is further differentiated according to the project-specific control data and the expert knowledge. Each of these can be further subdivided into variable and invariable parts.

5) <u>Photogrammetric production lines</u>

Photogrammetric production pertains to four lines:

- control network densification: cn (usually by aerial triangulation)
- terrain relief modelling : rm (by DTM, contour lines, etc.)
- image transformations : it (rectification, orhtophoto, etc.)
- terrain feature modelling : fm (2 or 3 dimensional; other than relief).

In a production environment, these lines are arranged sequentially. They are mutually related by the structures and flows of information and data, and the specifications. All lines can operate in parallel, and can provide full or differential products.

Additional production lines can supplement the above four, such as for engineering design and construction, industrial application, etc. These, however, are not representative of extensive geo-data bases, and will therefore be bypassed here.

III. Integration of production lines

1) General

A pre-requisite of integration is compatibility of the components and their interfacing. The core of integration is, however, the structures and communication of information and data. Optimal structures and communication increase production rates and quality of products, and simplify the required support. Integration has enhanced impact in differential production, where new and old information and data are merged. Examples are updating or upgrading an existing data base, or creating a specific thematic data base.
The information and data structures and their communication are strongly interdependent. The structures of input and output, and of intermediate products, address the knowledge base and the image base. The knowledge base comprises the basic information, specified by users, and the control data needed for execution of the required process(es). Each of these is differentiated further according to semantic and geometric domains.
The image base contains only the basic information and the communication links to the corresponding control data in the knowledge base (figure 10a, b).

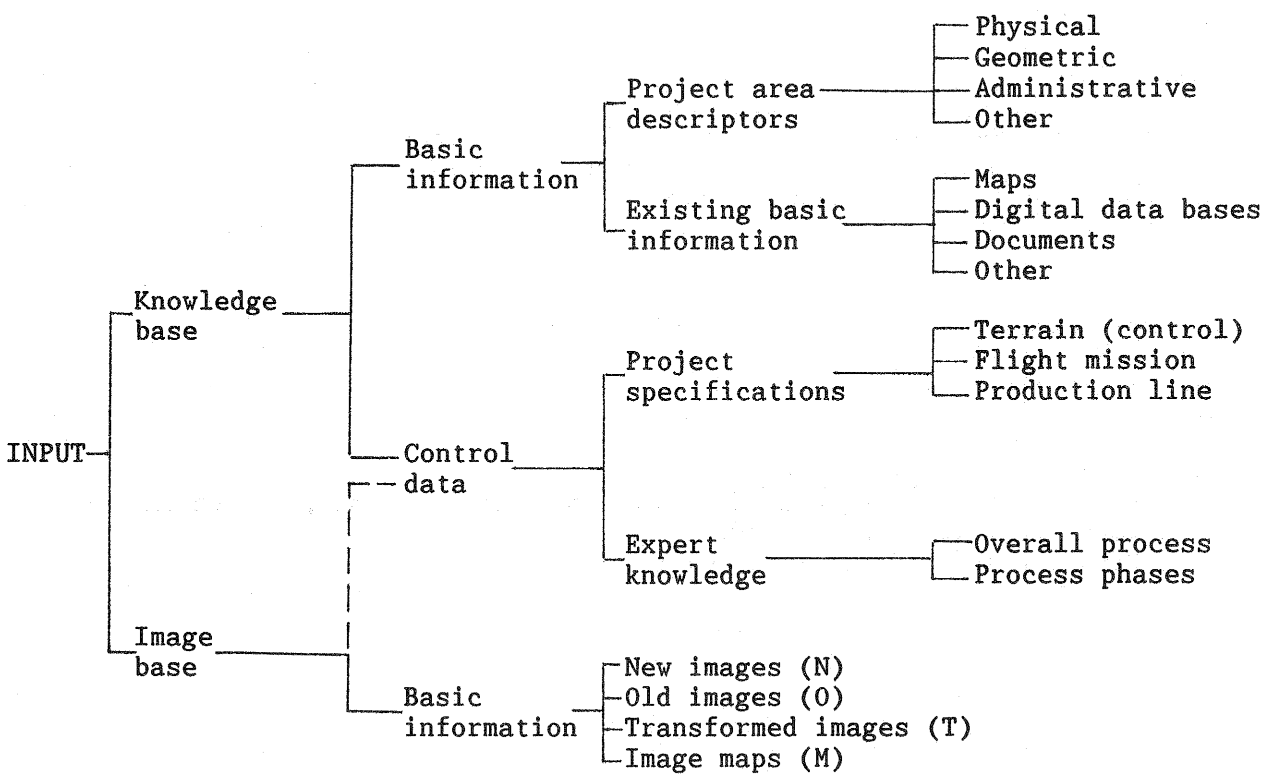

Fig. 10a: Input model

2) Input structure

The knowledge base contains basic information and control data (figure 10a). The basic information includes the descriptors of the project (or program) under consideration, descriptors of the project area (physical, geometric, administrative), and the existing geo information (maps, digital data base, other documents). The control data contain the project specifications pertaining to terrain, survey mission and production lines, and the specific expert knowledge. The image base contains new and old (raw) images, transformed images, and image maps (annotated). The image base can be represented in analogue and or digital form.

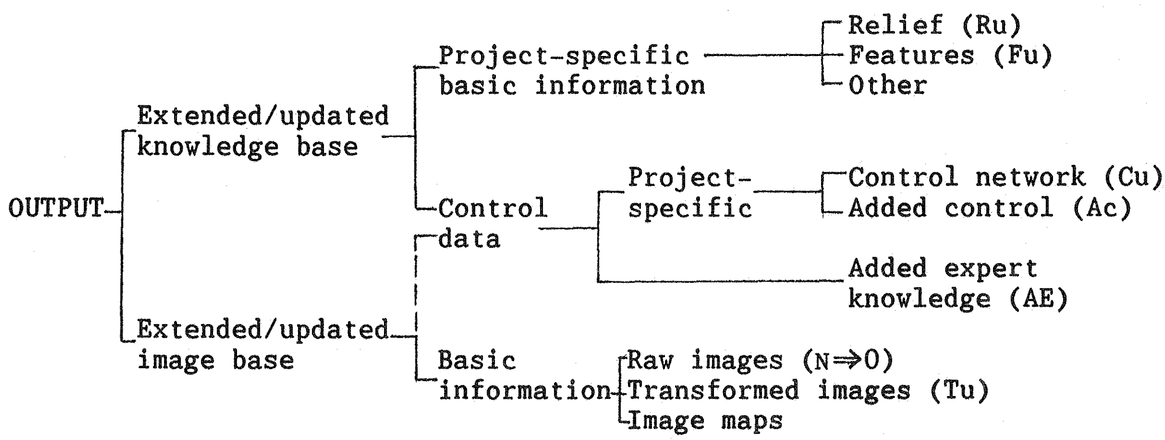

Fig. 10b: Output model

3) Output structure
The output can be an extended, updated or upgraded knowledge base and/or image base (figure 10b). Their further structure is as that of the input. The resulting new (and changed) basic information is project-specific; it is entered in the corresponding part of the knowledge base. The corresponding control data include the project-specific data (e.g., extended control network) and the added specific expert knowledge (gained in the course of the project execution). The output image base is structured as the input image base.

In input and output, the control data address the project-specific data and the specific expert domains. The project-specific data comprise three main sub-sets: The descriptors of terrain, the survey flight mission data, and the control data for production lines. Each of these can be further differentiated:

a) Terrain descriptors and data:
- Administrative: regional division, geographic names, intended use of land, restrictions on land, etc.
- Economic and social: land value, land use, etc.
- Physical and environmental: relief, cover, climate, pollution, etc.
- Geometric: location, boundaries; shape, size, orientation, etc.
- Ground control: type, class, quality measures, etc.

b) Flight mission descriptors and data:
- Planning: flight path, height; lay-out of frames; mission time; performance specifications, etc.
- Image sensor system: camera-lens, film-filter, motion compensation, exposure time, etc.
- Auxiliary devices: GPS, CCNS, IS; quality measures, etc.

c) Production descriptors and data pertain to the individual production lines and to their main stages in the context of the project. The main stages are pre-, main-, and post- process, with the corresponding quality control. Typical control data are values of the constants and parameters, ranges of parameters and variables, thresholds, etc.

The specific expert domains pertain to the four main production lines, cn, tm, it, and fm. In each of these domains, the control data concern the overall process (a production line as a whole) and the individual process stages or operations involved. The main process stages are preparation, extraction and sampling, editing, conditioning, quality control, and integration of new (or changed) information and data into the existing knowledge base and image base. Interactive (man-machine) operations take place in all stages.

The overall process control concerns, among other things, the control strategy, concepts, models, procedures, software, formats, code, storage, communication, etc. The control of individual process stages and operations addresses the same items, though adapted to each individual stage and operation. If significant expert knowledge is gained in the course of production, the "added kowledge" should be integrated in the corresponding part of the knowledge base.

4) Communication in integrated system environment
Communication between the production means and the knowledge and image base is bidirectional. The communication and structures of information and data are interdependent, and should therefore be optimized jointly.
Figure 11 shows the communication in an integrated system environment. The flows of information and data are simplified, and the production processes are indicated by black boxes. Fluent communication is attained by arranging the production lines in an optimal sequence. Collective optimization of the lines is essential for effectiveness of the overall production system. In a sequential arrangement of the lines, however, optimization of each line individually contributes also to the optimization of the integrated system as a whole.
Hence, in the following attention is given to communication in individual production lines.

Legend (for figure 11)
Input: Raw images: N-new, O-old.
Processed images: T-transformed, M-image maps.
Control data C: Cc- for cn, Cr-for rm, Ct-for it, Cf for fm.
Terrain relief information R; Rc-relief data for control.
Terrain features information: F: Fc-features for control, Fo-old features, Fd-distinct features.
Processes:
cn - control network densification process; Ccu-integration of Cn and AEc into C.
rm - terrain relief modelling process; Ru-integration of Rm into R; Cru-integration of AEr and ACr into C; Tru - or Mru - overlay of Rm on T or M.
it - image transformation process; Tu-integration of Ti in T; Ctu-integration of AEt and ACt into C.
fm - feautures modelling process; Fu-integration of Fm into F; Mfu-overlay of Fm on T or M; Cfu-integration of AEt and ACf into C.
Output:
Cn- control network; Rm-relief model; Ti-transformed images; Fm modelled terrain features (other than relief).
Byproducts:
AEc, AEr, AEt, AEf - added expert knowledge gained in each production line;
ACc, ACr, ACt, ACf - added control data gained in each production line.

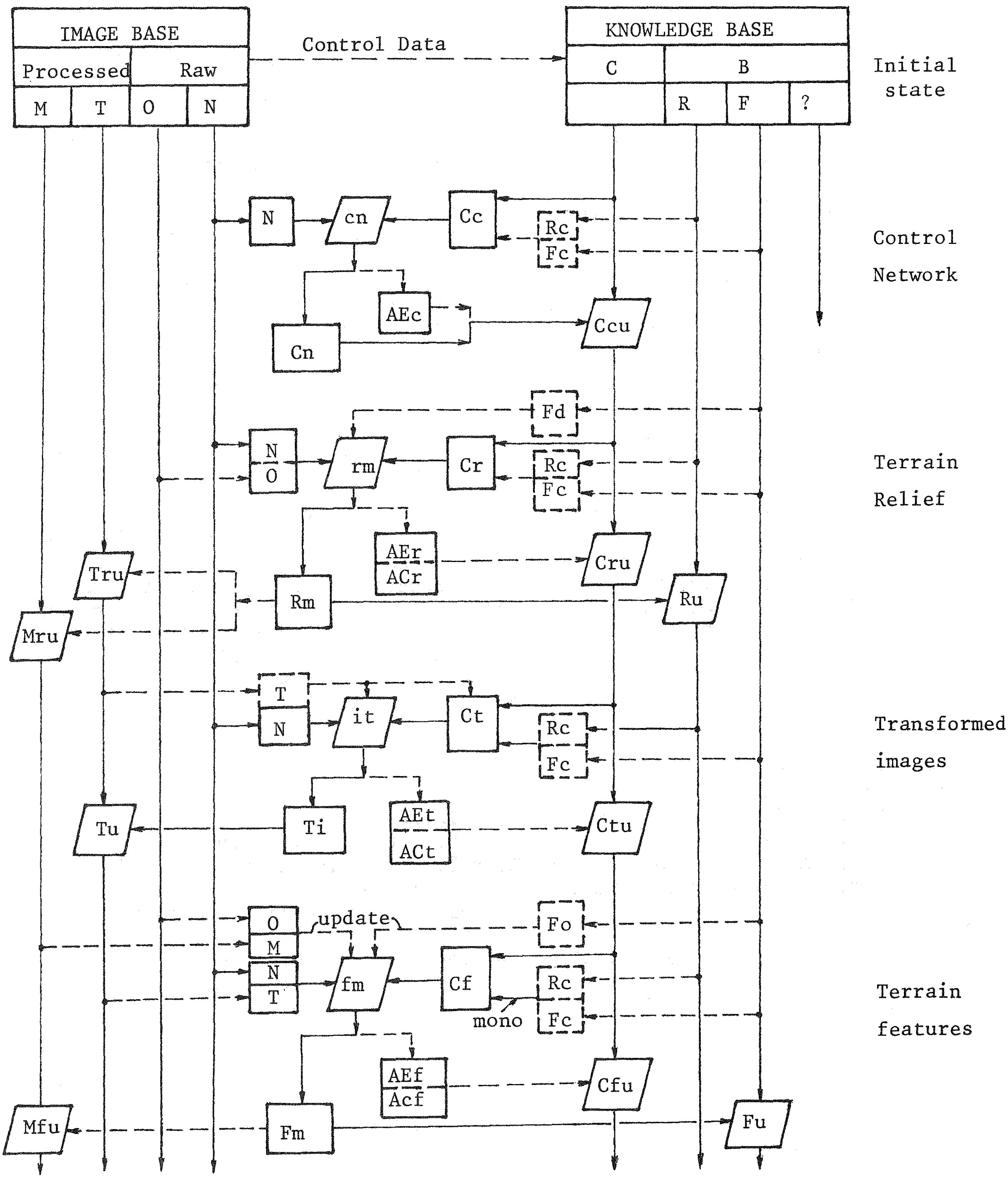

Fig. 11: Communication in overall production system

a) Control network densification (cn)

As shown in figure 11, the input is retrieved from the knowledge base (C) and from the image base (N) (figure 10a). The control data Cc comprise the project-specific data and the cn-expert knowledge. In addition to control points, distinct terrain features (Rc, Fc) can also sometimes serve as control data.

The output of the cn-process (Cn) is primarily the project-specific control network, survey camera position and altitude data, values of additional parameters, quality assessment data, etc. (figure 10b). A byproduct can be added cn-expert knowledge (AEc) gained in the course of the process. The Cn and AEc data are integrated into the corresponding parts of the knowledge base (Ccu).

b) Terrain relief modelling (rm)

The input from the image base is new images (N) and, in the case of differential rm (for updating or upgrading), the old images (O) of the project region. The control data Cr are retrieved from the knowledge base; these may include distinct 3D terrain features (Rc, Fc; figure 11). Such features may represent the skeleton and/or the boundary information for rm. The control data include also the rm-expert knowledge.

The primary **output** of rm is new terrain relief information Rm (contour lines, point grid, profiles, etc.) Byproducts can include added project-specific control data (ACr: orientation parameters, quality assessment data, etc.) and added rm-expert knowledge (AEr) gained in the rm process. Rm, ACr, and AEr are integrated into the corresponding parts of the knowledge base Ru and Cru.

Contour lines are sometimes overlayed on transformed images (Tru) or on image maps (Mru).

c) Image transformations (it)

Image transfromations pertain to both the geometric and intensity domains. The most common geometric transformations are from the perspective to orthogonal projection (rectification, orthophoto), using analogue or analytical techniques. Digital techniques are feasible at present for low-resolution images.

The input to it retrieved from the image base is new images (N) and, in the case of differential restitution, the existing transformed images (T) (figure 11). The control data (Ct) are retrieved from the knowledge base; these include also Rc, Fc and the it-expert knowledge.

Occasionally for example for updating, control data can also be extracted from the exisiting transformed images (T).

The basic output is tranformed new images (Ti) which are integrated in the image base Tu. Added project-specific control data (ACt) and added it-expert knowledge (AEt) are similarly integrated into the knowledge base (Ctu).

d) Modelling terrain features (fm)

Terrain features (other than relief) can be modelled fully or differentially in 2D or 3D space, in analogue or digital form. Modelling implies feature extraction (semantic) and spatial positioning (geometric).

The input to fm from the image base is new images (N) or transformed images (T) (figure 11). For differential restitution, the existing features Fo are retrieved from the knowledge base, or the corresponding old images (O) or image maps (M) are retrieved from the image base. The control data (Ct), including the fm-expert knowledge, are retrieved from the knowledge base. For fm by mono plotting or for guidance in stereo plotting, the control data are supplemented by the terrain relief data (Rc).

The basic output is the newly modelled terrain features (Fm) provided with some attributes. Fm is integrated into the knowledge base Fu. Selected items of Fm can be overlayed (graphically or digitally) on the transformed images (T), and then integrated into the image base (MFu). The two byproducts of fm, i.e., added control data (ACf) and added fm-expert knowledge (AEf), are integrated into the knowledge base (Cfu).

IV. CONCLUSION:

Integrated information systems should be considered in the context of scientific-technical, social-economic and administrative environments. The context provides a frame of reference for building and operating the system, and the knowledge gained in the process of developing a system and in its operation can effect changes in some parts of the environment.

A basic pre-requisite for system integration is a thorough knowledge of the components involved, their mutual relationships, the methods of integration, and of the users' problem-solving models.

Integration implies optimization. In photogrammetric system integration, the core issue is the optimnization of the production lines. Thus the structures of information and data, and their communication between the knowledge and image base, and the production means are of paramount importance. The production lines should be optimized both individually and collectively.

In geo information production, emphasis is being displaced from primary, new surveys to differential surveys, and from analogue to digital techniques. The capabilities of the integrated systems should reflect this trend. The fast developing information technology calls for flexible approaches, i.e. to provide easy modifications, upgrading and expansion of the integrated systems.