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# AUTOMATIZATION OF SPACE PHOTO DATA INTERPRETATION IN FOREST RESOURCES ASSESSMENT

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ABSTRACT: The principles of the specialized conversational man-machine complex of aerospace data interpretation used for assessment of forest resources are presented along with distribution of functions in solving the main tasks between a man and a computer. The flow-chart of automatized interpreter working place is given and described.

The results of experimental researches in aerospace forest data processing are presented , confirming principal possibility for designing of the complex proposed.

Normal functioning of the forest remote sensing system is connected with regular transmittance, processing and analysis of a large data flow. Conventional interpretation methods don't solve the problem. Therefore the system must include the conversational man-machine processing complex which permits to analyse data and register the analysis results quickly.

The complex should be based on the following main principles:

- completeness of task scope;
- universality of photodata utilization;
- complexing in various aspects: of photodata, feature groups, ground-truth and imagery data, man-machine functions, etc;
- flexibility of task solving mode, methods, algorithms and routines;
- possibility of interpretation results assessment by a common criterion;
- possibility of apparatus and algorithmic capacities to be increased stage by stage simultaneously with gradual shifting man functions on machines;
- providing independent simultaneous work of several interpreters in one system;
- connection with similar systems of different levels.

These principles determine the choice of technical and algorithmic means of interpretation. Basic computer of sufficient computating power forms the basis of the complex. The computer must be equipped with information searching system with central data bank and automatized depository of data. Several working places for operators-interpreters must be attached to the computer. It's important that this complex should permit an interpreter to monitor the whole process of man-machine interpretation and conduct manual interpretation. To gain this aim the working place must be equipped with monitoring stereoscopic device and interactive display. It must be also equipped with its own peripheral buffer minicomputer that fulfills slow operations of image reading and especially of conversational mode. In this case the basic computer will be effectively utilized and may provide work of of several interpreters. To provide optimum conditions for an operator-interpreter as well as for rational combination of human and computer possibilities an automatized working place should be designed by module principle. Separate working places may consist of a complex of technical means. The working place must be equipped according to specific characteristics of the tasks to be solved.

For solving the main tasks of forest inventory interpretation it's advisable to equip an automatized working place with the basic module, a set of removable peripherals and a set of off-line technical means and devices ( Fig.1 ):

a ) the basic module including monitoring mini-computer, a set of peripheral memory units (magnetic discs and tapes), the terminal with the control panel and the communication line to the basic computer;

b ) a set of removable peripherals interfaced with minicomputer including means of playback and digitizing of photodata, plotter, display system, etc.;

c ) sets of off-line technical means and devices for an interpreter to execute separate interpretation procedures.

Stereoplotter for monitoring the process of data playback as well as a set of devices for registrating and plotting are to be included to the set.

Software must include total software of basic and peripheral computers, application software of automatized interpretation, routine sets of information searching system and automatized depository of photodata.

Automatic means of the complex must execute maximum functions, including data aquisition, processing, cumulation and storing, solving interpretation tasks as well as display of results in given forms such as tables, thematic schemes and maps and processing of interpreter's instructions. A human operator just controls the whole process of interpretation and executes non-formalized operation such as taking of final decisions.

In the All-Union aerophotographic forest management organization "Lesprojekt" man-machine methods of photodata interpretation are investigated for potentiality assessment of automatized aerospace forest imagery processing. In research works the complex of technical means P-1700 Photomation (Optronics) is used.

Up to date more than 100 various routines united in the system have been worked out and tested. Obtained data permit to estimate the potentialities of automatized forest information processing and outline ways of its improvement. The investigations were carried on in the following main fields:

- Computer delineation of forest boundary and homogeneous plot contour with determination of plot areas;
- computer delineation of enlarged land categories with automatic plotting of their scheme;
- computer delineation of forest plots with domination of deciduous or coniferous species, outlining of plot schemes and area determination;
- automatization of stand inventory index determination, etc.

P-1700 system permits processing of colour and black and white airphotos with image shape to 300 × 300 mm on photographic film and paper. Automatic scanning of photographs may be conducted by the apertures of 12.5, 25 and 50 micron. Each optical density count is represented by an octad corresponding to 256 levels. Operational core memory contains 64 K bytes, memory addressing cycle is 1.6 msec.

The system is equipped with external cumulators on magnetic tape and disk, teletype, photographic recording device and printer/plotter. We also used computer EC-1020, photodata input into which was executed with compatible magnetic tapes.

Aerospace photos of forests from different regions of the country were processed: pine stands in Rjazan and Irkutsk districts, larch stands in Yakut and Buryat Autonomous Soviet Socialist Republics. To obtain statistically reliable results mass-statistic machine experiments in image processing of more than 1500 forest inventory compartments were carried out.

Determination of stand inventory indices by aerospace photos was devided into two stages. On the first stage contour interpretation was made on enlarged space photos obtained with MCP-6 - the board camera of manned spaceship "Sojus 22"

The operations included: division of the area into districts, delineation of lands,belonging to various categories, outlining of forested areas, division of these areas into compartments homogeneous by their forest growing conditions and dominant species, outlining of these compartments and determination of outlined areas. On the second stage for each homogeneous outlined compartment medium-scale photosamples were selected. They were subjected to machine processing for determination of such inventory indices as volume, density, diameter, height, age. The indices were determined by non-parametric recognition algorithm "K nearest neighbours". Base data units obtained by ground observation of typical forest plots were used at training samples. Base data units also served for computing of planning errors of inventory index determination by "sliding test" method. Planning error stability was veryfied on specially prepared check data unit. Experimental researches on the first stage showed that processing and analysis of photographs obtained by MCP-6 were executed rather reliably with man-machine interpretation methods.

The results of machine processing were delivered to the means of registrating in a form of enlarged land categories scheme containing results of land classification by the following classes:

- forest sites with domination of pine;
- forest sites with domination of larch;
- burned areas;
- non-forested areas.

The contour boundaries were edited by an operator-interpreter, resulting scheme served as a base for forest compartment detection to be machine-processed for determination of their inventory indices.

Temporal characteristics of machine processing were estimated by the following data:

- time for computer education in detecting land categories by educational photosamples was 20 min. per class;
- enlarged land categories scheme using false colour composite with format of 30 x 30 cm was 15 min.

There are, for example, the results of error computation for two data units. Tables 1 and 2 present the main parameters characterizing those stands in which ground-truth data for base and check units were obtained. The base unit contained values of age, height, diameter, density and volume for 91 larch stand compartments as well as feature vectors obtained for each compartment during machine processing of its images.The check unit contains similar data for 35 additional larch stand compartments of the same region.

Relative determination errors for each of the five inventory indices in the check and base data units are presented in tables 3 and 4. Relative values of errors were obtained by dividing absolute values to mean values of inventory indices. As it is seen from the tables the errors obtained on the base and check samples are similar. It shows stability of planning errors obtained on the base sample. The tables

also characterize accuracy potentiality of inventory index machine determination on 1:16000 airphotos. Root mean square errors increase by 5% with the decreasing of scale to 1:50000.

Table 1

Characteristic of Larch Stands Used for Forming the Base Data Unit

| Inventory index | Inventory index values (for 91 compartments) | | |
|---|---|---|---|
| | minimum | maximum | mean |
| Age (years) | 18 | 232 | 126 |
| Height (m) | 1 | 25 | 16.3 |
| Diameter (cm) | 1.8 | 32.3 | 16.9 |
| Density (-) | 0.21 | 1.0 | 0.63 |
| Volume ($m^3$/ha) | 10 | 358 | 161 |

Table 2

Characteristic of Larch Stands Used for Forming the Check Data Unit

| Inventory index | Inventory index values (for 35 compartments) | | |
|---|---|---|---|
| | minimum | maximum | mean |
| Age (years) | 18 | 196 | 111 |
| Height (m) | 3.2 | 23.6 | 16.9 |
| Diameter (cm) | 3.9 | 24.6 | 16.4 |
| Density (-) | 0.39 | 1.0 | 0.62 |
| Volume ($m^3$/ ha) | 18 | 358 | 163 |

Table 3

Assessment of Index Determination Accuracy with the Check Data Unit

| Inventory index | Relative root mean square error % | | Relative systematic error % | |
|---|---|---|---|---|
| | For all stands | For production stands | For all stands | For production stands |
| Age | 24 | 15 | 5 | 4 |
| Height | 14 | 13 | 4 | 1 |
| Diameter | 19 | 19 | 3 | 2 |
| Density | 15 | 15 | 1 | 1 |
| Volume | 14 | 12 | 4 | 3 |

Table 4

Assessment of Index Determination Accuracy with the Base Data Unit

| Inventory index | Relative root mean square error % | | Relative systematic error % | |
|---|---|---|---|---|
| | For all stands | For production stands | For all stands | For production stands |
| Age | 23 | 16 | 5 | 4 |
| Height | 16 | 12 | 5 | 1 |
| Diameter | 18 | 19 | 2 | 1 |
| Density | 15 | 14 | 1 | 1 |
| Volume | 16 | 14 | 3 | 2 |

The data listed in tables 3 and 4 demonstrate that main inventory indices, stand volume among them, have been determined with the accuracy of no less than 15-19%. Worse results were obtained in determining stand age, testifying to relatively low informativity level of stand canopy image.

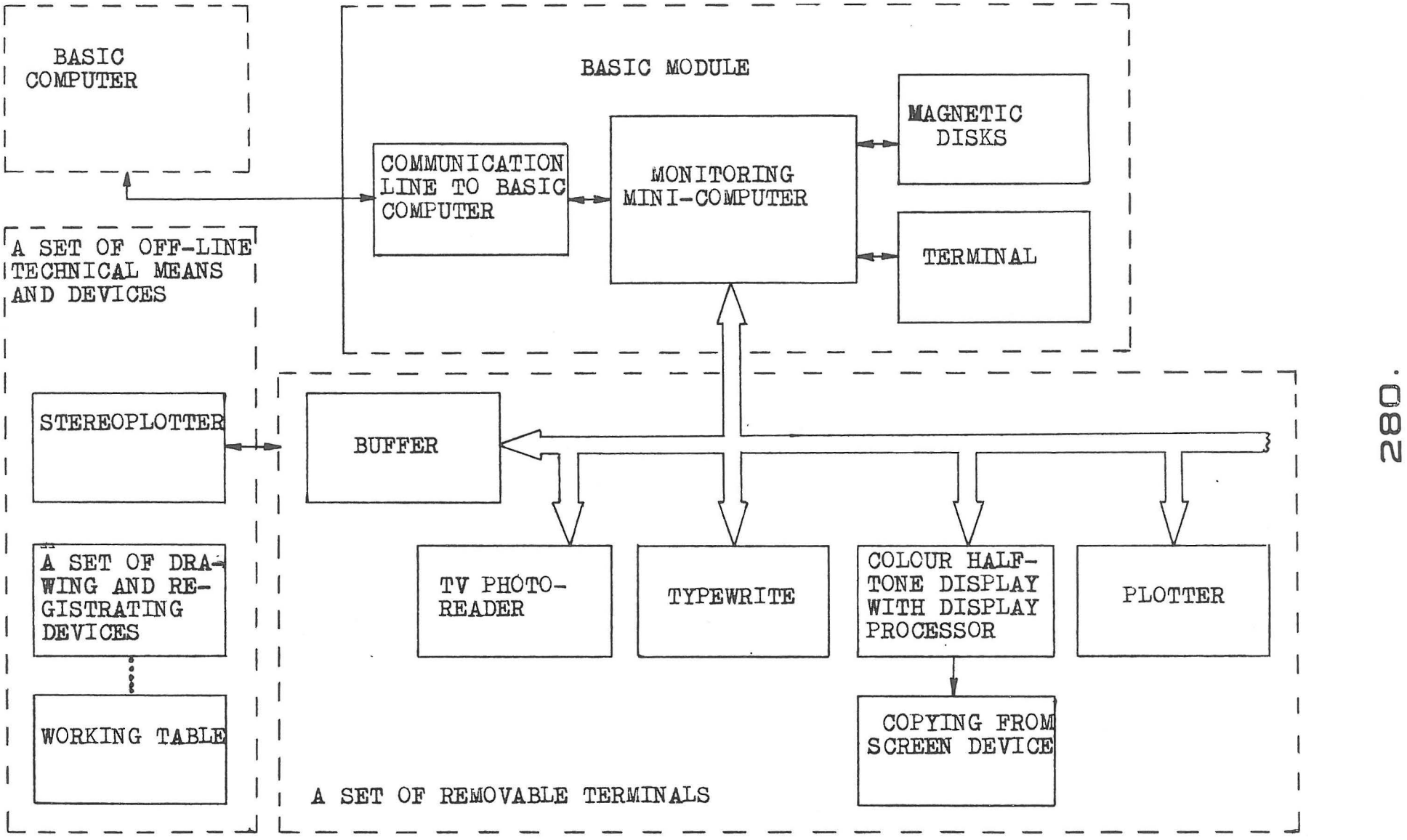
The data listed above also indicate that determination accuracy of most stand inventory indices of production fund (excluding young forests and young timber stands) is higher

than that of stands of all age groups.

Data processing time depending on the area of a compartment was from 1 to 5 min. per compartment.

Thus, our experiments confirm real possibility of aerospace forest data machine processing with acceptable validity and productivity.

Fig.1 The flow-chart of automatized interpreter working place (see the next page)


BASIC COMPUTER
BASIC MODULE
MAGNETIC DISKS
COMMUNICATION LINE TO BASIC COMPUTER
MONITORING MINI-COMPUTER
TERMINAL
A SET OF OFF-LINE TECHNICAL MEANS AND DEVICES
STEREOPLOTTER
BUFFER
A SET OF DRAWING AND REGISTRATING DEVICES
TV PHOTO-READER
TYPEWRITE
COLOUR HALF-TONE DISPLAY WITH DISPLAY PROCESSOR
PLOTTER
WORKING TABLE
COPYING FROM SCREEN DEVICE
A SET OF REMOVABLE TERMINALS