SOFTWARE CONCEPT AND STRUCTURE FOR A REMOTE SENSING DATA PROCESSING SYSTEM

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The information system for multispectral satellite information processing which has been developed at the Institute of Atmospheric Optics of the Siberian Branch of the Academy of Sciences of the USSR is described. The software design concept and a version of its programmatic implementation are proposed.

The role of environment data acquired by means of remote sensing has grown dramatically in recent years. In view of that, requirements imposed on the processing of thusly obtained information have also correspondingly increased. All this has given rise to the necessity of creating problem–oriented automatic data processing systems (ADPSs) geared to the processing of remote sensing data and adapted to specific application problems and special–purpose observation systems.

The subsystem of identification and reconstruction of cloud parameters, which is a component of ADPSs for multispectral satellite observations implemented at the Institute of Atmospheric Optics of the Siberian Branch of the Academy of Sciences of the USSR, has been described in Refs. 1 and 2. In these papers great importance was laid on a subject–area adaptable data processing. At the same time, the expansion of the scope of the applied problems involved in subject-area adaptable processing requires a stringent system approach to ADPS design.

The purpose of this paper is to present the concept and structure of ADPSs geared to satellite observation data processing. The idea of integrating the database and software necessary to solve the problems under consideration based on the concept of a decision support system (DSS) forms its base.[3]

The basis for the program system is a software bus. This is a program-oriented hardware for the synthesis of the given application-area software (SW) and the special-purpose SW which provides optimal integration of individual functional modules into a single program structure.

Since at present the problem of satellite monitoring cannot be strictly formalized, the system should have the capability of processing unstructured (expert) knowledge. Obviously, implementing a conventional expert system can hardly be efficient due to large amoun of empirical data. Therefore, it is on the basis of an expert-modeling structure that the ADPSs must be designed. Its logical output elements might be added to or replaced by structured knowledge (functional programs).

Thus, taking into account the peculiarity of the problem to be solved, ADPSs were constructed as expert-modeling information systems (IS) of satellite monitoring with the capability of interactive operation. Figure 1 shows a functional diagram of the IS.

The system consists of four basic functional parts (they are represented in the scheme as four basic blocks):
– primary processing block;
– archive data block (data base block);
– model block incorporating the observation models and investigated processes;
– block of mastering, analysis, and atmospheric correction of the data and reconstruction of the optical-meteorological parameters of the atmosphere and underlying surface (subject–area adaptable processing block).

Blocks of video and statistical image processing, and an expert system block and an output block are added to the system. Creating the expert system represents a large independent problem, therefore it is not considered in detail here.

The consistency of the different types of input data is arrived at via the interaction of the indicated blocks. The feedback loops allow one to correct the current data comparing them with the characteristics that are computed in the model block, and to adapt the models to the real data. After the subject-area adaptable processing, the corrected information modifies the data bases that serve as one of the bases for constructing the models, in particular, statistical models. Thus, a self-consistent closed loop for analysis and processing of the input data is formed, and it allows one to carry out efficient monitoring of the state of the atmosphere and underlying surface.

The structure described above is observed at all hierarchical IS levels. Now let us consider each of the IS basic blocks. The block of primary processing of the input data is traditional for IS's of this type. It incorporates first of all procedures of binding (temporal and geographical) of satellite sensing data and their standardization. Taking account of the potential availability of additional data (standard meteorological and aerological data and the data of special-purpose subsatellite experiments), one may discuss the necessity of a control procedure. In the process both the simplest forms of control, for instance, threshold value control, and more complicated, e.g., static control of aerological data are used. The heterogeneous nature of the input data requires that procedures for ensuring data consistency including consistency in time, taking into account the asynchronous character of satellite data with respect to the standard observation data, be included. A procedure of data compression appears to be a necessary attribute of primary processing, especially because of the large quantities of satellite data.

The other three principal functional blocks – archive information, subject-area adaptable processing, and model blocks – are the IS kernel, and their close interaction influences the performance of the IS.

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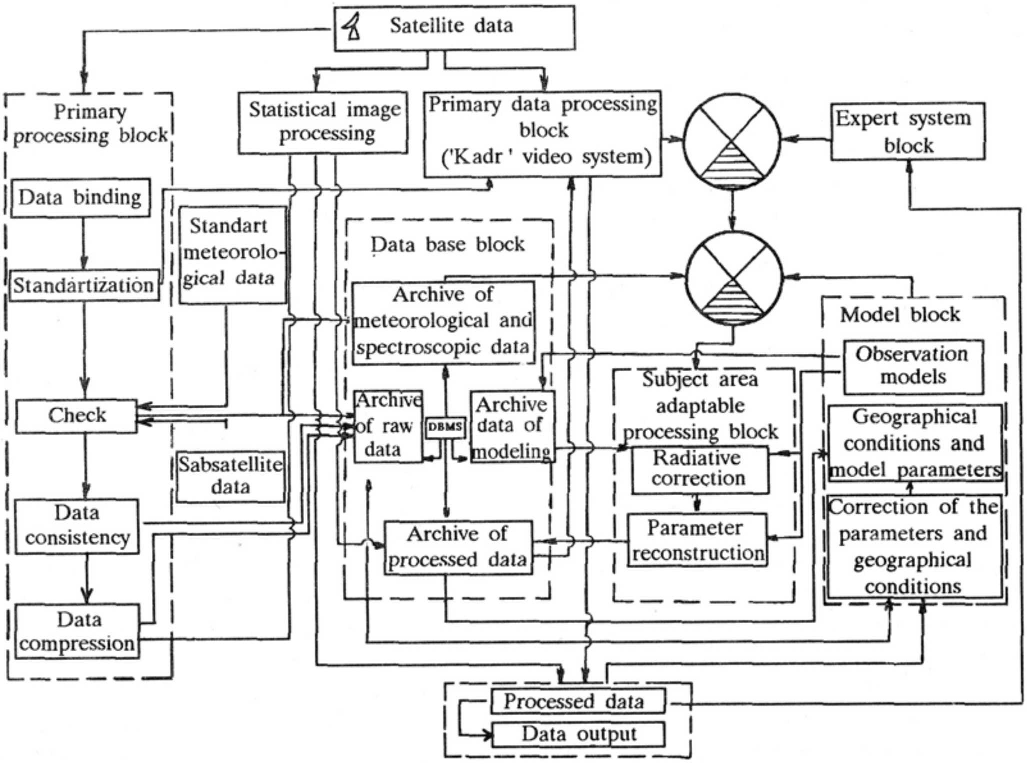

FIG. 1. Functional diagram of informational system.

The importance of the data base block in data processing systems is quite evident and can hardly be overestimated. Archives of meteorological and aerological data and spectroscopic data are the basis for solving problems of radiative correction of satellite observations. A raw data archive is necessary for processing large–format images, because it is impossible to store them in the main memory. Archives of model data processing, along with the model block, are a main tool in solving the problem of radiative correction and reconstruction of optical and meteorological and other parameters of the atmosphere as well as underlying surface.

A specific example of the problem of cloud type identification given in Ref. 1 is an illustration of the last point. In this case, the archive block contains, in particular, data on cloud types (microphysical structure) and the threshold values of the outgoing radiation intensity at the upper boundary of the atmosphere for each of these cloud types. This makes it possible to make direct use of the statistical and threshold methods of cloud identification.[4] In addition it is well known[5] that these methods, as a rule, are rigidly linked to a specific geographical region and season, i.e., they are not universal. For other geographical regions and seasons, one should have a new static database which includes new threshold values, which, as a rule, are not available.

Using the model data archive which incorporates data on microphysical models of different cloud types, and specially developed observation models from the model block which are adapted to a given geographical region and season and make it possible to theoretically calculate the outgoing radiation intensity in the given spectral range at the upper boundary of the atmosphere (which is measured by a radiometer placed onboard the satellite), one can recalculate new statistical characteristics and threshold values. Then, one may use the threshold or statistical methods of cloud type identification once more, after entering these data into the output data archive.

We have just presented only one example of the interaction of the basic functional blocks. In fact, the capabilities of the IS are much broader. Comparing the results of observation with model calculations makes it possible to solve a number of inverse problems: determining the optical and meteorological parameters of clouds, reconstructing the vertical temperature and humidity profiles, and others.

Reparding the concept of the given IS, it is necessary to emphasize that its salient feature is the model block. This makes the IS relatively universal as compared to other processing systems of this type, which operate, as a rule, only with *a priori* archive information.[4]

The large amount of data and the stringent requirements on the processing rate call for the use of multicomputer complexes which incorporate general–purpose computers in this information system. In our case, we used a two–processor system which incorporated a "Kadr" videosystem developed at the Scientific-Engineering Complex "Institute of Atmospheric Optics, Siberian Branch of the Academy of Sciences of the USSR"[6] and an ES – 1066 computer. The "Kadr" videosystem is designed for visualization of multidimensional information, support of the interactive processing system and primary image processing, i.e., it is an image processing block while at the same time it is a part of the output device.

The given videosystem allows one to perform on–line data visualization and special–purpose processing. The latter incorporates, along with various standard procedures (filtering, geometrical transforms, and the like), processing of images based on their structure and text indicators and attributes. These results are subsequently used to improve the quality of the subject-area adaptable processing of multispectral images.

The block of statistical processing is designed for calculation and analysis of the spatio–temporal statistical characteristics of the processed images, which are used, on the one hand, in the model block and in the block of subject–area adaptable processing as additional data to improve the quality of reconstruction of the optical and meteorological characteristics of the atmosphere and underlying surface and, on the other, to provide a basis for implementing the procedures of raw data compression.

The IS must be extremely convenient for the user and operate in the interactive mode. As a result, special requirements are imposed on its program implementation.

The IS software is realized in the FORTRAN–77 language as a system of programs (SPs) in virtual machines using the subsystem for interactive processing (SIP), PANEL, and a number of subprograms implementing macrocommands of the SIP, such as FSTAT, FSREAD, and so on.

By taking into account the large amount of data processed and requirements on the processing rate, one can substantially improve the system performance when entering the data from the external media, and shorten the time required for programming the functional modules of the SPs. Figure 2 shows the general scheme of the SPs.

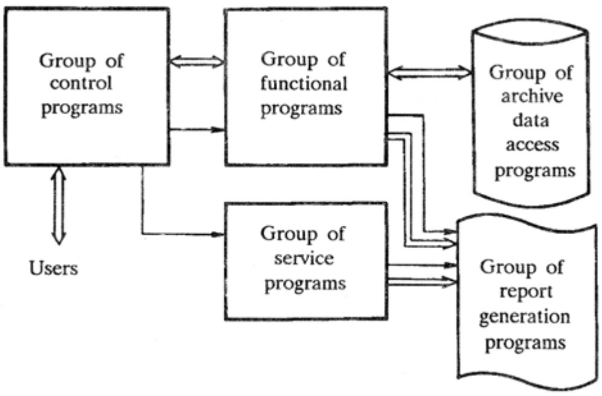

FIG.2. Scheme of the system of programs.

All the functional modules of the SPs can be classified into the following groups:

1) programs supporting the control of the operation of the chain of functional modules of the SPs;

2) HELP programs including reference information for the user as well as service programs;

3) functional programs;

4) programs of data control, data compression, and navigation through the data programs; and,

5) programs of report generation and data representation.

The first group implements the IS-user interaction in dialog form. In the process of operating the program, the user is offered a collection of functional capabilities of the IS in the form of menu, and each capability is selected simply by pressing the proper function (PF) keys.

Here is an example of operating with the menu of the program MAIN.

Menu of the program MAIN:

Select the type of processing and press a PF key.

PF1 — Standardization;
PF2 — Subject-area adaptable image processing;
PF4 — Statistical image processing;
PF5 — Performance of computations using a radiative model of the cloudy atmosphere; and,
PF6 — Sample of processed image fragment.

To enter the operational system, press PF3.

To enter the service subprograms, press PF12.

Let us suppose the user wishes to standardize the raw data. After the user pressed the proper PF-key he is offered a new menu which lists the IS functional capabilities pertaining only to the standardization procedure.

Menu of the standardization procedure:

Select the type of standardization and press a PFkey.
PF1 – Standardization using data from a machine-readable medium
PF2 – Standardization using display data entry;
PF3 – Entry into the main menu;
PF4 – Archive the results: assign a number to the archive record;
PF5 – REad the results from the archive ¦ ¨ from 01 to 50; and,
PF12 – Access the service subprograms.

Here the user may assign a unique name to the file of standardization results.

After selecting the appropriate form of standardization and entering the required data directly from the display screen, the user receives a job processing message. He may then repeat the previous standardization calculations after changing the raw data or go back to the previous menu and continue operating with the IS functional modules, using the remaining functional capabilities (where necessary) listed above in the menu.

This principle of IS-user interaction through the menu system is obeyed at all the hierarchical processing levels. This makes it possible to process both in a strictly fixed chain of operation of the functional modules, and with arbitrary selection of the individual modules which are required at the moment.

At any stage of processing, the user may call a group of HELP service programs. These programs include a program for generating checkpoints; a checkpoint restart program, an intermediate data scan program; a generated report scan program; and an SPs job control program.

The first two types of service programs allow one to stop and/or restart processing at any stage. The third program listed above makes it possible to scan and transfer any intermediate data to the report being generating, and to create files which are necessary for working with the "Kadr" videosystem. The purpose of the fourth service program is quite evident. The fifth one controls the scanning modes and/or intermediate output.

The functional programs group implements computations in the model block and the block for subject-area adaptable processing, using all the necessary input data and generating an output data stream for its subsequent processing or storing. In addition, control of the input data stream is guaranteed. If the input data necessary for the given module are not available, then an information message about the impossibility of performing the computation is sent, and the SP modules are listed whose operation provides computations using the module selected by the user.

The last two of the basic SPs are programs for adapting the system to a specific computing environment. In particular, they optimize access to external media, make the link with the operational system, and execute a number of similar functions.

Thus, SPs have been realized which make it possible to solve in a uniform way the problem of IS-user communication. In addition, it should be emphasized that the salient features of the IS under consideration are its openness to expansion and adaptation to subject-area adaptable processing of various types, as well as the possibility of translating it into another computing environment with minimal resource consumption. At present, this IS has been implemented on the basis of the ES-SM computer network at the Institute of Atmospheric Optics, and serves for processing multispectral digital and analog satellite data obtained from the NOAA and METEOR satellites. The implementation of the IS in the ES-IBM/PC(XT, AT) computer network is now being completed.

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