Some Aspects of a Client-Server Architecture System for Processing Radar Images

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Abstract. This article discusses some aspects of a client-server architecture system designed to process radar images.It is assumed that data obtained remotely are processed to determine oil pollution on the water surface.The synthesis of monochrome images and the infological model of the system are considered. The developed application provides the ability to preview the image, forming a graphic file from satellite data; implements functions that allow you to annotate images, marking areas of interest and adding comments; implements, if necessary, an algorithm for merging monochrome images; implements a keyword support system that allows flexible categorization of all images; provides the necessary level of information security through the separation of user rights and authorization systems. The developed software product allows access to files stored in the GIS database archive in real time simultaneously by a large number of users, i.e. represents its network (web) application. The software product contains three levels: a user interface on a client browser, a web application, and a database server.

Keywords: Radar Image, Geographic Information System, Data Base, Monochrome Image, Monochrome Image Merging Technique, Algorithm for Merging Monochrome Images Using an Information Measure, Radar Image Application.

1 Introduction

Currently, the main source of information about the state of an extended monitoring object (for example, water surface, land surface) are radar images obtained from Earth satellites equipped with radar stations with a synthesized aperture (SAR) [1]. At present, SARs are increasingly used in various technologies of remote sensing of the Earth (RS), and in some of them, such as the study of dynamic processes in the ocean, SAR is recognized as the only possible tool for obtaining reliable information. This is due to two main circumstances that distinguish SAR from remote sensing sensors operating in the visible and infrared ranges of the electromagnetic spectrum [2],[3]:

- SARs are capable of receiving radar images (RRI) of the Earth's surface, regardless of the state of the cloud cover and surface illumination;
- The radar image is dependent on some specific characteristics of the underlying surface: surface dynamics, dielectric constant, microrelief.

Accumulated SAR images are stored in aGeographic Information System(GIS) database. The developed software product allows access to files stored in the GIS database archive in real time simultaneously by a large number of users, i.e. represents its network (web) application [4-6]

The software product contains three levels: a user interface on a client browser, a web application, and a database server. Based on this, the system requirements for the application under development are as follows:the interface is implemented using HTML with support for JavaScript and Dynamic HTML based on templates, since HTML is a means of organizing an interactive dialogue between the end user and the levels of the system. JavaScript combined with DHTML makes the web page dynamic. To develop a universal web application, a programming language is used that supports almost all used DBMSs. The DBMS, in turn, supports the standard SQL language, which allows you to perform all kinds of queries: fetch, add, update, delete.

A prerequisite for providing access to the archive of SAR images is the ability to preview the source file, that is, to obtain the so-called quicklook image. This operation must be fully automated. On an existing SAR image, it is necessary to be able to note anomalies, add comments, i.e. Create annotated images.

An integral part of any system providing access to the database is the search engine. When designing this application, a search engine was provided for several parameters: date, keywords. Search by date is possible both for a certain interval and for a selected day. Keyword search implies the presence of a certain number of processed images, that is, those to which the specialist assigned some categories. A single image may contain several keywords, such as “slicks” and “temperature front”. In addition, it is possible to also introduce an estimate of the frequency of occurrence of certain phenomena in the pictures, which can be ensured by a simple calculation of keywords by their frequency of occurrence. It is possible to expand the application and include other geographical areas in the monitoring of the sea surface. A mechanism is provided for recording all user actions so that it is possible to undo any change.

It is possible to use the application simultaneously with a large number of visitors. Application performance should not fall as the number of images on the site grows. The interface is friendly, contains hints, has a concise, non-distracting design, navigation is convenient, supports hierarchical structure. Address (navigation) lines have a convenient, catchy look.

The administrator responsible for maintaining the site has the following options:

- manage the application through its web browser;
- user management: editing data, changing a password, deleting, adding or removing rights;
- adding and removing keywords;
- editing, adding and deleting user comments;
- creating and deleting user groups.

The developed system is located on a web server, accessible from anywhere in the world around the clock and should at the first stage (during the first year) provide access to at least 20 people a day with an average number of views of 30 pages with SAR images.

A regular requirement for backing up data is also a necessary requirement.

2 Method of Monochrome Images Fusion

Usually, the observed sensor is somewhat biased and rotated relative to the reference sensor, therefore, to increase the accuracy of determining the parameters of the imaged object, it is necessary to find a function F that more efficiently (with a minimum deviation) displays the readings of the observed sensor $S2$ (x_1, ..., x_n) on the readings of the reference sensor $S1$ (x_1, x_2, ..., x_n) (Fig. 1).

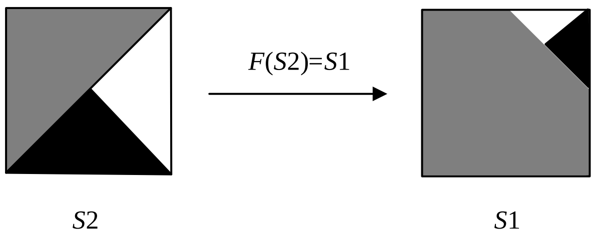

Fig. 1. Image Combination Method

The solution to the data fusion problem in this case is to find the translation vector (rotation and displacement), which correctly calibrates two images with the same configurations.

There are several ways to solve the problem of combining images. Consider the “tabu search” (TS) and “genetic algorithms” (GA) [7],[8] algorithms used to integrate the data of two images. The TS algorithm consists in translating one image relative to another and finding a correspondence function between them. The points in which the search was performed during the execution of the algorithm are stored in the “tabu” list and are not viewed again while they are in it. The fast minimum is ensured by optimization and the use of parallel search.

When executing the genetic algorithm, possible responses to queries are stored as rows. Many of these rows form the gene pool. The quality of possible responses can be evaluated through the fitness function. The relative quality of the answers is provided by the rows, which are used to create a new generation of rows, where their contents are used to create new generation generations in which the contents of the rows provide high-quality answers, more likely to continue the generation of the next generation. There are many strategies for determining the operation of obtaining a new generation.

Each of the above algorithms has its own peculiarities: if TS is characterized by a rapid convergence, as a rule, to local minima, then for GA it is a global minimum due to a larger number of calculations. A new algorithm was proposed in [7], which has the advantages of each of them. The proposed algorithm for the efficient registration of two-dimensional images and their subsequent merging consists of the following main steps.

1. The formation of the size of the "working frame" - the area of the sensors, whichwill be subjected to translation and rotation, to determine the direction of convergence of the algorithm.
2. Formation of the initial direction of convergence of the two sensor readings inherent in genetic algorithms in order to bypass local minima.
3. Choosing the direction and convergence step by maximizing the matching function Fitn_f is an action inherent in the TS algorithm.
4. Averaging the readings of the two sensors.

At the first stage, all necessary variables are initialized, and the readings of two sensors (cameras) are obtained. The translation step, rotation angle, initial position and size of the “working frame” of the image are also initialized.

At the second stage, a set of initial directions is generated along which the “working frame” is shifted in the observed image and for which the correspondence functions between the reference and the observed images are calculated. The number of generated directions is set empirically, and depends on the size of the processed image. At the third stage, the direction with the maximum value of the correspondence function is selected, and entered in the Tabu list. Then a cycle is organized, the number of iterations of which is established empirically depending on the degree of correspondence of the two images and the achieved accuracy of their registration. Six possible directions (up, down, left, right, right and left angles of rotation) are selected for broadcasting the “working frame”. The correspondence function is calculated for these selected directions and they are searched in the Tabu list. If one of the directions is already in the Tabu list, then the correspondence function of this direction is assigned the maximum value. Otherwise, the direction with the minimum value of the correspondence function is determined and entered in the Tabu list. The selected direction is used for further search. After completing this cycle, two images are merged by translation in the selected direction of the observed image relative to the reference and subsequent averaging of the two images.

Since the question of choosing the appropriate correspondence function was left open in [9], it is proposed to choose the Kullback connectivity criterion [10] as the correspondence function, which is nothing more than the amount of information on Shannon in the image y about the image x

The Kullback connectivity criterion depends on the mutual probability distribution density (PDD) of the pixel intensity of two images:

$$\rho(x,y) = \int \log_2 \frac{w(x,y)}{w(x)w(y)} w(x,y)\mu(dxdy), \tag{1}$$

where$w(x,y)$–mutual PDD of two images ;
$w(x)$, $w(y)$– PDD of images x and images y respectively;
μ –measure of the distance between two pixels.

In [11], the choice of this function of the correspondence of two signals is justified, since mutual information is one of the most accurate, powerful, and stable measures of the correspondence of two signals due to the fact that

- There are no restrictions on the nature of the relationship between the pixel intensities of two images;
- No assumptions are made about the objects depicted; to apply the informational connectivity measure, the image is not pre-parameterized or any of its characteristics;
- Among all varieties of informational connectivity measures, the Kullback measure has an almost linear loss function to minimize Bayesian risk when distinguishing between two hypotheses [12].

The listed advantages of the selected informational compliance measure allow you to fully automate the process of merging images without performing any preliminary processing.

3 Infological Model of a Data Analysis System

Based on the task, we can distinguish the following main objects of the system: images; Comments marked areas; keywords; monitoring areas; users user actions; group of users; user rights. The key object of the system is the “Images” array. The data in the array comes from the data source. Arrays: Keywords, Comments, Actions, and Marked Areas are related objects in the Image array. In turn, the “Image” belongs to one of the “Regions”. The "Users" array is a subset of the "Groups" array. The objects in this array are capable of creating related objects. Creating links is limited to the "Rights" array.

To achieve maximum efficiency of data organization, any information array must meet the requirements of the third normal form (which automatically includes the requirements of the first two) [13]:

- each array entry must contain a unique code;
- each field of each record should depend on a unique code;
- the fields of the same name in all records in the case of duplicate data must contain a unique code that refers to a separate directory.

The application should contain the following information about the stored SAR images: the path to the file (full file name), the path to the quicklook image, description of the image, region, date of recording, date of receipt in the archive. The list of elements does not meet the requirements of the third normal form, so it is necessary to decompose. The object "district" is allocated in a separate directory with a unique identifier (code).

Objects: “Comments”, “Keywords” and “Marked areas” belong to a separate image and should contain the following information: image code, user code of the commenter, content, date of addition, date modified by the moderator or administrator, as well as an activity flag (show on page or not). Here, the content can be the comment text, or a keyword, or the coordinates of the marked area. The list of elements complies with the requirements of the third normal form, since images and users are already listed in the corresponding tables.

The User Actions object must contain information about the action (add, disable, delete or edit), the user code, the object over which the action was performed, and the execution date.

All actions must be placed in a separate directory "Types of actions" containing the action code, its name and description. Also, all system objects are listed in the "Objects" directory containing the object code and its name. Thus, the list of elements is reduced to the third normal form.

Information about users. The application should contain a sufficient amount of information about the user in order to fully provide all the functionality. The following data set allows this to be provided: user code, username, password, email address, date of user addition, activation flag (access to the application is allowed or closed).

Here you can note the object directly associated with the user - this is a user group. A separate table is selected for user groups containing the following information: record code, group name. The user group object meets the requirements of the third normal form.

The user rights object associates an individual user with his group. The user rights table contains the following information: record code, user code, group code, and meets the requirements of the third normal form.

As with any software product, erroneous or conflict situations may periodically occur in the application. To process errors and ensure stable operation of the application, it is necessary to create a locking mechanism and error handling. The result is achieved by combining the situation warning in the system software code and the corresponding information in the database.

For these purposes, a “Services" object is required containing the following fields: operation code, operation name, comment, execution flag, return code, creation date, date of the last change.

Output information. To achieve the development goal, the web application must have the following output:

- PCA image in preview mode (quicklook file), shooting date, short description, file name;

- comments on the image;
- areas marked on the image;
- keywords.

The list and description of the output messages are presented in Table 1.

Input information. The input data for the application are SAR images in the form of *N*1 format files, which are daily delivered to the server from rolling archives.

Table 1. List and description of output messages

Message	Identifier	Presentation	Frequency of issue	Date of issue, s	Recipient of information
SAR-image	Images	Videogram Mashinogram	On demand	Up to 120 unprocessed, 2-3 for processed	User
Comments	Notes	Array	Same	2-3	Same
Marked areas	selections	Videogram	Same	2-3	Same
Keywords	Tags	Array	Same	2-3	Same

*N*1 files can be of various types, depending on the shooting mode of the ASAR instrument:

- Image Mode (IM) – standard mode;
- Alternating Polarisation Mode (AP) –alternative polarization mode;
- Wide Swath Mode (WS) – broadband mode;
- Global Monitoring Mode (GM) – global monitoring mode;
- Wave Mode (WV) – spectral mode.

In addition, separate products are formed for each of the five shooting modes listed.

4 Results

To test the algorithm for merging monochrome images, we used a radar image of the North Atlantic near the Galicia bank in the area of the “Prestige” tanker accident in November 2002, obtained from the ERS-2 satellite [14]. Fig. 2 shows that for clear sea water a weak contrast gray background is characteristic. Dark spots against this background are surface films of oil pollution, white spots are sea vessels. From the tanker “Prestige” - the white point in the southern part of the image, a dark plume stretches northward, which is divided into two arms - the north and east. Separate dark spots of the fuel emulsion, formed as a result of leakage from the “Prestige” tanks in the first days of the accident, are clearly visible.

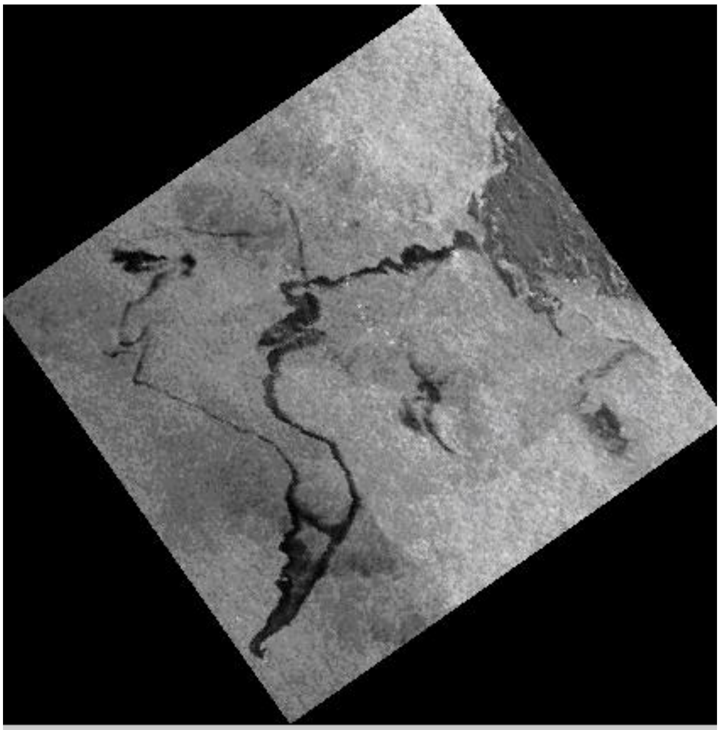

Fig. 2. Source image

Fig. 3 shows the same image, but rotated and offset relative to the original. Fig. 4 shows the result of combining two images. Figure 5 shows the calculated mutual density distribution of the probability of pixel intensity. Figure 6 shows the mutual density distribution of the probability intensities of the pixels, calculated in accordance with expression (1) after applying the processing algorithm. Figure 7 shows the image obtained as a result of the algorithm for merging monochrome images.

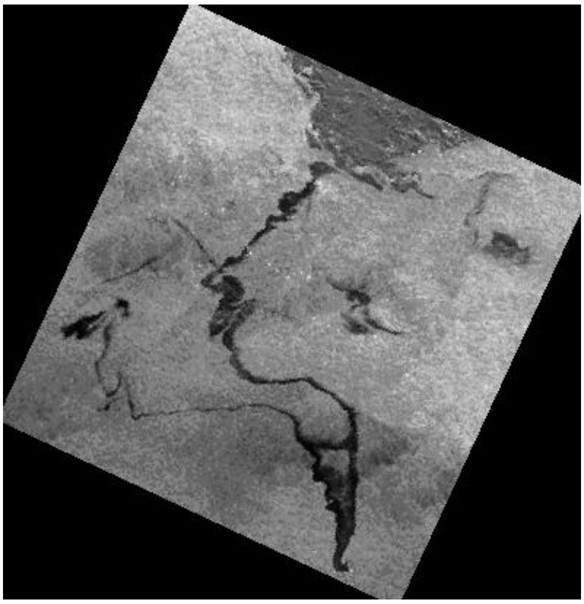

Fig. 3. Image rotated and offset from the original

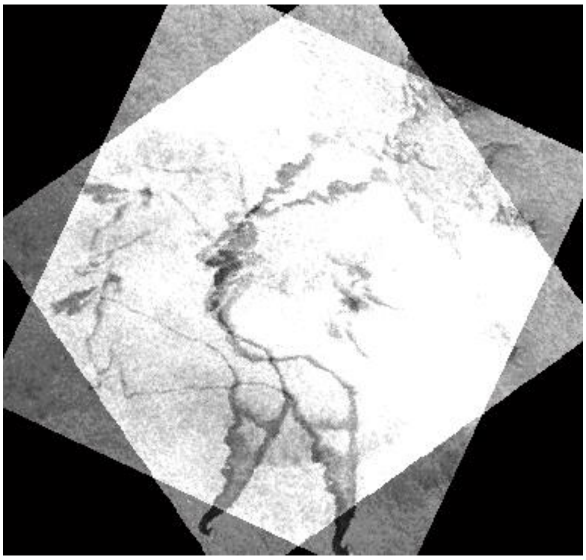

Fig. 4. The result of combining two images

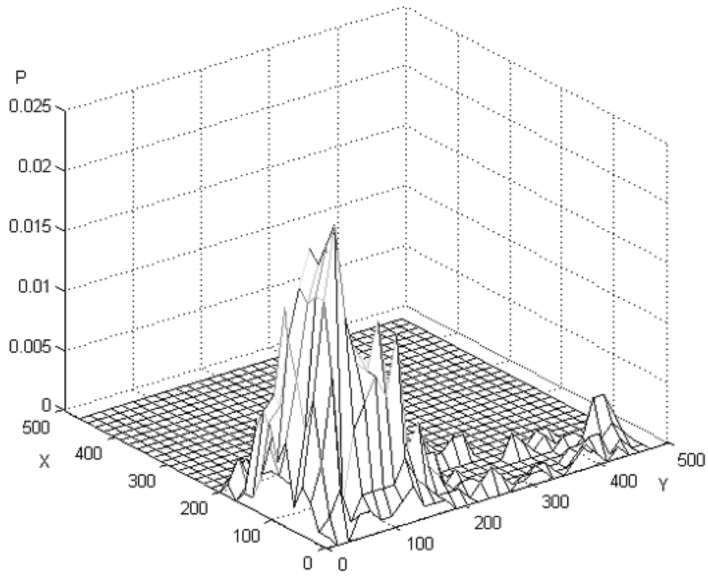

Fig. 5. Mutual PDD of Combined Images

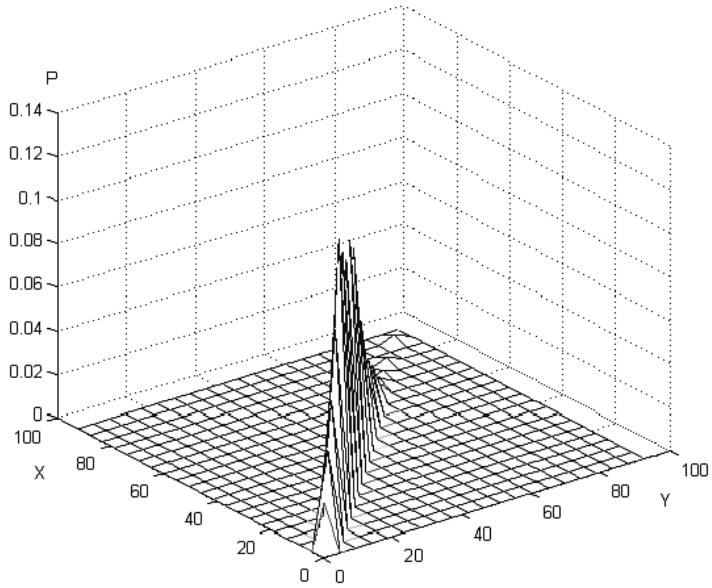

Fig. 6. Mutual PDD of two images that have undergone the fusion

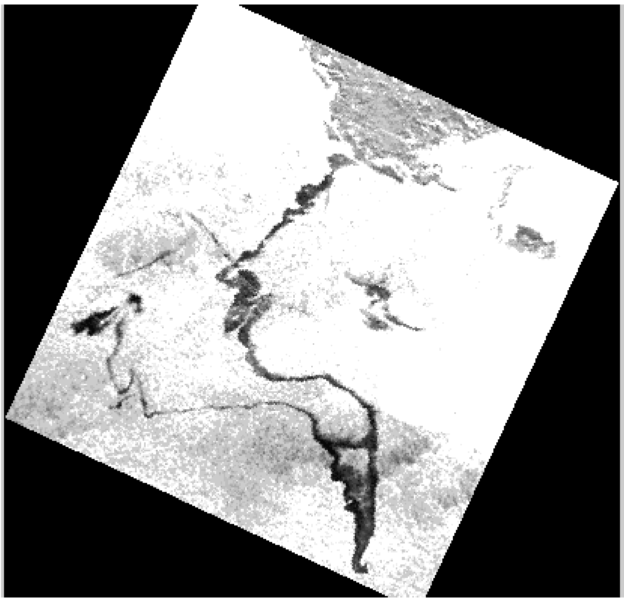

Fig. 7. The result of monochrome images fusion

The above results indicate that the implementation of the algorithm for merging monochrome images at the parameter level using the information measure of compliance allows you to fully automate the process of merging images without performing any preliminary processing.

5 Conclusion

The developed application provides a preview only for accurate and medium resolution images in alternative polarization mode (APP, APM), accurate images in standard mode (IMP) and wideband images in medium resolution (WSM). This limitation is due to the fact that these types of images come daily from the rolling archive, and support for a larger number of products can greatly complicate the development and is not essential.

The developed application provides the ability to preview images, forming a graphic file from satellite data; implements functions that allow you to annotate images, marking areas of interest and adding comments; implements, if necessary, an algorithm for merging monochrome images; implements a key word support system that allows flexible categorization of all images; provides the necessary level of information security through the separation of user rights and authorization systems.

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