ACQUISITION, PROCESSING AND ANALYSIS OF SPACE IMAGES AT RISKS MANAGEMENT OF NATURAL AND TECHNOGENIC EMERGENCIES

The chapter is devoted one of possible approaches to automation in the field of the risk management, based on data processing of remote space monitoring of the spatially-distributed natural and technogenic objects for timely detection maintenance, diagnostics and the development predicate of the dangerous phenomena and emergencies. For acquisition of a digital image set for Earth's surface it is offered to use shooting from space satellites and unmanned aerial vehicles. We propose to eliminate a disadvantage inherent in standard unmanned aerial vehicles management schemes which are associated with a limited range of management through the use of digital imaging systems included in the control loop. The visualization system synthesizes a three-dimensional image of cockpit-exterior space on the basis of the unmanned aerial vehicles position and terrain. The set of mathematical methods and stage-by-stage procedures of computer processing of the space images are offered, allowing to make a preliminary filtration, to estimate them information compatibility, to carry out qualitative recognition, fixing and tracing of artificial objects. The considered integrated automation means complex provides necessary reliability and quality of achieved results, and also differs high speed that allows to use it and for the analysis of situations in real time.

1 BASE PRINCIPLES OF AUTOMATION FOR RISKS EMERGENCY MANAGEMENT ON THE BASIS OF REMOTE SPACE MONITORING DATA

Maintenance of all-round safety of the person, society, the state and the world community became a priority of the next decades, has turned to one of overall objectives for strategy of a civilisation existence in modern and predicted conditions.

Scientific-technical and social-economic progress of last centuries has considerably changed the world, essentially having improved working conditions, quality of a life, education and culture. At the same time technological progress has shown the negative side connected with an exhaustion of resource possibilities of the Earth and extensive character of their operation, a number of the crisis phenomena in social, economic, political spheres, and also with the advent of new technogenic threats. Interdependence of natural and technogenic spheres has essentially amplified.

Natural and technogenic dangers are an integral part of a life for the population of modern Europe. Danger of adverse processes influence for technogenic sphere and scales of the human and material losses increase.

The probability of occurrence of natural and technogenic accidents considerably increases possibility of that in a zone of emergency there will be the territories sated with engineering constructions and utility-power systems. In the largest cities natural disasters are capable to cause a series of technogenic failures (fires, explosions, emissions of chemical substances etc.), having catastrophic consequences.

Natural cataclysms, such as flooding, typhoons, a tsunami, volcanic eruptions, droughts and forest fires, lead to different consequences and depend how the society prepares for them, predicting their occurrence, and what measures accepts after their approach. For example, building constructions which are not answering to standards of seism stability in area where the probability of earthquakes is high, obviously increases number of possible victims, and thereby human scales of misfortune.

For decrease in losses, increases of stability for functioning of productive-economic and social systems at all levels (interstate, the countries, territories, the enterprises, the organisations) it is necessary to carry out measures of protection from emergency. However, realisation of protection measures is connected with considerable expenses that demands to correlate with expense from a prevented damage.

For potentially dangerous events speech should go about prevented risk on the basis of monitoring operative data for natural and technogenic objects. At risks management of emergencies it is necessary to estimate efficiency of actions for their decrease on the basis of all saved up data sharing (the integrated data ware). These actions should provide realisation of management strategy by the risks, reflecting activity mainstreams on achievement of a comprehensible risk level in all its aspects. Thus each strategy demands reception and processing of the certain kind and type information. Correct interpretation of the information about a condition and functioning of dangerous objects, about their interrelations, and also about geophysical both other phenomena and processes is provided with their adequate and correct description with application of a corresponding mathematical apparatus. Set of these descriptions makes subject domain model (SDM). In actions three basic strategy of risk - management by emergencies should be presented:

- strategy of prevention of the reasons of natural and technogenic failures and accidents' occurrence;

- strategy of natural and technogenic accidents' localisation and prevention of dangerous conditions formation when the reason of accident' occurrence on technical, economic, social or other reasons to eliminate it is impossible;

- strategy of the maximum possible easing of natural and technogenic factors' influences on people and environment, liquidations of accident and its consequences in the shortest terms.

For maintenance of effective computer information-program support for realisation of the given strategy it is offered to develop the integrated automated information-analytical emergency system (IAES) of remote space monitoring of the spatially-distributed natural and technogenic objects that allows timely to detect, diagnose and forecast of the dangerous phenomena and emergency' development. Creation of IAES is the modern, perspective, scientifically-proved strategic, system approach to complex automation of emergency risk-management.

One of the most informative and technological sources of data for IAES are pictures of observable territory [Images of the Earth and Outer Space, 2005]. They can be received as by means of space vehicles (satellites) [United Nations Coordination of Outer Space Activities, 2003], so be means of modern unmanned aerial vehicles [Verona, 2009].

The modern level of facilities development and Earth' research methods from space, program complexes for space data processing and a wide dissemination of geographical information systems (GIS), allow to receive qualitatively up-to-date information on a condition of territories, land objects, processes and dynamics of their condition change. New information quality defines new methodological approaches, and also perspective technologies in acquisition and target application of results of the earth remote sensing (ERS) for complex researches, the analysis and efficient control development of regions. The basic directions of these works concern the most urgent questions and the problems facing to the state, regional and municipal controls. Such problems concern:

- prediction, search and development of new mineral deposits on insufficiently explored and remote territories;
- rational use and periodic inventory of natural resources;
- an operative data ware of the state, regional and municipal controls;
- the account of the earth's and the organization of rational land tenure;
- monitoring of emergencies, ecological disasters, natural and technogenic accidents;
- space diagnostics of an infrastructure, including technical communications.

The urgency of these problems defines necessity of creation of the organizational-technical structure providing their effective decision. The space monitoring centers and the geospatial analysis which can be created at different levels of regional, state and interstate management on the basis of the corresponding scientific, industrial and educational organizations can become similar structures [Space Monitoring Center, 2009].

Main objective of The space monitoring center (SMC) creation: maintenance of reception, complex processing of archival and operative data of ERS, and also the all-round analysis of the territory researches results with a view of granting of the fullest, timely and objective information about nature-resource potential, an economic, ecological condition and dynamics of nature-technogenic complexes development. The goal attainment allows accepting of administrative decisions of various scales.

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SMC activity is focused on decisions of following primary ERS' goals:

- operative pictures acquisition of the same territory with the various spatial permission;
- shooting conducting in various spectral ranges practically at any time;
- repeated pictures acquisition of any territories, including remote and insufficiently explored sections
- space pictures formation into regular time numbers.

As a rule, ERS methods are much more economic than traditional ways of spatial data acquisition. However for reception of an objective picture for dynamics of processes resulting in investigated territory the space picture is necessary for recognizing and decoding correctly, i.e. to pass from brightness surface characteristics to physical properties of a surface or objects and to spend specialized complex processing for reception of necessary information quality. So the technology of researches on the basis of space monitoring data (fig. 1 [Serebryakov see, 2008]) provides the decision of following technological problems:

- operative ERS data acquisition provides monitoring those or other kinds of territorial natural resources, branches of a national economy, environmental problems, emergencies;
- a pre-processing of space pictures, their preparation to further automated and expert decoding and also to visual representation for regional authorities;
- the deep automated analysis and thematic data ERS processing for preparation of a wide spectrum of analytical maps on various subjects, definitions of various statistical parameters, developments of competent administrative decisions and definition of technologic realisation;

- preparation of analytical reports, notes, presentation materials on the basis of space shooting materials of region territory, formation of offers and recommendations about the decision of problems, attraction of investments, redistribution of forces and the means put in development of a national economy.

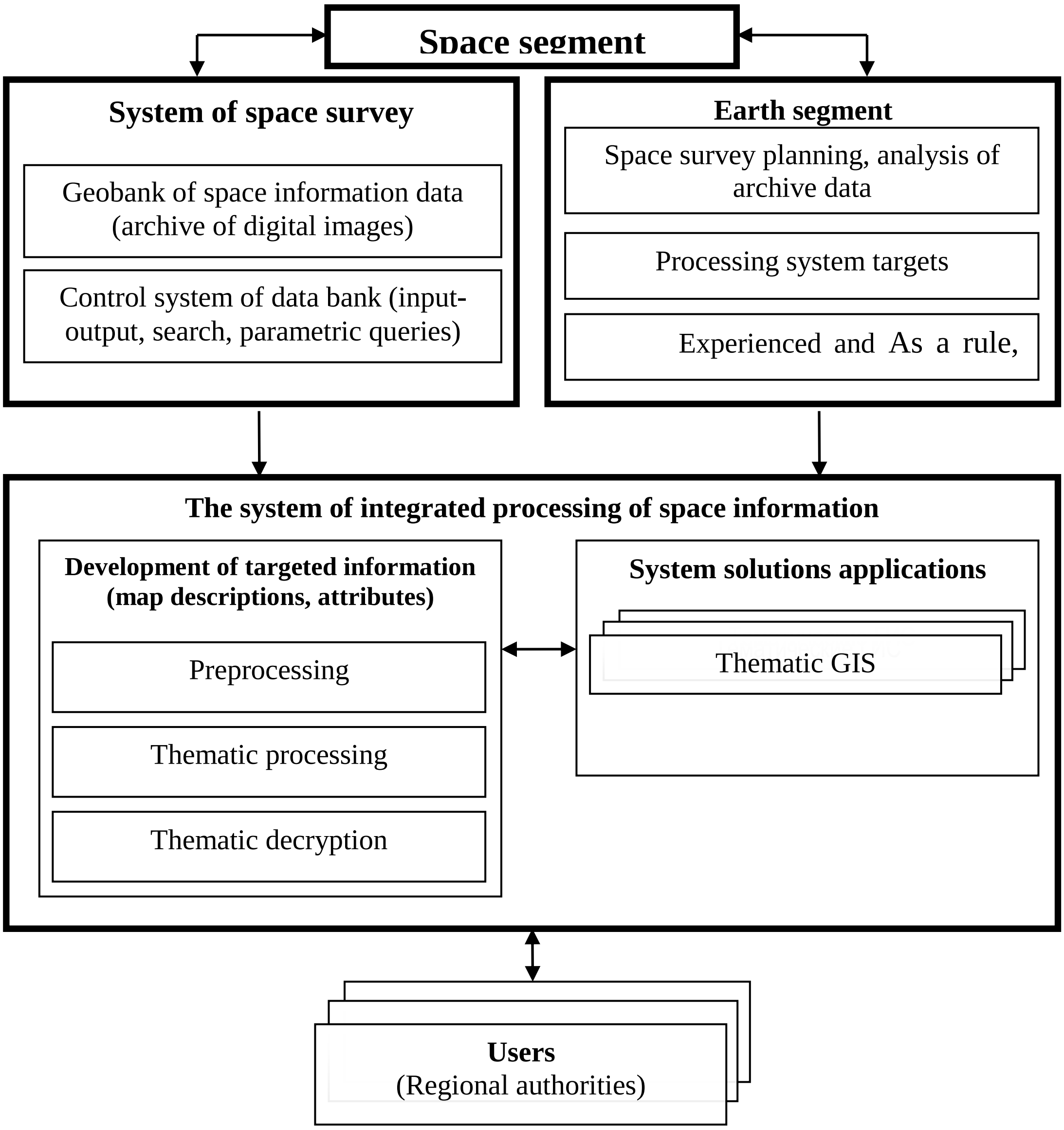


Figure 1. General technological scheme of remote space monitoring

However use ERS on the basis of the data received from modern satellite equipment, along with doubtless advantages, possesses also a number of lacks. Basic lacks ERS are huge volumes of the satellite photos databases, essential timetable for preliminary processing of primary satellite photos, decrease in quality of pictures under adverse weather conditions, necessity of licenses purchase since there is no status of a public condition of the photos received from modern commercial satellites, problems of the state secret preservation.

Use of modern flying machines (aircrafts, helicopters, unmanned aerial vehicles (UAV), equipped with special equipment is one from the perspective approaches expanding and supplementing ERS possibilities.

Thus especially it is necessary to allocate UAV use, capable to transfer not only the visual information, but also a number of other data, which acquisition it is complicated, and so it is impossible when other kinds of techniques are used.

UAV management method offered in the second subsection with use of digital imaging systems (DIS) allows expanding considerably a circle of solved problems, to raise quality and reliability of the achieved information, to lower risk of the device loss.

In the third subsection of the given work the method, allowing to estimate information capability of the achieved pictures is offered, and to reveal the areas containing the images of clouds or a smoke from fires. The stage-by-stage algorithm allowing with high degree of accuracy to allocate a zone of a possible arrangement of specified objects for the further processing is developed.

One of the important problems at the Earth's surface monitoring is detection and identification of objects. The mathematical method of restoration of the third coordinate (such as height) offered in the fourth subsection, is based on calculation of intensity curvature function for the image lines. Application of scale space representation (SSR) of images for the decrease of matching points amount is offered in this section, allows raising speed of image processing. It allows not only to conduct renewal of three-dimensional data of the Earth's surface in real time, but to track movements of transportable objects which were captured by satellite's camera. Efficiency of object tracking depends exclusively on frequency of data acquisition from the satellite which conducts certain Earth's surface region observation.

In the fifth subsection application questions of remote space monitoring territorially extended gas-transport networks (GTN) of a high pressure, management technological objects (MTO) having a significant amount the raised danger are considered.

2 SATELLITE IMAGERY FOR EARTH'S SURFACE MONITORING

2.1 Earth's surface image acquisition from satellites

2.1.1 General information

Space imagery of Earth's surface consists of photographs of Earth made by artificial satellites or other equipment, located outside the Earth atmosphere. Recently results of satellite imagery achieved wide distribution due to popularity and simplicity of processing. All satellite images, which were made and published by NASA, are distributed for free and are considered as a public property. There is also a list of private companies which execute commercial satellite imagery projects for different applications.

Satellite images have many applications in agriculture, geology, forestry, biodiversity conservation, regional planning, education, intelligence and warfare.

Images can be made in visible colors and in other spectra. There are also elevation maps, usually made by radar imaging.

Satellite image acquisition could have different application which depends on properties of the trajectory of satellite motion - orbit: inclination, elevation and synchronization of orbit. Depending on the chosen orbit it is possible to take pictures of a certain territory of Earth's surface with different frequency, under a different corner and at different luminosity, resolution and color detail levels.

Resolution of satellite images depends not only on the elevation of orbit but also from the type of photographic equipment.

On the first step of satellite image acquisition transformation of raw sensors data to digital image representations is applied. Type of transformation depends on the frequency range of photographic equipment. On the second step digital satellite images are put to different preprocessing operations: filtration of noise, merging of the color map of low-resolution and monochromatic high-resolution map to produce color images of the Earth’s surface, edge detection, merging and etc.

Forming and processing of color-brightness constituent of satellite imagery in a greater measure depends on the used range of electro-magnetic waves. In addition, for the analysis of large territories at the high level of detail it is necessary to merge together overlapping square satellite images to form rows and to merge rows of satellite images to form high-resolution maps of a certain territory.

Decoding and analysis of satellite images presently is mostly executed by automated or semiautomatic complexes of software.

2.1.2 Photographing the Earth’s surface from satellites at different orbits

Depending on the chosen orbit it is possible to achieve Earth’s surface images at different resolution and color detail levels. Orbits differ by elevation over the level of sea - altitude. There are low Earth orbit, medium Earth orbit and geostationary orbit. Low Earth orbits (LEO) are ranging in altitude from 0–2,000 km (0–1,240 miles). Medium Earth orbit (MEO) is ranging in altitude from 2,000 km (1,240 miles) to just below geosynchronous orbit at 35,786 km (22,240 miles). High Earth orbits are located above the altitude of geosynchronous orbit 35,786 km (22,240 miles). Obviously Low Earth orbits provide maximum resolution images.

Orbit altitude depends on the inclination and satellite motion synchronization. Satellite imagery for earth utilizes satellites flying at geostationary and polar inclined orbits for earth observation and geosychronization and geliosynchronization correspondently.

A geostationary or geosynchronous orbit is one in which the satellite is always in the same position with respect to the rotating Earth. The satellite orbits at an elevation of approximately 35,790 km because that produces an orbital period equal to the period of rotation of the Earth. By orbiting at the same rate, in the same direction as Earth, the satellite appears stationary - synchronous with respect to the rotation of the Earth).

Geostationary satellites provide global view, enabling coverage of weather events which is especially useful for monitoring severe local storms and tropical cyclones. But the use of geostationary satellites is limited to global change analyses only because of low resolution. Because a geostationary orbit must be in the same plane as the Earth's rotation, that is the equatorial plane, it provides distorted images of the polar regions with poor spatial resolution. This fact brings more limitation applied to the application of geosynchronous orbit satellites for satellite imagery.

Polar-orbiting satellites provide more global visual information, circling at near-polar inclination (the angle between the equatorial plane and the satellite orbital plane -- a true polar orbit has an inclination of 90 degrees). Orbiting at an altitude of 700 to 800 km, these satellites cover at high level of detail the parts of the world most difficult to cover on site.

Polar satellites operate in a sun-synchronous orbit. The satellite passes the equator and each latitude at the same local solar time each day, meaning the satellite passes overhead at essentially the same solar time throughout all seasons of the year. This enables regular data collection at consistent times as well as long-term comparisons and allows to eliminate influence of shadow casting and illumination variation.

Inclined orbits are ate the range from polar to geostationary. They have an inclination between 0 degrees and 90 degrees. Inclined orbits are located at altitudes of few hundred kilometers and thus pass a certain region on Earth each several hours. So satellites at inclined orbits are able to provide extremely high resolution images of a certain territory of the Earth's surface several times each 24 hours in a difference from polar satellites. These satellites are not sun-synchronous, however, so they will view a place on Earth at varying times which sometimes is a problem for the Earth's surface analysis.

Thus satellites circling at different orbits may be used for different real applications of satellite imagery. Global changes of certain Earth regions, such as weather changes, large fires and floods, could be detected at a high frequency with the use of geostationary satellites. High-resolution images of the Earth's surface could be photographed from polar satellites with a consistent illumination once a 24 hour cycle. Satellites circling at inclined orbits are able to observe a certain territory of the Earth's surface at extremely high level of detail several times each 24 hours.

2.1.3 Technical properties of space imagery

As it has been already noted the resolution of satellite images varies depending on the instrument used and the altitude of the satellite's orbit. For example, the Landsat archive offers repeated imagery at 30 meter resolution for the planet. For many smaller areas, images with resolution as high as 10 cm can be available. But most of it has not been processed from the raw data yet.

GeoEye-1 satellite provided the world's highest resolution commercial satellite imagery. The 0.41 meters resolution panchromatic images allow the satellite to distinguish between objects on the ground that are even smaller than half a meter apart.

However satellite imagery is not able to provide satisfactory details and may be subject to atmospheric noise and obstacles. That's why satellite imagery is sometimes supplemented with aerial photography, which has higher resolution, but is more expensive per square meter. Satellite imagery can be combined with vector or raster data in a GIS provided that the imagery has been spatially rectified so that it will properly align with other data sets.

2.1.4 Disadvantages of satellite imagery for the Earth's surface monitoring

Because the total area of the land on Earth is so large and because resolution is relatively high, satellite databases are huge and image processing (creating useful images from the raw data) is time-consuming. Depending on the sensor used, weather conditions can affect image quality: for example, it is difficult to obtain images for areas of frequent cloud cover such as mountain-tops.

Commercial satellite companies do not place their imagery into the public domain and do not sell their imagery; instead, one must be licensed to use their imagery. Thus, the ability to legally make derivative products from commercial satellite imagery is minimized.

Privacy concerns have been brought up by some who wish not to have their property shown from above. Google Maps responds to such concerns in their FAQ with the following statement:

"We understand your privacy concerns... The images that Google Maps displays are no different from what can be seen by anyone who flies over or drives by a specific geographic location."

2.2 Application of UAVs for the tasks of environmental and technological objects monitoring

UAVs play one of the key roles in solving problems of emergency monitoring. They allow solving a wide range of tasks for the Ministry of Emergency Situations (MES), Ministry of Defense, as well as the national economy. In particular, a UAV can be used as a robotic tool that can perform manufacturing operations in areas dangerous for humans. It is capable of conducting engineering, radiation, chemical and biological exploration; delivering extra special cargo; broadcasting and rebroadcasting the information in emergency situations dangerous for humans, and solving a wide range of other tasks. UAVs may well be engaged in environmental monitoring, protection of gas and oil pipelines and other strategic facilities including nuclear power plants (NPP), they can monitor the situation in the forests and peat bogs, traffic safety on the roads of the country, conduct ice reconnaissance.

In recent years the range of UAVs has expanded considerably that makes it possible to choose the most optimal variant for solving a particular problem. UAVs flight performance lies in a fairly wide range: the take-off weight is from several kilograms to several tons, the payload is from several to hundreds of kilograms, the flight duration is up to tens of hours, the range is up to several thousand kilometers, the speed is up to hundreds of kilometers per hour.

The advantages of such aircraft include:

- mobility and compactness;
- high degree of readiness for departure;
- variegated tasks performed;
- high flight and technical characteristics of the UAV;
- ease of maintenance and reliability;
- economic benefits in comparison with manned aircraft taking into account regular increase in prices of aviation fuel and services for execution of aviation operations and maintenance.

Besides, sometimes using UAV is the only way of solving problems in case of natural disasters and accidents.

2.2.1 UAV control by using DIS when solving emergency monitoring problems

The most flexible solution in emergencies is to use UAV remote control. The UAV control system should contain the on-board set (OS) which provides the following tasks:

- definition of navigation parameters, angles of orientation and motion parameters of the UAV (angular velocity and acceleration);
- UAV navigation and control when flying along the target trajectory;
- stabilization of the UAV orientation angles in flight;
- delivery of telemetric information about navigation parameters, angles of orientation of the UAV to the transmitting channel;
- payload control.

The operator controls the machine either by using a video camera mounted on the UAV or by using visual observation of the aircraft. The main disadvantage of this method is the limited range of control which varies from a few kilometers by visual observation up to several tens of kilometers using the video channel. In addition, control becomes impossible in the dark, in conditions of limited visibility or its total lack, in case of strong interference in the video channel.

Due to the absence of visual contact with the ground even when radio equipment is available the operator-pilot undergoes a serious psycho-physiological stress that prevents the adoption of proper decisions. It may lead to the failure in accomplishing the task or to crash.

To date a large number of devices that enable to improve the accuracy and reliability of UAV remote control in poor visibility conditions has been developed. However they all have limitations that do not allow controlling the aircraft in rapidly changing external conditions typical for emergency situations (ES).

To eliminate these shortcomings we propose using DIS for UAV control [Gusyatin, 2002]. The principle of UAV control by the proposed method is shown in Fig. 2 a. DIS ensures the production of the image of the UAV surroundings on the basis of telemetry data (linear coordinates, determined by means of GPS or GLONASS receiver and the angular ones defined with the help of sensors installed on board the UAV), coming from aircraft OS, height map and, if possible, area images obtained by a satellite or from a database. As a result the operator can see the qualitative synthesized image of terrain over which the flight is realized regardless of the actual weather conditions and control the UAV.

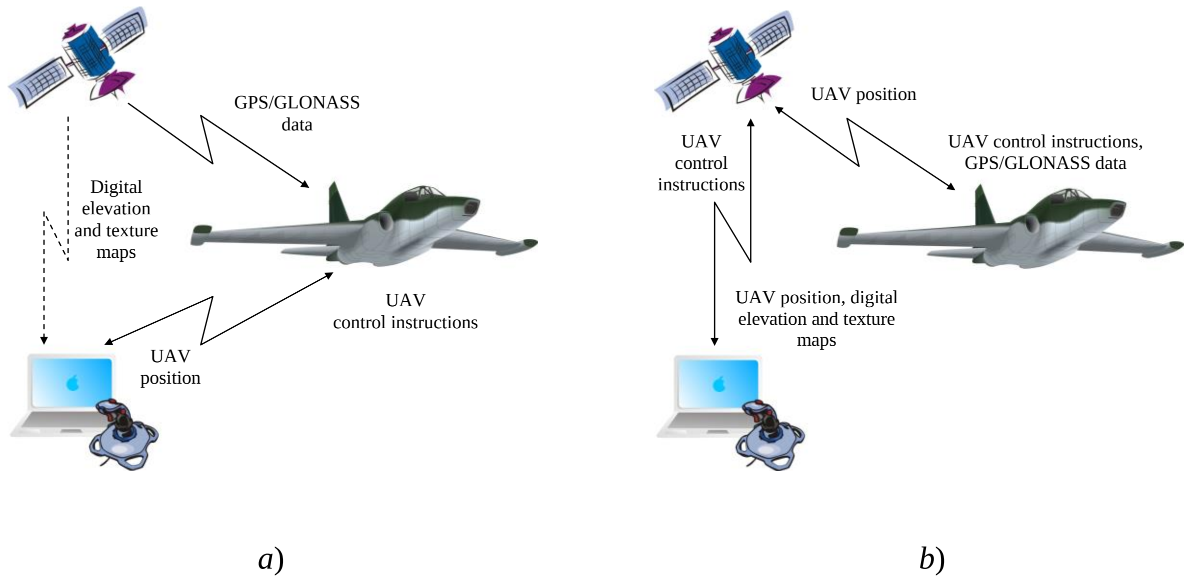
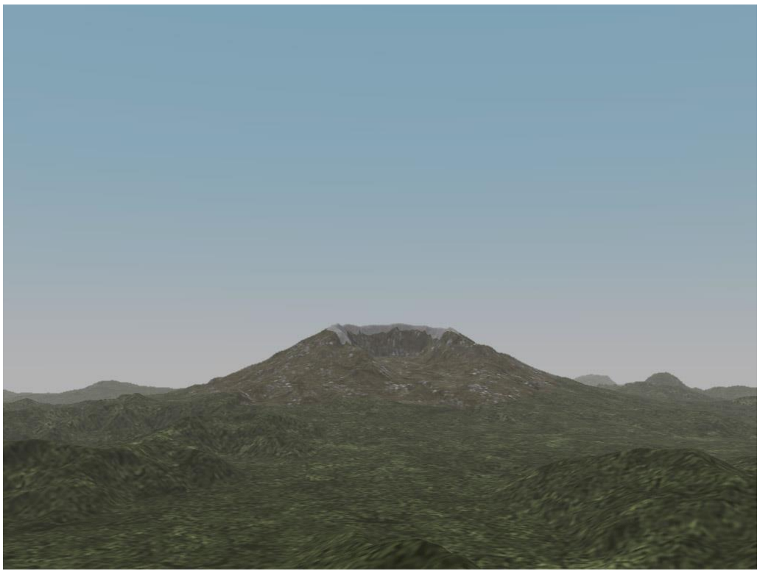


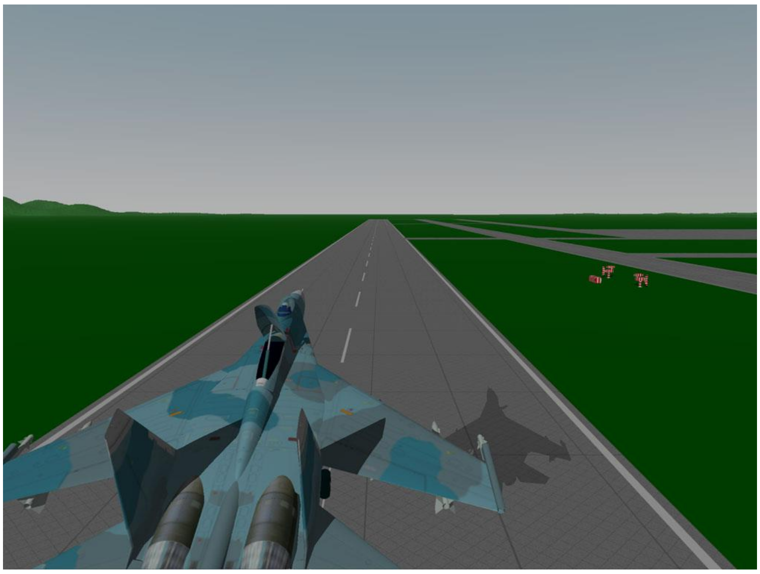
Figure 2. The principle of UAVcontrol with the use of DIS. *a) direct data link between the UAV and DIS; b) data link between the UAV and DIS via satellite*

Another advantage of this method is the reduction of the amount of information being transmitted, since there is no need in the video signal to control the UAV that will increase reliability and reduce power consumption.

Using a channel of communication via geostationary satellites will extend the UAV range because there is no necessity to install repeaters on the flight path and reduce the risk of accident due to miss of communication signal. The principle of UAV control by the proposed method is shown in Fig. 2 b. In this case the data about the UAV position calculated by OS is transmitted via satellite to DIS, and control commands from the operator also via satellite are received by the UAV. Figure 3 shows image frames obtained as a result of DIS work. Fig. 3 *a* shows image of terrain, synthesized using digital elevation and texture maps. Fig. 3 *b* shows image of airport environs in the landing of aerial vehicle.



a)



b)

Figure 3. Images synthesized by DIS *: a) image of terrain; b) image of airport environs.*

2.2.2 DIS structure

DIS structure is shown in Figure 4. DIS contains the following blocks: a universal computer, a specially designed graphic processor unit (GPU) and a graphics display device (DD).

Data from the UAV OS represents three linear (x, y, z) and three angular coordinates (φ, θ, γ) determining position and orientation of the aircraft in space. Terrain data represents a map of heights H (x, y) and the area image in the form of a texture map T (x, y). In addition, if necessary, data about the position of artificial objects O containing information on their type, position, size, etc. can be transmitted to the mainframe.

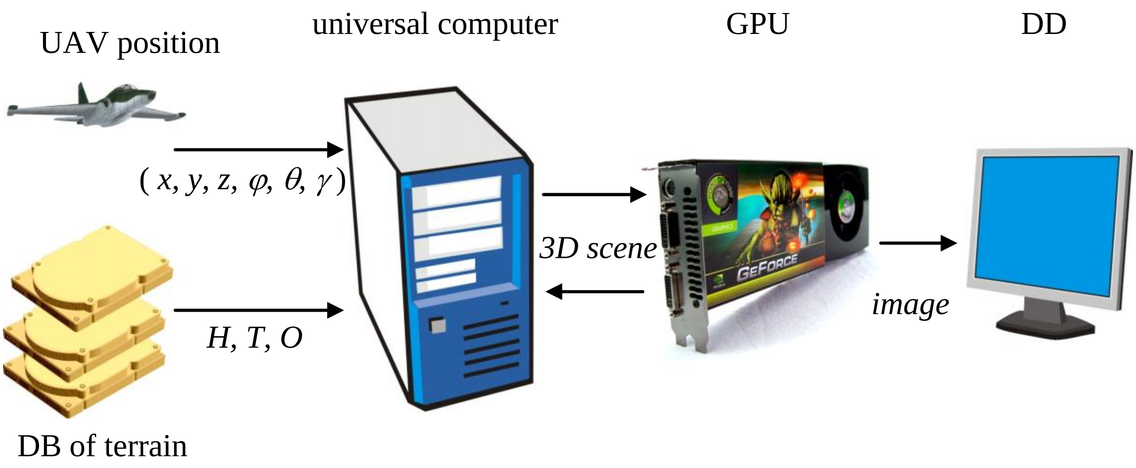


Figure 4. DIS structure

The mainframe performs calculations that do not require a great performance - "slow" calculations:

- processing of information on the position of objects in the scene;
- processing of information about changes in illumination (position of light sources);
- scanning the scene space;
- loading the data to GPU storage devices;
- implementation of the visualization system operator interface.

Partially processed data are then fed to the GPU where calculations are made requiring high performance ("quick" calculations). The frame image formed in the GPU is presented on the display device.

2.2.3. Requirements to modern visualization systems

To obtain a realistic dynamically changing picture the visualization system must meet several requirements which can be formulated when analyzing the human vision mechanism and the work of its nervous system. The perception of a light pulse entering the eye is realized with a delay. When the pulse action ceases a visual sensation retains for approximately 0.14 sec. [Vavilov, 1981].

Whereas to achieve a smooth motion during the scene synthesis it is necessary to form at least 30 frames per second [Babenko, 1984; Krasovsky, 1995]. The output of generated images is displayed mainly on the dot-matrix output device. The image appears as a set of discreet elements called pixels (from ‘picture element’ in English). The size of pixels as well as their number is fixed. The richer the content of the scene is the greater is the amount of information contained in it, i.e. the higher the realism of the displayed scene is the greater the number of elements in the image must be for its full transmission.

The ability of a photorecording device to integrate a signal in space and time improves the signal to noise ratio [Hall, 1979]. When watching a television image with the fixed number of elements in the frame the eye can realize space integration at the stage of observing the image obtained. And since the vision inertia time is longer than the demonstration time of a single frame a time integration is implemented. Human vision is characterized by space integration in the angle ~ 0,5 º [Hall, 1979; Lloyd, 1975] and time integration within the vision inertia time is about 0,1 - 0,2 sec. [Rose, 1973; Leonov, 1977].

Thus on the basis of the analysis of the visual and nervous systems of man we can form the basic requirements to the visualization system operating in real time. The system must provide the image frame in no more than 0.14 sec from the moment of receiving the input signals. To obtain a realistic image the angular resolution of the system must be not less than 0.02°. And the number of synthesized frames per second should be not less than 30.

2.2.4. Methods for obtaining dynamically changing realistic images in real time

DI systems display information about processes or objects in the form of a synthesized image on the display screen. Unlike other systems the sources of input information here are not physical processes or objects themselves but their mathematical models. In general the models appear as sets of data, numerical characteristics, parameters, mathematical and logical relationships which reflect the structure, properties, interconnections and relationships between the object elements as well as between the object and its surroundings.

The method most widely used when synthesizing the image is the one of ray tracing according to which we simulate a geometric path of each light ray being involved in image making. This process is based on the laws of geometrical optics such as the laws of refraction, reflection, linear propagation, etc.

The basic idea of the ray tracing method is reduced to doubling on a computer of all the geometric transformations which each light beam would make on the way the source - the object - the receiver. In this case we only consider the rays falling to the center of receptors or coming from a limited number of points on the image surface. On the basis of the law of light rays reversibility one can model a beam path both on the way the object - the image and the reverse one. Therefore two ways are distinguished: direct and reverse tracing. In direct tracing we take a point calculated on the image surface as the primary position and simulate the path of a ray from it both to the light source and the receiver of the image. In reverse tracing a receptor center at the image receiver is taken as the primary position and the path of a ray from it to the object and further from the object on the source of light is simulated.

Advantages of the direct tracing method: a smaller amount of computation needed for synthesis of low and medium complexity scenes; uniform representation of all the objects in the scene. Disadvantages: the need for objects approximation (the need for preliminary triangulation), the complexity of applying textures and calculating the brightness of points on the surface, the difficulty of parallelizing the computation process.

The reverse ray-tracing method is more preferable when processing very complex scenes because it is very easy to make a classification of the scene objects and identify those having appeared in the visible region. Moreover it becomes possible to handle analytically the figures described without their preliminary triangulation thus avoiding extra transformations and significantly improving the quality of synthesized images.

Performance of today's universal computers has reached rather high level but it is still not enough to perform the tasks of image processing in real time. Therefore at present DIS development is carried out in two directions: the use of mainframes with increased productivity and the use of specialized image processing systems.

Making realistic images in DIS requires transfer and processing of large volumes of data [Babenko, 1984; Kovalev, 1988]. The number of natural (mountains, rivers, rugged terrain, forests, cloud layer, etc.) and artificial (houses, roads, factories, airfields, and various buildings) objects in the scene must be sufficiently large in order to achieve the necessary level of realism. This in turn also requires the transmission and processing of large volumes of information that greatly increases the system performance requirements.

Getting realistic images of a scene is impossible without processing the atmospheric and meteorological conditions in accordance with the existing standards. It is also necessary to be able to form the scene image for different seasons in the daytime, in the twilight and at night [Babenko, 1984; Kovalev, 1991; Mazurok, 1994].

Currently in the vast majority of systems the isotropic model of the atmospheric layer is used [Mazurok, 1994; Gusyatin, 2000]. This approach greatly simplifies the calculation of the atmosphere transparency and gives good results if there are minor changes in the position head of the observer and the objects in the scene. When these conditions are not met (for example, for the aircraft trajectory), the realism of synthesized images is greatly decreased.

Real time for DIS implies that the image frames change each other every 33 msec or more frequently. Since most of the calculations must be performed during a single frame image, the DIS performance should be about several trillion operations per second. Such operations must be complex like multiplication, division, exponentiation, the computation of trigonometric functions, etc.

To date the cost of systems with universal computers having this capacity, as it is evident from the above review, is quite considerable. Therefore, most of the world's largest DIS producers develop and use specialized computer systems.

Specialized microchips which are the foundation of all modern three-dimensional graphics cards have performance high enough for real-time (ATI Radeon R800, Nvidia GT200). These processors contain large quantities of ALU which can be programmed using CUDA technology from Nvidia or Sream SDK from ATI to solve both the issues of visualization and mathematical problems.

2.2.5. General structure of DIS graphic processor unit

Block diagram of special graphic processor unit is illustrated in Figure 5. GPU contains n separate channels. Each channel can handle objects of different types of scenes such as synthetic mobile and stationary objects, relief, cloud formations, light sources, etc.

Objects of each of these types are stored in its database (DB) and processed separately. With such a division parallelization of scene processing and optimization of processing each type of object becomes possible.

The sources of data for imaging the earth's surface are digital height maps which, depending on the situation can be transmitted to the GPU by a satellite in real time, or taken from the database formed in advance. To improve the quality of synthesized pictures the images of the area obtained in the aerospace photography can be drawn on the Earth's surface formed.

Artificial mobile and stationary objects included in the synthesized scene are taken from the database on the ground of the analysis of aerospace images of the terrain we are interested in and the subsequent identification of objects. The description the analysis is given in the following sections.

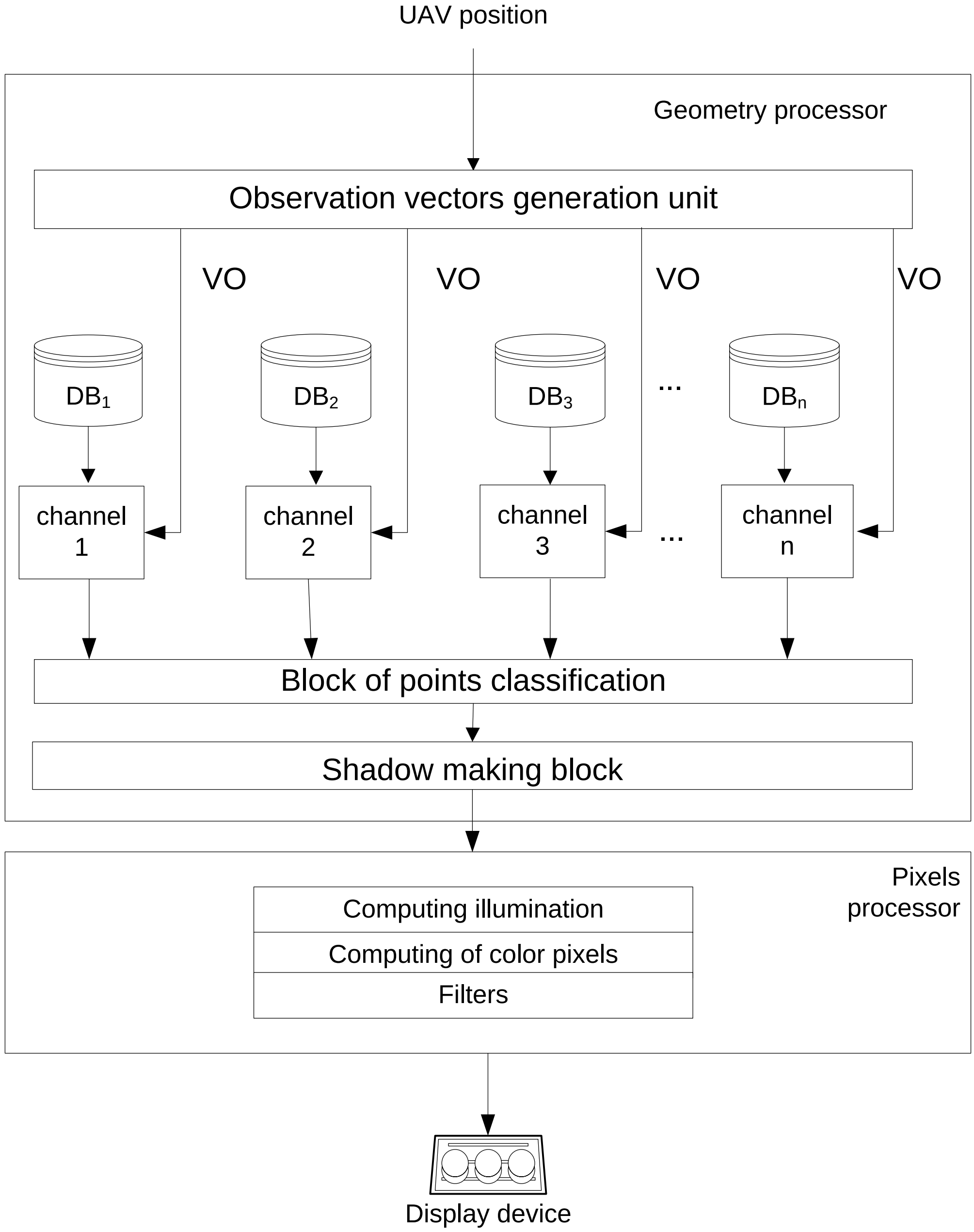


Figure 5. Graphic processing unit structure chart

Special graphic processor unit is a frame pipeline, so data about the scene changes enter DIS for each frame image: a new position of the observer from the channel of communication with the UAV, the location of objects in the scene and light sources as a result of area image analysis. At certain moments of time the position of the display system corresponding to the next frame image is fixed that completely defines the position of all the vectors of observation (VO) relative to the base coordinate system. Observation vectors generation unit produces all the vectors of observation VO corresponding to the current situation of the monitoring system. VO comes to specialized calculators of all channels and each of them produces rays tracing for a certain type of objects in the scene. Each type of the objects listed above has its own characteristics permitting to optimize each of the specialized calculators for the fastest possible visualization of objects of this type with the lowest hardware cost.

Each of the calculators generates the following output: position (coordinate information), surface color, normal (vector-gradient) to the surface at the given point of intersection, surface properties, transparency, etc. This data comes to the block of points classification, which sorts them by distance and eliminates the invisible points (not requiring processing). The remaining points come to block the formation of terrain and artificial objects shadows where the information is supplemented by data as for the presence or absence of shading. After the shadow making block the information comes to the pixel processor, where the color of the pixel is determined on the basis of information received [Bugriy, 2004; Ostroushko, 2004]. In the pixel processor the image filtering is realized to remove aliasing.

3 ANALYSIS OF INFORMATION CAPABILITY OF AEROSPACE EARTH MONITORING DATA

3.1 Analysis of detail level and overlapping of aerospace Earth images for information capability

Modern satellite systems have reached high precision, which allows for detailed monitoring of the Earth's surface, monitoring of atmospheric processes and even talk about the possibility of building security and timely response systems in emergency situations, based on aerospace survey systems. However, the use of these systems to monitor moving ground targets is highly expensive in terms of performance computing, because it requires the work of the satellite equipment at its maximum power to produce an image at maximum capacity. To effectively detect moving objects (ground transportation) and the danger on the original cosmic survey's images, a prerequisite is to obtain the source satellite imagery with a spatial resolution not less than 500 mm.

Peculiarity of space survey is the presence of atmospheric fronts, which may interfere geo-spatial monitoring. To detect clouds and atmospheric fronts it is necessary to develop a cloud detection algorithm, which will allow proper pruning of these areas of satellite image. Also, this system can be used for automatic monitoring of atmospheric fronts for the weather forecast and floods.

Along with the problem of partial or complete image's overlap by clouds, there is a problem of the observed images object deformation on the reason of the shadows. This problem, to date, no universal solution, so to solve this problem, uses different methods depending on the tasks and the observed objects.

An important characteristic of aerospace monitoring is the frequency of shooting. To meet the challenges of weather forecasting adopted the optimal time of shooting - 6 hours. Let’s try to analyze the required frequency of shooting in order to achieve sufficient information capability of aerospace surveillance, while ensuring the safety of industrial facilities. GeoEye-1 satellite, owned by GeoEye Inc.[www.satimagingcorp.com, 2010], has the most modern parameters, to date, as satellite that used for civilian purposes Earth monitoring. For example, let’s take parameters of GeoEye-1 satellite to calculate the frequency of shooting necessary to monitor moving ground targets, while ensuring safety at sites such industrial facility, the pipeline. According to the organization GeoEye Inc., satellite, GeoEye-1 for one image can cover a square with a side of 15.2 km. As a cross-country ground transportation will take a main battle tank T-72. Speed of the T-72 cross country up to 45 km / hour. If we assume that the protected area is located in the center of the image, then we can conclude that it is necessary to capture the motion of the object before it reaches the center of the territory. Thus, it is necessary to photograph an object at least once while he covered a distance of 7.5 km (minimum for perpendicular directions). At a speed of 45 km / h, transport, moving on cross country, covers this distance in 10 minutes. It is therefore necessary to shoot the protected object and the contiguous territory not less frequently than once every 10 minutes. Given the characteristics of satellites, alleged by GeoEye, low-latency capture the same territory is 2 hours. Thus, we can conclude that the frequency of shooting from a satellite - not enough, so images from the satellite can be used only for monitoring the construction of buildings on the protected area.

Analysis of methods and technologies for Aerospace Surveillance shows that monitoring of large industrial facilities could more efficiently be conducted with the help of UAVs. However, the best monitoring results can be achieved by combining the two systems of monitoring: global monitoring of protected objects from satellites, and clarify the situation in the emergency areas, as well as those at heightened risk, with the help of the UAV.

3.2 Detection of clouds and fire based on the model of active contours

Images obtained by the means of aerospace vehicles are fuzzy. Weak contrast, usually caused by a wide range of reproducible brightness, often combined with non-linear characteristics of transmission levels. The nature of the variation of pixel brightness from minimum to maximum value also affects the image quality. Therefore, signs of objects can be distorted and not well identifiable. Correction of brightness palette significantly improves image quality. Contrast the original image will improve the efficiency of algorithms for segmentation and clipping of clouds in the image, so you first need to increase the contrast.

The clouds have a fractal structure, because of their image on the photograph will have an arbitrary shape with partially or completely blurred. The most effective method to extract the boundary of arbitrary shape objects is a method of active contour. Problems of this kind have been solved by the authors in the measurement of intraocular pressure [Belous, 2009].

Applying active contour method it is assumed that the desired boundary in the image is a smooth curve on a two-dimensional image. The initial data is given an initial approximation to the boundary in the form of a closed curve which does not necessarily correspond to the actual situation of the border, but close to it. This curve relies flexible and extensible, and under the influence of external forces, it is deformed and shifted so as to best meet the boundary.

Usually, when solving the problem of detection limits, on the original image are determined by the point of maximum gradient, which then bind to the border. The method of active contours using fit initially continuous closed line to the position of maximum gradient. The final state corresponds to the achievement of minimum potential energy of the model line. External force, under the action of which the line is deformed and displaced, depending on the source image. Inner strength, impeding change, determined by the properties of the model. This inner strength, preventing too sharp bends strings, performs the same role that image smoothing before computing the gradient: reducing the influence of small-scale noise. This fits the usual force of elasticity [Soifer, 2003].

The main disadvantage of the active contour method is the need of the initial boundary approximation and big computational cost, which value depends on the accuracy of the initial approximation provided. Also a problem of forced premature stop of local minima approaching process when the initial approximation of the set is not very accurate [Terzopulos, 1987]. Solving the problem of cloud detection borders of averaged brightness regions, that respect to clouds and thus have maximum brightness value within an image, can be used as initial borders. Thus, the problem reduces to the allocation of closed regions with high brightness and subsequent refinement of the cloud on the given image.

Promising solution to this issue is the method of «Magic wand». Method «Magic wand» it was the first interactive segmentation methods, however, it can be successfully used to work in automatic mode, if properly set the initial point of the object [Davidov, 2007]. To use this method indicates one or more starting points of the object, and the algorithm selects the neighboring pixels with similar color and adds selection to the object. To assess the "similarity" is defined by thresholds distance between colors. At the same time in the region "similar" colors are allocated only connected pixels.

The method works effectively for the allocation of sufficient monotone in color objects. With severe color variations accurate distinguishing of objects against the background by the use of this algorithm is impossible. If the threshold is too low sensitivity cannot devote a large portion of the object. Increasing the threshold leads to the fact that the selection "takes place" outside the facility. In the case of spotted an object or blurred boundaries between the background and the object of the algorithm is practically helpless [Soifer, 2003].

For use «Magic wand» require an initial reference point, and install them is problematic because of the possibility of covering the territory of the rented snow. The most effective is the segmentation of images on objects using the method of search boundaries on the basis of the gradient and the subsequent use of the above methods.

Allocation limits based on the gradient is one of the easiest ways to select boundaries. Data is based on a spatial differentiation of brightness functions [Soifer, 1996]. For the two-dimensional intensity function A (x, y) differences in the directions x and y are recorded partial ∂ A (x, y) / ∂ x and ∂ A (x, y) / ∂ y, which are proportional to the velocity change of brightness in the respective directions.

The disadvantage of the algorithm is that it passes borders with small differences of brightness and includes a number of border parts of the image containing large changes of brightness. Noise source image will contaminate the filtered image, since it considers only the boundary points [Davidov, 2007].

Original image of aerospace survey carries a large number of small objects, which are not informative because of cutting off the clouds. Using of Gaussian smoothing filter will provide an opportunity to reduce the influence of the above objects in the original image. To restore the cloud, fuzzy Gaussian filtering, as well as to improve the clarity of the boundaries proposed to subsequent increase of contrast methods of linear contrast. Thus, for solving the problem of cloud pruning on the image the following algorithm of aerospace survey will be effective.

At the first stage is filtering by a Gaussian to smooth the boundaries of clouds.

At the second step use contrast modification of images, this technique will provide a more accurate light cloud and smoke.

The third stage performs grading images for the separation of images into separate zones. For maximum accuracy and garbage collection is used for grading algorithm Sobel. The algorithm uses Sobel eight counts of brightness in the vicinity of the central point, [homepages.inf.ed.ac.uk,2010].

$$G(x, y) = \sqrt{Gx_{x,y}^2 + Gy_{x,y}^2}\ ,$$

$$G(x, y) \cong \left|Gx_{x,y} + Gy_{x,y}\right|,$$

$$Gx_{x,y} = \left[A_{x-1,y-1} + 2A_{x-1,y} + A_{x-1,y+1} \right] - \left[A_{x+1,y-1} + 2A_{x+1,y} + A_{x+1,y+1} \right],$$
$$Gy_{x,y} = \left[A_{x-1,y-1} + 2A_{x,y-1} + A_{x+1,y-1} \right] - \left[A_{x-1,y+1} + 2A_{x,y+1} + A_{x+1,y+1} \right].$$

G (x, y) - brightness values point at the coordinates x, y after the operation of the gradient;

$Gx_{x,y}$ – intermediate value of the gradient along the x parallels;

$Gy_{x,y}$ – intermediate value of the gradient along the y parallels;

A(x,y) – brightness values in the point of coordinates x, y;

The fourth step is the union of similar images in the zone of brightness using the algorithm "magic wand". Last, the final stage, divides the image into zones of high brightness (clouds), and the zone of low brightness (of the Earth's surface). As a result of this algorithm to obtain an image, divided into zones of high brightness and low brightness areas. Zones of high brightness may represent clouds or smoke. To determine whether clouds of smoke have been detected it is necessary to analyze the shape of clouds.

4 OBJECT DETECTION AT AREAS CONDUCIVE TO ACCIDENT

4.1 Aerospace image analysis for object appearance and disappearance detection

Object detection and tracking is one of the most important parts of the external surveillance of areas conducive to accidents. Tasks range, which requires prompt object detection that appear to be exposed to danger or present danger for the area of appearance, allows avoiding the emergency situations of local and global levels, is very wide. It includes detection of heavy transport and moving equipment above an underground gas pipelines, spontaneous building of dwellings and production structures near-by ground or above the underground chemical or explosive substance storages, illegal garbage dumping and a lot of other tasks.

Large amount of different methods of aerospace object detection and tracking has been offered up to present. The methods of object detection based on certain characteristic features were developed by [Mayer, 1999] and [Gerke, Heipke, 2001]. Basic problem, attended with the use of the methods of this group is absence of temporal data utilization, simplifying detection of new object, and also presence and position translation of shadows aside object data, that complicates introduction of stable features.

The methods of finding out appearance of transportable objects are offered based on spatiotemporal aerial and space image photigrammetric change analysis. Objects detection is carried out by forming backgound object and earth surface map, i.e. steady background. Whereupon appearance of objects is revealed by comparison of new images against the background map [Lei, Li, 2008], [Hinz, 2004], [Grabner, 2008]. The basic lack of this approach is also influence of shadow cast and earthly surface illumination changes. In the case of satellite image analysis this limits the application of the plain spatiotemporal approach out to global change detection that could be vegetation of the fields, finding out submergences, large fire spots as well as large buildings and others.

However development of methodology of shadow casting modeling, detection and removal applied to aerospace images makes possible the detection of small transport objects after this kind of preprocessing as shown by [Zhao and Nevatia, 2003] and [Hinz, 2004]. Methods of searching for transportable objects allow to determine the size and the speed of objects, and also to track vehicles, but require high frequency update of images and high resolution, which is not always possibly in the area of monitoring of large territories and is impossible for the satellite monitoring.

The other effective approach of object detection, no matter new or old they are, is application of photogrammetry for calculation of three-dimensional model of the Earth's surface [Paparoditis,1988], [Masafumi Nakagawa, 2002]. This approach is widely used in the area of in GIS map reconstruction. Reconstruction of 3D information is possible because of the directional flight of a satellite or an unmanned aerial vehicles above the inspected territory and overlapping of neighbor images, which allows utilization of the pair/triples of neighbor images for point-to-point matching and reconstruction of 3D point coordinates of the territory surface (Fig.6). The separation of shadow is considerably simplified thus. Also new important information appears for the analysis - not only plane sizes but also height data of objects is detected. The problem of approach is low speed of 3D data recovery that eliminates the use of approach in the conditions of time limitations while monitoring emergency objects.

One of the most effective approaches to decrease temporal expenses at 3D data recovery is to decrease the amount of the compared points by the means of building of a representative set of characteristic points [Mikolajczyk and Schmid, 2002], [Lazebnik, 2005]. This approach is utilized mainly for stereometry surface recovery in the case when pair or sets of images are presented at different scales or are subject to different project transformations. However the application of 3D data recovery on the horizontally translated pair of images is obviously also possibly and will provide reducing of calculation expenses on point matching and 3D data calculation.

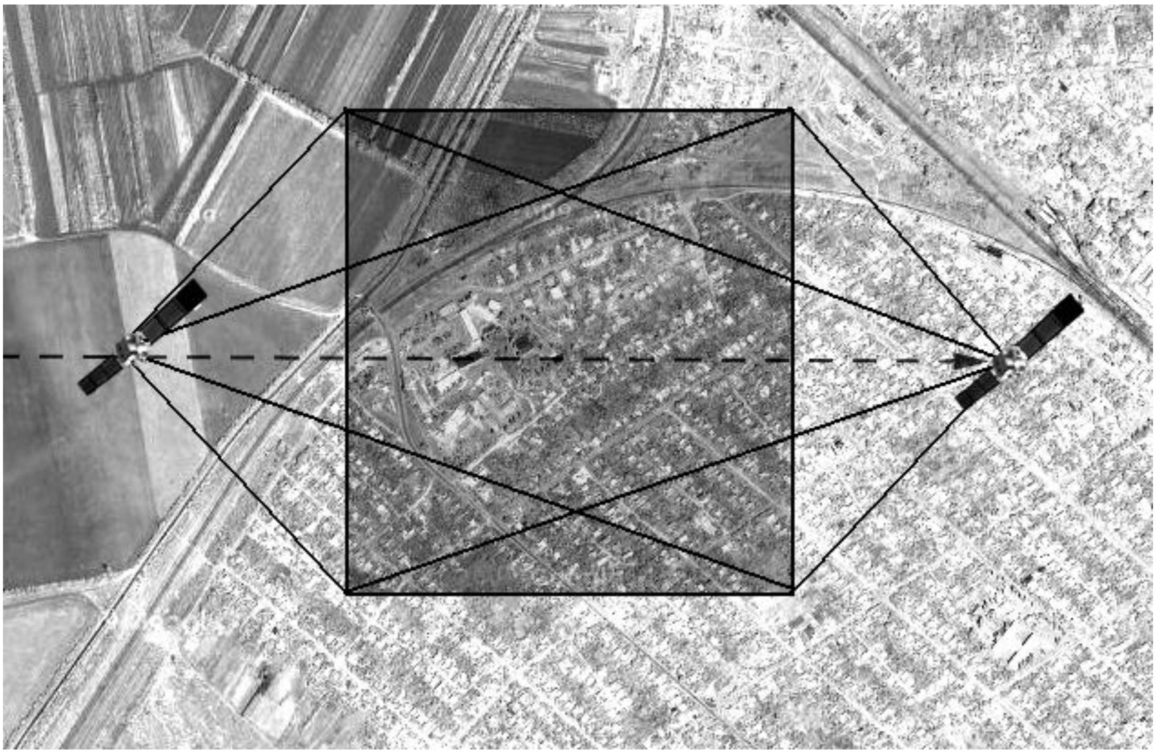


Figure 6. The overlapping of a terrain images made from the moving satellite

Application of the combined approach, utilizing spatiotemporal presentation of the recovered Earth's 3D surface data is offered in this work. Utilizing scale space representations of images is thus offered for renewal of three-dimensional information for the considerable decrease of point match operation amount by the means of selection of the most informative image points and regions.

Application of scale space presentations has shown good results at different problem areas, where the selection of informative/characteristic points is providing high decision-making accuracy at considerably increased performance [Belous and Kobzar, 2008], [Kobzar, 2008], [Bilous and Bondarenko, 2008].

A task of 3D data reconstruction by the pair of aerospace images is less complex by calculation expenses as compared to similar tasks from other areas, where it is necessary to take into account not only horizontal translation of points at the change of view point but also vertical translations, conditioned perspective distortions and rotation. I.e. the task terrain 3D surface map reconstruction consist in detection of matching points at both images, achieved from different view points, and the calculation of the third coordinate having the relative displacement of such points (Fig.7).

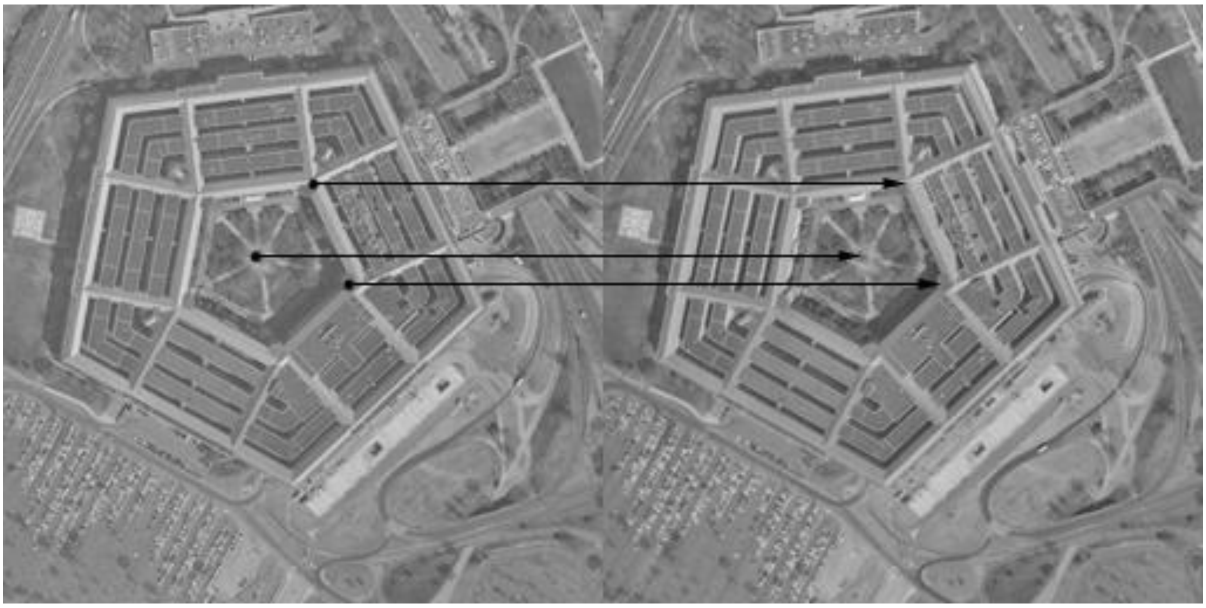


Figure 7. Point matching of the stereo pair of satellite images

The offered application of scale space representation of images for the decrease of matching point amount supposes the successive calculation of curvature function at different levels of scale in image rows while they are scanned in any order. Thus, by submitting intensity as the function of the point translation on a horizontal line of the surface, we get a continuous curve defined by equation in an obvious form *y = y(x)*, for which curvature is calculated by a formula:

$$k = \left| \ddot{y} / (1 + \dot{y}^2)^{3/2} \right| .$$

Real digital images acquired from satellites could be used to produce discrete curves only. Such discrete curves in general case can contain hollows and peaks. As differential description, curvature is very unsteady to discretization and noise and cannot be utilized for finding of characteristic points as it applies to an initial curve. For this reason representation of curvature is offered at different levels of scale by the means of curvature function convolution with Gaussian kernels of the successively increased width [Linderberg, 1994]:

$$L(x;\sigma) = \int_{\xi=-\infty}^{+\infty} g(\xi;\sigma) f(x-\xi) d\xi ,$$

$$g(\xi;\sigma) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\xi^2/2\sigma}$$

where $g : \mathrm{R} \times \mathrm{R}_+ \setminus \{0\} \to \mathrm{R}$ it is the Gaussian kernel.

As a result of tracking curvature zero-crossing points, all the points that do not present considerable intensity changes of initial image rows are eliminated. Introduction of a certain scale threshold level provides selection of the set of characteristic point which influence on the image intensity gradient is considerably even at the high levels of scale. Such points are assuredly represented at two images of the same territory and, in most cases, represent edges of certain objects, even if the point of view changes. I.e. acquisition of characteristic point set makes it possible to recover basic surface height changes and detect objects, located on a certain Earth's surface territory.

Comparing surfaces of certain territory, recovered in different moments of time, it is possible on divergence of intensity and geometrical (height above the locally averaged level of the Earth's surface) difference with high accuracy to expose objects appearance or disappearance of size that would depend only on image resolution.

4.2 New approach to m-weight based calculation of curvature function estimation

As a differential characteristic, curvature is very unsteady to discretization and noising of images. Therefore, for providing of acceptable noise immunity at construction scale-space representations the function of curvature must be estimated indirectly.

Next formulation of m-weight of curve by which it is possible to formulate the estimation of curvature and satisfying to the requirement $\lim_{m \to +0} k_m = k$ (requirement for all estimations of curvature) is offered. For the calculation of such m-weight of curve the points of curve are needed only. The initial geometric curvature estimation method was proposed in [Karkischenko 1998].

It is proposed to use m-estimation of curvature to build curvature base scale-space representations to increase the rapidness of such representation construction. Proposed m-estimation is given in 2-dimentional parametric form of curve representation because it is easily converted to 1D form of ECG but may have a lot of other application in 2D [Belous and Kobzar, 2009].

Lemma 1. Let m is neighborhood of point $\gamma(u) = (x(u), y(u))$, into which m-weight of curve given in parametrical view $\Gamma = \{(x(u), y(u) \mid u \in [0, L]\}$ is estimated. Then the following asymptotic formula $v_m = v_m^o + O(m), m \to 0$ takes place, thus v_m^o calculated on the following formula:

$$v_m^o = \left| S_m^o - \bar{S}_m^o \right| \Big/ \max(S_m^o, \bar{S}_m^o),$$

where $S_m^o, \bar{S}_m^o$ – are areas of sectors of circumference with a radius Δu :

$$S_m^o = \pi m^2 \angle(\overrightarrow{v^-}(u), \overrightarrow{v^+}(u)) / 360°$$
$$\overline{S_m^o} = \pi m^2 \angle(\overrightarrow{v^+}(u), \overrightarrow{v^-}(u)) / 360°$$

where $\overrightarrow{v^{-}}(u)$ - a vector connecting the point of curve $\gamma(u)=(x(u),y(u))$ and $\gamma^{-}(u)=(x(u-m),y(u-m))$;

$\overrightarrow{v^{+}}(u)$ - a vector connecting the point of curve $\gamma(u)=(x(u),y(u))$ and $\gamma^{+}(u)=(x(u+m),y(u+m))$ (fig.8).

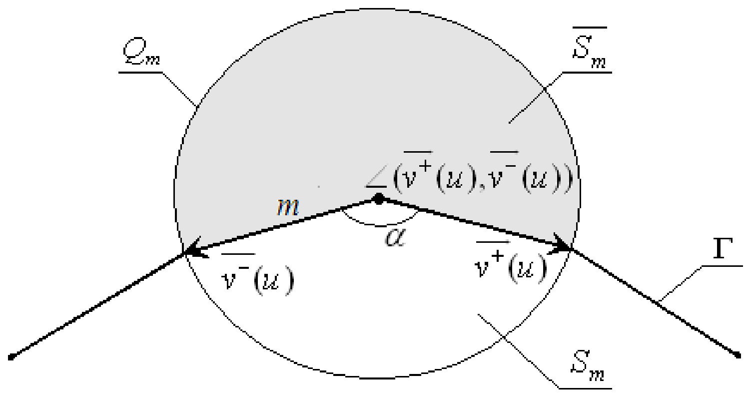


Figure 8 Neighborhood for m-rate of function of curvature of contour curve

Lemma 2. Let $m=\Delta u$ is Neighborhood of point into which curvature of curve Γ given in parametrical view $\Gamma=\{(x(u),y(u)\,|\,u\in[0,L]\}$ is estimated. Then the following asymptotic formula takes place:

$$k=3\pi v_m^o/(4m)+O_m^o(m),\ m\to 0\,.$$

Lemma 3. It is possible to assert that it is possible to obtain finding of estimation k_m^o with required accuracy at estimating of curvature to sectoral method by introduction of the following limitation:

$$v_m^o<\xi_m^o,$$

where ξ_m^o is some cut-off of m-weight.

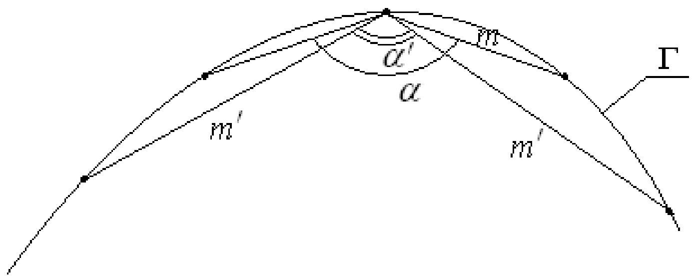


Figure 9 Neighborhood of sectoral m-rate of function of curvature of contour curve

Lemma 3 has a double value for the construction of SSR of curvature and proper handle. At first, changing of neighborhood m it is possible to check accuracy of m-rate of curvature in points of contour curve.

Secondly, as at $k \to 0$ error of sectoral rate $O_m^o \to 0$, it is possible to assert that for finding of transit points of curvature through a zero it is possible initially to take maximum size neighborhood m. In addition, for points with small curvature it is possible to take small neighborhoods m' (fig.9) with guaranties here finding of estimation of curvature with given accuracy and fast-acting.

4.3 Adaptive discretization technique for fast curvature scale space reconstruction

To achieve rapid estimation of curvature with the given accuracy it is possible to connect m-neighborhood and step Δu of curve $\Gamma = \{(x(u), y(u) \mid u \in [0, L]\}$ discretization.

A curve is represented by the set of points $\Lambda = \{(x_i, y_i) \mid i \in [0, M_u]\}, M_u = L_u / \Delta u$, distance between any two points λ_i and λ_{i+1} of set Λ is equal thus to

$$\|\lambda_i - \lambda_{i+1}\| = \Delta u = 1,$$

where $\|\cdot\|$ is the Euclidean metrics.

For the construction of discrete scale-space representation with invariant to scaling, ration the amount M_u of points of curve Λ with losing or adding new points to some general value M, I.e. lead $|\Lambda| = M$. Thus, accept $L = M$ as new length of contour.

In addition, choose the step of discretization on a scale $\Delta\sigma$. Then representation of points of curve Λ on a scale σ, such that $\sigma (\text{mod}) \Delta\sigma \equiv 0$ (or $\sigma = \Delta\sigma \cdot j, j \in N$), can be easy found on the following formula of the discrete approaching of Gaussian convolution:

$$x_i^\sigma = \sum_{j=-[M/2]}^{j<[M/2]} x_{i-j} g(i-j, \sigma), \quad y_i^\sigma = \sum_{j=-[M/2]}^{j<[M/2]} y_{i-j} g(i-j, \sigma),$$
$$g(x;\sigma) = \frac{1}{\sqrt{2\pi\sigma}} e^{-x^2/2\sigma} \qquad (4.1)$$

Thus, $x_{i-j}^0 = x_{i-j}$, $y_{i-j}^0 = y_{i-j}$.

For the construction of SSR of curvature it is necessary to find the values of function of curvature in all M points of discrete curve for each of N_σ levels of scale. The calculation of position of some λ_i point on the levels of scale $\sigma > 0$ according (4.1) requires $O(M^2)$ operations, while due to rule 3σ only points in neighborhood 3σ bring in a meaningful contribution to the sums (4.1). It is possible to transform formulas (4.1) to the following kind for considerable decreasing of amount of operations, that is ordinary practice at the use of Gaussian convolution in discrete spaces:

$$x_i^\sigma = \sum_{j=-[3\sigma]}^{j<[3\sigma]} x_{i-j} g(i-j,\sigma), \quad y_i^\sigma = \sum_{j=-[3\sigma]}^{j<[3\sigma]} y_{i-j} g(i-j,\sigma) \tag{4.2}$$

Thus, at the maximal amount of levels on which the calculation of curve points is needed (and this amount in practice depends on how quickly on a curve will be not a single zero transit point of curvature) $\sigma = M/3$ for some $\Delta\sigma$ middle complication of calculations of every level will be order $O(M^2/2)$.

As for the exposure of maximums of SSR of curvature all levels of scale are needed, it is possible to apply another property of Gaussian convolution:

$$(f(x) * g(x,\sigma_1)) * g(x,\sigma_2) = f(x) * g(x, \sqrt{\sigma_1{}^2 + \sigma_2{}^2}) .$$

Let σ_i is a level of scale for which the discrete curve $\Lambda^{\sigma(i)}$ of which is already calculated. For the calculation of curve $\Lambda^{\sigma(i+1)}$ of the following level of scale in accordance with chosen $\Delta\sigma$ it is necessary to execute Gaussian convolution of curve $\Lambda^{\sigma(i)}$ with a kernel σ^+ size of which can be calculated on the following simple formula:

$$\sigma^+ = \sqrt{\sigma_{i+1}{}^2 - \sigma_i{}^2} .$$

Thus for curve evolving at a certain range of scales required for discrete scale space reconstruction the following iterative calculation scheme may be used

$$\begin{gathered} \Lambda^0(u) = \Lambda(u) \\ \Lambda^{\Delta\sigma}(u) = \Lambda^0(u) * g(u,\Delta\sigma) \\ \dots \\ \Lambda^\sigma(u) = \Lambda^{\sigma-\Delta\sigma}(u) * g(u, \sqrt{\sigma^2 + (\sigma-\Delta\sigma)^2}) \end{gathered} ,$$

It allows to make average complication of calculations of every level to the order of $O(M \cdot \sqrt{M})$ at the maximal amount of levels (till to $\sigma = L/3$) on which the calculation of curve points is needed.

After the calculation of curve of every scale, directly the estimation of curvature can be expected by proposed sectoral m-weight of curve. Corner α_i^σ for the point $\lambda_i \in \Lambda^\sigma$ of curve at some level of scale $\sigma = \Delta\sigma \cdot j,\ j \in N$ it is possible to calculate as:

$$\alpha_i^\sigma = \arccos\Big((x_i^\sigma - x_{i-1}^\sigma)(x_{i+1}^\sigma - x_i^\sigma) + (y_i^\sigma - y_{i-1}^\sigma)(y_{i+1}^\sigma - y_i^\sigma)\Big) / |\overrightarrow{v_+^\sigma}||\overrightarrow{v_-^\sigma}| ,$$

where $\overrightarrow{v_+^\sigma} = \lambda_{i+1}^\sigma - \lambda_i^\sigma$;

$\overrightarrow{v_-^\sigma} = \lambda_i^\sigma - \lambda_{i-1}^\sigma$.

After this it is simple to receive sectoral m- weight v_m^o and estimation of curvature k_m^o of point λ_i^σ due to formulas (4.1) and (4.2).

Considering such curvature scale space reconstruction approach a problem of optimal m level selection, and discretization step at $\Delta\sigma$ scale utilization for achievement of satisfactory curvature scale space estimation. Obviously there is no right ahead solution of this task as it is hard to estimate how exact the CSS estimation should be for different application. However proposed scale space construction approach based on the sectoral m-estimation of curvature function allows to find a tradeoff between estimation accuracy and robustness by changing the m-neighborhood and the power of M set.

The next method of construction of images of SSR of curvature on the basis of adaptive binary simplification of contour curve and calculation of sectoral m- weight neighborhood m of which can be related to the level of simplification of curve is offered.

For finding of estimations of curvature of contour function at all levels of scale on the first step it is required to ration the contour curve so that length of discrete curve and amount of points were multiple 2: $L = M = 2^N, \Delta u = 1$.

Definition 4.2. Binary simplification of discrete curve is an operation of exception of every second point from set Λ^σ of points of curve at some level of σ scale. In other words set Λ_η^σ of points of simplified curve can be found as:

$$\Lambda_\eta^\sigma = \{\lambda_i \in \Lambda_{\eta-1}^\sigma \mid i = [0, M_{\eta-1}], i(\mathrm{mod})\, 2 \equiv 0\}$$
$$\Lambda_0^\sigma = \Lambda^\sigma \tag{4.3}$$

Definition 4.3. The level of simplification η of discrete curve Λ_η^σ on a scale σ is equal to the amount of simplifications in accordance with (4.3) created for receiving of curve Λ_η^σ from a curve Λ at all levels of scale $\sigma' < \sigma$. Obviously $\eta \le \log_2(M)$.

It is suggested to calculate the curves of the followings levels depending on the level of simplification, using for development of curve only those points which was saved after binary simplifications on previous levels:

$$x_i^\sigma = \sum_{i \in \{\lambda_j \in \Lambda_\eta^{\sigma-\Delta\sigma} \| \|x_i^{\sigma-\Delta\sigma} - x_j\| < 3\sigma^+\}} x \cdot g(\| x - x_i^{\sigma-\Delta\sigma} \|, \sigma^+), \tag{4.4}$$

where x_i^σ is the first coordinate of located point $\lambda_i \in \Lambda_\eta^\sigma$ of curve on a scale σ at the level of simplification η;

σ^+ - kernel of convolution which necessary for receiving of curve Λ_η^σ from curve $\Lambda_\eta^{\sigma-\Delta\sigma}$ calculated due to formula (4.3).

By analogy y_i^σ can be calculated.

We will enter cut-off ξ_m^o for m- weight of curves. We will simplify a curve each time during iterative development in accordance with a formula (4.4), when maximal weight of points of curve appears below than some cut-off:

$$\max_{\lambda_i \in \Lambda_\eta^\sigma} v_m^o(\lambda_i) < \xi_m^o + \Delta\xi ,$$

where $v_m^o(\lambda_i)$ is a value of m- weight of curve Λ_η^σ in a point λ_i ;

$\Delta\xi$ - additional element which guarantees implementation of condition $v_m^o(\lambda_i') < \xi_m^o, \lambda_i' \in \Lambda_{\eta+\Delta\eta}^{\sigma+\Delta\sigma}$ on the curve of next scale and level of simplification.

Due to Lemma 3 it guarantees the calculation of estimation of curvature by sectoral m-weight of curve Λ_η^σ with given accuracy level. Actually, simplification of curve takes place when a curve is smoothed out so that the maximal estimation of curvature $v_m^o(\lambda), \lambda \in \Lambda_\eta^\sigma$ of points of discrete curve decreases to some apriory given level $C \cdot \xi_m^o$ and simplification of curve does not bring to the increase of maximal estimation of curve curvature $v_m^o(\lambda), \lambda \in \Lambda_{\eta+\Delta\eta}^{\sigma+\Delta\sigma}$ higher than some other level $C \cdot (\xi_m^o + \Delta\xi)$, $C = 4m/3\pi$ on next scale.

Application of method of adaptive discretization allows to considerably accelerate the process of construction of scale-space representations, that will influence on increasing of velocity of as process of recognition of ECG elements and determination of their boundaries so and the process of forming of average signal which was offered in this work.

Application of developed adaptive discretization technique provides considerable robustness improvement of scale space representation calculation which by the proposed object detection approach leads to the increase of 3D surface data reconstruction performance and characteristic point set acquisition process speed caused by fast point matching. It also provides stable set of feature points for accurate object detection.

Thus it is proposed to analyze changes of 3D Earth's surface characteristic point model achieved by the means of scale space representation of image rows for object appearance and disappearance detection. Whereupon the utilization of 3D data provides the increase of detection accuracy eliminating shadow and illumination distortions and considerably increase the performance of 3D data reconstruction and analysis processes by achievement of characteristic point set by the means of developed curve adaptive discreatization technique for fast calculation of curvature scale space.

5 THE MAIN GAS-TRANSPORT SYSTEM AS OBJECT OF COMPLEX REMOTE SPACE MONITORING

The gas-transport industry is one of leading branches of economy for many countries of the world. The main pipelines of a high pressure which are a part of gas-transport systems (GTS) of the modern states represent the difficult territorially-distributed network. GTS includes hundreds objects of the raised danger. Transported natural gas is dangerous explosive, large failures on a linear part of pipelines of a high pressure and other technological objects can have catastrophic consequences, especially in densely populated areas.

In spite of the fact that in comparison with other types of transport pipeline transport is one of the most reliable. So there are till 25-30 failures, or to 0,2 failures on 1000 km a year on gas pipelines, for example, Russia annually. Throughout last 5-7 years this indicator remains rather stable. However there are a number of the preconditions testifying to presence of growth susceptibility on pipelines of a high pressure.

First, a gas-transport network ageing continues. As last 10-15 years, for example, in the states of the post-Soviet territory rates of new building, major repairs and reconstruction of gas pipelines essentially lagged behind rates of their ageing. Now to 80 % of gas pipelines operation term exceeds 20-25 years that essentially increases risk of occurrence of extreme situations.

Secondly, development of oil and gas deposits on a shelf of the seas, building of sea pipelines, and also their lining in mountain district where earth flows, avalanches, landslips, high waters, flooding are possible. All it causes occurrence of new dangers and threats, demands introduction of the no completely fulfilled and tested technologies.

Thirdly, last 5-7 years on pipelines emergencies, connected with subversive and terrorist actions have increased.

Space image are claimed in many industrial and social-economic branches, but especially steadfast attention to them the enterprises of a fuel-energy complex show, and first of all, the companies which are engaged in pipeline transport of hydrocarbons. For such enterprises are characteristic lengthy lines of pipelines, when only remote methods can prove, as the most operative and effective. For example, the gas-transport system of Ukraine has the general length more than 37 thousand kilometers. Hundreds technological objects are located in different areas of the country on distance from tens to thousand kilometers from each other.

Space image can be used as directly, and in a complex with other data for the automated decision of applied problems.

It is possible to allocate following base directions of complex remote space monitoring GTS objects application:

1. Use as visual replacement of a topographical basis of corridors and platforms of transport and gas storage objects (fig. 10), including territories outside of security zones, to scales 1:5000. Undoubtedly, all enterprises involved in GTS, have executive land shooting of the objects, the vulgar to scales 1:500, linear to scale 1: 2000. However, shooting, as a rule, is limited by a security zone of objects (for the main gas pipelines the security zone is established 100 metres from extreme threads of pipelines in a corridor of communications), that essentially limits information-spatial security at level of the concrete enterprise. Aerospace images of the high permission allow observing the territories located in 2 - 3 kilometer buffer zone round objects of transport and gas storage.

2. Updating of executive objects shooting of gas transport and storage to scale 1:2000. Annually tens new objects are put into operation in the enterprises of gas transport. Not always probably to make executive shooting operatively. Aerospace images of the high permission will allow updating and adding executive shooting of linear GTS objects, in time to spend inventory, certification and their statement on the cadastral account.

3. Construction of digital district models (DDM) and digital relief models (DRM) of corridors and industrial platforms for GTS objects, for example, gas-compressor stations and adjoining territories (fig. 11) to 2 meters on height. DRM will allow to estimate deformation loadings on a gas pipeline in places of a relief excess, to reveal local falls on district (potentially explosive sites), to calculate zones of electromagnetic visibility of radio relay aerials.

Figure 10. An image from QuickBird satellite - *a corridor of the gas main pipeline*

4. The predesign analysis of the territories intended for commissioning of new GTS objects, to scales 1:5000. Available topographic maps have hopelessly become outdated and do not give the complete information about the territories planned to development. Aerospace images possess a time urgency and spatial accuracy necessary for acceptance of the strategic decision on building of objects. Besides, on their basis carrying out of ecological examination within the limits of design activity for again put in operation of objects is possible.

5. Monitoring of corridors and industrial platforms of GTS objects, and also adjoining territories to scale 1:2000, that will allow to estimate operatively change of a situation in 2-3 kilometer zones from objects of gas transport (put into operation of new GTS objects, building in territory of "accessory manufacturers", changes of natural and landscape conditions). Work can be carried out in semi-automatic, and in some cases in an automatic mode in such program complexes of data processing of remote sensing, as ENVI.

Besides, following applied problems can be solved with use of remote monitoring means for an estimation of integrity and safety of GTS objects and environment surrounding them:

1). Revealing and mapping of zones of probable occurrence for technogenic failures and accidents, risks estimation:

Figure11. An image from Quick Bird satellite - gas-compression station

- in crossing places of existing or projected objects for gas transport and storage with railway and highways, other kinds of pipelines, high-voltage transmission lines and other linear technogenic objects;
- in rapprochement places of existing or projected objects for gas transport and storage with all abovelisted objects;
- in places of a close arrangement of the large localised technogenic objects: factories, territories of mining operations, places of various kinds household and industrial wastes recycling;
- in places of a close cultural-historical monuments arrangement;

2). Revealing and mapping of zones of probable occurrence of natural accidents, an estimation of risks:

- in crossing places existing or projected objects of transport and storage of gas of natural objects: woods, bogs, the rivers, lakes, reserves, wildlife preserve;
- in crossing places existing or projected objects of gas transport and storage tectonic active geological structures, dynamically intense zones, deep breaks, seismically active areas;
- in crossing places existing or projected gas pipelines of zones for development modern ravine, river, wind, glacial, frost erosion, active development of gravitational

processes (landslips, taluses, collapses, avalanches), water logging territories, places of a karsts development, soil slumping.

3). Detection and monitoring of the ecological negative processes proceeding in a security zone of gas pipelines, connected with extraneous sources of pollution and technogenic influence.

4). Revealing and mapping of changes in the geodynamic active zones connected with territories of underground gasholders, on the basis of radar shooting and interferometry. Regular shootings by radar satellites of territories of underground storehouses (depth of occurrence to 1 km, capacity of ten billions cubic meters, pressure 120 atmospheres) will allow estimating motions of a surface to within the first millimeters, both in zones of depressions, and in possible zones of a earth surface raising. Early detection of shift superficial deformations in zones of a pipelines arrangement.

5). Monitoring of territories in security zones of the gas-transport enterprise about presence of self-capture zones and not authorised sites building inhabited and industrial targets. Such monitoring will allow stopping in time attempts of illegal use of the earth and if necessary to receive incontestable proofs of certificates of the earths self-willed capture. Aerospace images occurring at different times (fig. 12) can serve as forcible argument by consideration of claim affairs to violators of security zones of transport gas objects.

As an example it is possible to result developed and introduced in commercial operation in the Russian Federation geoinformation system of monitoring and forecasting of emergencies on objects of uniform system of gas pipelines of public joint-stock company "Gazprom". This system is supported in an actual condition and serves for the remote watching control over a condition of Russia GTS objects, and also for working out of the preventive measures, capable to prevent growth of potential failures and to provide essential reduction of risks and level of a emergencies damage at the enterprises of gas-transport branch.

Figure 12. Automatic revealing of not authorised building in a security zone of the main gas pipeline with use of program complex ENVI

In works [Borisenko, 2004], [Borisenko and Medvedeva, 2008] the base concept of construction, methods and effective implementers of the complex automated control system (CACS) are offered by gas-transport system of Ukraine. The subsystem of remote space monitoring is in it a case of one of the basac specialised component CACS. Use of the digital spatial information of complex space monitoring together with a set is standard-help, the passport and factual data collected by systems of land basing (microprocessor systems of modular automatics, industrial control on the basis of modern SCADA, the automation system of operative-dispatch control on the basis of MES [Ponomarev, 2006]) allow to organise highly effective, reliable and qualitative support of decision-making on complex multilevel management of the distributed main gas-transport networks of a high pressure [Borisenko, 2008].

CONCLUSIONS

Studies carried out separately by Russian and U.S. experts clearly indicate that we are soon expected to undergo global climate changes. An ever increasing number of natural disasters and technological accidents clearly confirm this. Therefore tasks for improving the quality of forecasting, reconnaissance and monitoring the situation with the emergencies are relevant.

Using digital area images allows you to automate the process of monitoring and improving the quality of forecasting and detection of abnormal situations. Digital images obtained by satellites are not always informative because of time and weather factors. The use of UAV allows you to minimize the influence of these factors and improve the information content of images. The fact that UAVs can be used in areas hazardous to human is particularly valuable. It enables you to perform aerial surveillance of highways, pipelines, power lines, to fly in emergency situations, man-made and natural disasters, floods, large-scale fires at industrial enterprises, military depots; aerial photography, environmental and radiation monitoring with the possibility of mapping the extent of radiation (or other) contamination.

Using DIS for solving UAV control problem can serve as emergency monitoring in conditions of limited visibility. A possibility gained by the operator to control the UAV by means of synthesized image eliminates not only the visibility limitation but also the influence of meteorological conditions on aircraft control. This helps to improve considerably the quality of management, reduce the risk of accidents when monitoring natural disasters or man-made accidents.

The proposed methods of image processing enables to estimate the information content of the images obtained and to carry out restoration of the height of objects represented on the photo, with the aim of their further recognition and registration of movement within the monitoring zone. The proposed method uses the representation of the brightness function curvature at different levels of scale to increase the original data resistance to noise and sampling. The approach proposed for calculating the curvature of the curve is distinguished by improved performance and availability of monitoring the accuracy of curvature estimation at the points of the contour. Together with the method of adaptive sampling for fast curvature scale space representation it allows to solve the task of restoring the height of objects in limited time mode with high accuracy.

As area of effective practical use of the offered synergy of technologies, mathematical methods and algorithms of digital images processing the main gas pipelines of a high pressure which are objects with a high risk level of emergencies occurrence are considered.

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