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EFFICIENT UPDATING DIGITAL MAPS BY REMOTE SENSING IMAGES AND THEIR USAGE FOR APPLIED TASKS

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Abstract

An efficient procedure for updating digital maps by using remote sensing images is proposed in the paper. An algorithm for matching of remote sensing images with digital maps based on modified polynomial approximation is proposed that gives a smaller error in the determination of coordinates than other methods. Map updating algorithm is described. Practical experiments of the procedure are given and other practical tasks will be shown in the presentation.

1. Introduction

One of the most important information channels in updating digital maps is remote sensing images obtained from a satellite [1]. Images can be efficiently used to update a digital map, i.e. to introduce new objects from image that are absent in digital map or to modify existed in map objects.

However, to be used for this task, remote sensing images (RSI) first should be transformed in a map projection and scale, i.e. matching of remote sensing images with digital maps (DM) should be performed [2]. In spite of quite many papers published on his topic, there are still many problems with accuracy of matching and convenient user-friendly tools for object extraction from RSI and map updating.

In this paper, we propose an efficient procedure for updating digital maps by using remote sensing images. An algorithm for matching of RSI and DM based on modified polynomial approximation is proposed that gives a smaller error in the determination of coordinates than other methods. Map updating algorithm is described. Practical experiments of the procedure are given and other practical tasks will be shown in the presentation.

2. Digital map and remote sensing image representation

Digital map consists of cartographical objects that are stored in a vector form. Technology of map digitizing is described in our papers [5, 8]. Every object has five main parameters: type, name, geometry, semantics and links with other objects.

Object's type is defined from its classificator category. Name is an identificator allowing to define object in database. The geometry (object coordinates) is determined from the object's position on the image and is different for different object types. Line objects are represented by their skeletons, symbols - by one or two points, and regions - by their contours. Semantics reflect some of the characteristics (geometric, constructive, and others) of the real terrain object by an appropriate graphical pattern on the map. Object links show its connections with other map objects. For every object in map this information should be defined.

Remote sensing image is represented as standard gray-scale image in raster format.

The main stages of the procedure for DM updating by RSI are the following:

1) Image quality enhancement. If necessary shift, rotation and other transformations can be performed.

2) Matching of remote sensing images and digital maps.

3) Updating of digital maps.

We shall not consider image quality enhancement here. There many algorithms for this task and we have our own algorithms. Let us consider the second and third stages in more details.

3. Matching of remote sensing images and digital maps

The procedure of matching of remote sensing images and digital maps includes the following steps:

1) Indication of reference points by interactive tools. The operator uses mouse to single out the corresponding reference points on two images, which are marked for the visual control. Image and map of the same area are extracted and displayed simultaneously. As reference points, some well defined objects are chosen (road intersection, heights, etc.).

2) Image transformation in Gauss-Kruger projection by using elements of internal and external orientation. Geometric and photometric distortions are reduced simultaneously. This is done by automatic tools. In the result, reference points are identified as well as their coordinates.

3) Extraction of image fragment with desired objects that have to be modified. For the comparison and visual evaluation of further results, image is superimposed on the map.

4) Matching of image and map fragments. Aim of the procedure is to establish polynomial dependence between coordinates of reference points of both images. We use matching algorithm based on modified polynomial approximation. Reference points are used to calculate coefficients of expressions and coefficients are used for calculating the coordinates of an arbitrary point on the remote sensing image. This is an automatic procedure.

For calculating the coordinates of the desired points using the modified method described above, the following should be performed:

(1) The reference points on the remote sensing image and their corresponding reference points on the map are singled out.

(2) The coordinates of the reference points are used for constructing the system of equations [3].

(3) The systems of linear equations and are solved for determining the equation coefficients a_j and b_j[3].

(4) Expressions and the coefficients a_j and b_j are used for calculating the coordinates of an arbitrary point on the remote sensing image.

To control the process of matching, we introduce the coordinates of control points, which take no part in finding the model parameters, and determine the discrepancies in the relative positions of elements on the transformed image.

In experiments, input data were remote sensing images and vector maps (Fig.1). Files of the digital map made up a vector model of the image that contained the coordinate description of contours and information on their inclusion. A vector model of an image is formed by the binary raster representation of the image obtained as a result of raster-to-vector transformation.

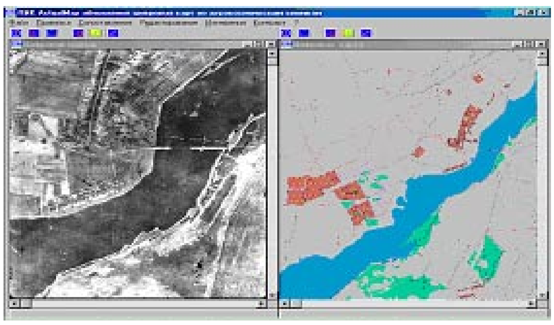

Fig.1. Remote sensing image and digital map

For matching, remote sensing image and digital map of the same area in some other scale and projection are extracted and displayed simultaneously (Fig.2).

Fig.2. Remote sensing image and digital map for the same territory

The operator uses a mouse to single out the corresponding reference points on two images, which are marked for the visual control of their relative movement (Fig.2). For the comparison and visual evaluation of the results of matching, the display shows the transformed remote sensing image superimposed on the image of the map.

For example, the transformation using a second degree polynomial and the method of least squares with 11 points made it possible to match an image of the photograph to the corresponding topographic map with the average error of 2 pixels. This error was obtained in the case of control with three points not used for determining the model parameters [3].

For the given degree of the polynomial, the accuracy of matching may be enhanced by increasing the number of reference points. However, it should be remembered that the inaccurate reading of the coordinates of reference points increases the error.

The estimates of accuracy of the transformation varied with the positions of the reference points. This means that, for a uniform approximation, it is necessary to choose more reference points in complex regions of the image.

Below, we present the results of the comparative analysis of two methods of matching, namely, the standard polynomial method and the modified method. To determine the optimal degree of the polynomial and the accuracy of transformation, we estimated the root mean - square error of coordinates as

$$\sigma_x = \sqrt{\frac{\sum \Delta_x^2}{r}} \; ; \; \sigma_y = \sqrt{\frac{\sum \Delta_y^2}{r}},$$

where $\Delta_x = x - x_c$ and $\Delta_y = y - y_c$ are the absolute discrepancies in the coordinates (x, y) of the reference points and the coordinates (x_c, y_c) of the same points calculated using, and r is the number of redundant points measured for control.

Numerical experiments with real images showed that the modified method gives a smaller error in the determination of coordinates.

It is especially important that for the same accuracy, the modified method needs less reference points that the standard method. In particular, the standard method based on a second degree polynomial needs no lees than 6 reference points, whereas, the modified method based on the expansion up to $(v/u)^2$ needs only 4 reference points [3].

4. Map updating based on matching results

One of the main tasks where matching is used is updating of digital maps based on remote sensing images. The main stages of DM updating:

- Matching of remote sensing image and digital map.
- Extraction of the required objects from RSI by interactive or automatic techniques (contours for area objects, middle lines for elongated objects).
- Computing the required object characteristics (geometric, semantic ones).
- Mapping and displaying of the selected objects with digital map.
- Recording information about modified objects in digital map.

Let us consider these stages in a little more details.

Figure 3 shows a remote sensing image and digital map for the same territory.

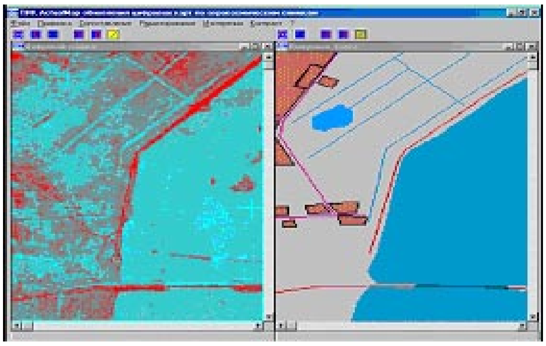

Fig.3. Fragment of remote sensing image and digital map for the same territory for map updating.

Then, we cut a part of remote sensing image and display it over the digital map (Fig.4).

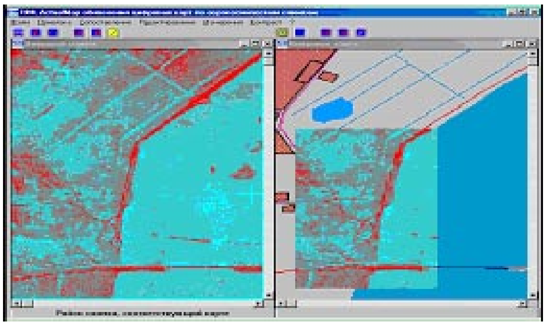

Fig.4. Cutting and matching of RSI part with digital map.

Image and map are compared by operator and changes are defined. All new objects detected on remote sensing image are extracted and their characteristics (geometric, semantic) are calculated. For new object its type and name and defined. The obtained information about new or modified object is added to digital map (Fig.5).

In a result, an updated digital map is obtained.

The developed procedure has been widely tested in several geographic information systems for updating digital maps and solving applied tasks.

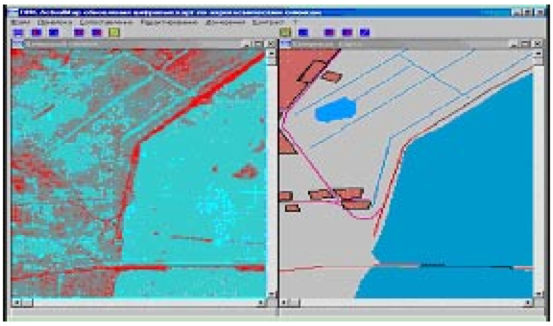

Fig.5. Updating digital map by the extracted image fragment (coordinates of lines have been changed).

5. Applied tasks based on joint interpretation of remote sensing images and digital maps

We showed updating of digital maps by remote sensing images. This is one of the main procedures in joint interpretation of remote sensing images and maps. This procedure has been used in many applied tasks.

We have long-term practical experience in solving practical tasks based on joint interpretation of remote sensing and map images. The following applied tasks have been solved with the help of the developed techniques [4-8]:

- discovery of fires on the satellite images with calculation their coordinates on maps;
- evaluation of forest state to produce forest maps from satellite image (forest status monitoring);
- classification of forest by wood species and age;
- transport navigation system with digital map using including road network analysis;
- pollution spreading forecasting on digital map taking into account atmospheric conditions (wind propagation and others);
- control of territory flooding and modeling of its dynamics;
- hazard (extreme) situation modeling;
- modeling of territory pollution spreading dynamics under throwing out of poisonous substances (chlorine, ammonia etc.) into atmosphere as a result of explosion, fire, including accidents of transport means.

The practical systems have been developed and used in organizations of Belarus and other countries. Some practical results and systems will be shown at Symposium by means of PowerPoint presentation.

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