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# METHODS OF AUTOMATIC ALIGNMENT AND ASSEMBLING OF AERIAL PHOTO MADE BY REMOTE-PILOTED VEHICLE



**It is emphasized that creation of reliable remote-piloted vehicle navigation and control system is an extremely actual problem. For these purpose, methods and algorithms of technical vision are used. The methods of automatic alignment and assembling of aerial photoimages based on the properties of image points are described.**

**Various algorithms are used to select such points, in particular, such as Harris Corner Detector SIFT, SURF, Lucas-Canada algorithm. It is emphasized that the use of the homology matrix for these purposes is extremely important.**

**The implementation of algorithms is invariant to scale, rotation or change of illumination. It implies an improved choice of characteristic points, and, accordingly, greater possibilities for achieving suitable mixing.**

**It is highlighted that to compare features from different images to each singular point descriptor is assigned. It is emphasized that to compare the neighborhoods of two points, approaches based on correlation are used.**

**Key words: remote-piloted vehicle, airphotoshooting, remote-piloted vehicle positioning, images stitching, points features, images alignment, image assembling.**

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# МЕТОДИ АВТОМАТИЧНОГО ВИРІВНЮВАННЯ ТА МОНТАЖУ АЕРОФОТОЗНІМКІВ, ЗРОБЛЕНИХ ЗА ДОПОМОГОЮ БЕЗПІЛОТНИХ ЛІТАЛЬНИХ АПАРАТІВ



**Створення надійної системи навігації та управління безпілотними літальними апаратами є надзвичайно актуальним питанням. Зазначено, що для цього використовують методи та алгоритми технічного бачення. Описано методи автоматичного вирівнювання та монтажу аерофотознімків на основі властивостей точок зображень.**

**Для виділення таких точок використовують різноманітні алгоритми, зокрема такі, як детектор кутів Харріса SIFT, SURF, алгоритм Лукаса—Канаде. Наголошено на використанні матриці гомографії для цих цілей.**

**Ключові слова: безпілотний літальний апарат, аерофотозйомка, позиціонування безпілотних літальних апаратів, зшивання зображень, властивості точок, вирівнювання зображень, монтаж зображень.**

## Introduction

Nowadays the use of remote-piloted vehicles in different spheres of life is extremely popular. That is why creation of theirs reliable navigation and control systems is relevant and important task. One of the alternative methods of navigation is the use of means, methods and algorithms of technical vision. It may be, for example, solved by algorithm for solving the problem of remote-piloted vehicles positioning on the video for flying above a flat terrain, based on a comparison of the so-called singular points on a satellite image of terrain above which remote-piloted vehicles make their flights. After the comparison, the parameters of the projective transformation between the two images are calculated, which allows to detect the position and orientation of the camera on the remote-piloted vehicle in the global coordinate system [1, 4, 8].

Methods based on the attributes begin with establishing of the correspondence between points, lines, or other geometric occurrences. Local invariant features are used to find matches between all images. The latter makes the work unsustainable: the order, orientation, scale and illumination of input images, as well as the immutability of the noise of the image, which is not part of the landscape. There is also the ability to recognize multiple panoramas from a variety of disordered images.

Allocation of characteristic points in image may result in different results depending on the used methods. Taking into account the speed and accuracy of finding the indicated points, it is possible to distinguish a large number of different algorithms, each of which has its own advantages and disadvantages.

Detection of correct characteristic points plays important role for proper stitching. So, it is extremely important to choose the correct detector of such points. For example, the Harris detector is looking for points with large changes in intensity in the neighbor areas. The distinguishing feature of this algorithm leads to the finding of angles and boundaries. The goal is to identify the angles and the use of normalized mutual correlation of the local intensity values at specific points for matching matches. To create panorama, having already defined values of the explored points between two images, one image is projected onto the other [1, 2].

**Peculiarities of detection and comparing of image characteristic points**

The stitching of panoramic image is widely presented in research literature and commercial applications. The methods of automatic alignment and assembling of aerial photos are usually divided into two types: straight lines and based on properties. Direct methods are aimed at repeated evaluation of camera parameters by minimizing the error function based on the difference in intensity in the overlay region. Their advantage lies in the use of all available image data, and therefore they provide fairly accurate notes, but require very careful initialization.

The basic geometry is quite clear and includes the estimation of the homography matrix for each image. This process requires initialization estimation, usually given by the user in order to roughly align or arrange the images. For example, some software requires horizontal or vertical scan, square image matrix, or user interface to get an approximate location of images [2, 6].

Nowadays, the problem of detection and comparing of image features is well enough considered in the literature. In order to compare features from different images it is important assign descriptor to each singular point. The simplest descriptor is the neighborhood of point. Approaches based on correlation are used to compare neighborhoods of two points. One of the simplest algorithms for extracting singular points are the algorithms for selecting angles for images, for example, Harris angle detector. But corner detectors are not invariant to scaling. For different scales of the same image, different angular points can be found on them. Also there are such algorithms as SIFT, SURF, GLOH etc. In all these algorithms, for each singular point its descriptor is calculated, which is to some extent invariant to changes in brightness and perspective transformations. There is a set of algorithms associated with the calculation of the so-called optical flow [1, 5, 6].

The classical approach is the Lucas-Canada algorithm and its extended pyramidal version which uses a representation of the image on several scales and which is characterized by greater resistance to scale variation. But the algorithms of optical flow were originally developed for comparing points from two images, which differ insignificantly among themselves. To compare descriptors of singular points from two images, the following methods are used:

- full search: for each descriptor from the first set, the distances to all descriptors from the second image are calculated and the best is taken;
- accelerated approximate method using hierarchical data structures.

In these methods so-called search index is constructed to find the nearest neighbors in a multidimensional space. Traditional methods such as correlation of images parts do not possess the invariant properties necessary for the correct correspondence of an arbitrary sequence of panoramic images. The scale-invariant features transformation (SIFT) approach is based on invariant features to achieve a "junction" of a fully automatic panoramic image. Compared to the previous approach, it has several advantages:

- the use of invariant features allows to carry out a reliable match between image sequences and panoramas, in spite of rotation, zooming and lighting changes in input images;
- when looking at gluing images as a problem of combining multiple images, it is possible automatically to detect relationships between images and recognized landscapes in an unordered set of data;
- the algorithm can result in high-quality results using multi-band conjugation to display seamless panoramas.

The SIFT algorithm detects a larger number of characteristic points than the other detectors, which reduces the probability of errors in local variations of mean errors among all the error of coincidence signs. Also, the cost of searching for several characteristic points is such that it affects the time spent on the execution of the algorithm, which is a great compromise between the quality of the characteristic points and the speed of the system.

The SURF algorithm is an improvement to the SIFT algorithm, which guarantees better efficiency.

The SURF algorithm is many times faster than SIFT. It demonstrates greater resilience to different image transformations than SIFT.

RANSAC (RANdom Sample Consensus) it is nondeterministic algorithm, that does not guarantee acceptable results, and the probability of success increases with the number of done iterations. According to these methods there are two types of data "inlayers" and "outlayers". "Inlayers" is data compared with a set of data, following a certain rule, which can be represented in the form of a mathematical model. "Outlayers" are erroneous data that do not satisfy this model and the statistical criterion of "inlayers". Such type of data is the result of an erroneous correlation.

The data analyzed by the RANSAC method is the homography of the correlated characteristic points. "Outlayers" are the errors of mutual correlation of intensity, and "inlayers" are good connection between the studied points. RANSAC it is an algorithm that iteratively follows the set of measurement results, evaluates the parameters of the mathematical model and tries to find the "outlayer" and disconnect them.RANSAC tries to find the best model by testing the various relationships between the characteristic points.

The homogram that returns the largest number of correct matches is chosen as a solution. "Outlayers" are diagonal lines that do not follow the statistical direction of "inlayer". These incorrect correlations can cause difficulties at the stage of conjugation of images, so they must be removed from RANSAC. This is because RANSAC indeed find homogram matrix that connects most of the points, and rejects incorrect coincidences as "outliers" [1, 2, 6, 7].

**Images blending with the use of homography matrix**

Correlation of the characteristic points of two images makes it possible to determine a model that can transform the points of one image to another. In this section we are talking about a homography matrix, which includes many kinds of transformations. This makes it possible to impose two images according to the position of the correlated characteristic points. In homography it is allowed to use projective transformations that establish the correspondence of lines. The application of the homography matrix allows the use of affine transformations that change the shape of the images, and gives the impression that the observer point of view is changing. Affine transformation respects the straightforwardness of lines and the relationships of the parties, thus preserving the principle of parallelism. Basically, in order to apply the transformation, matrix multiplication is necessary. Examples of affine transformations are scaling, displacement, and rotation.

Homogeneous coordinates are important if you want to use a transform matrix for affine transformations; this means that adding further coordinates extends the two-dimensional transformation matrix with one row and one row.

Due to the homography matrix and the extraction of points by the SURF method, images having the same common area can be connected. Since SURF is invariant to affine transformations, which is used by the homography matrix, the two image data can be scaled, shifted and rotated. At the same time, the blending of images should be carried out in accordance with the homography matrix. For this purpose, linear alpha gradient can be used to match the areas covered by the two images. The gradient controls the final image according to the pixel position, taking into account the weighted average value in accordance with the distance from the centers of these two images [2, 3, 9].

## Conclusions

It is emphasized that the creation of reliable remote-piloted vehicle navigation and control systems is an actual and important direction of development. One of the alternative methods of navigation is the use of means, methods and algorithms of technical vision.

Correlation of the characteristic points of two images makes it possible to determine model that can transform the points of one image to another. It is important take into consideration matrix of homography, which includes many kinds of transformations. This makes it possible to superimpose two images according to the position of the correlated characteristic points.

The processing of airphotoshoting from remote-piloted vehicles is similar to the processing of airphotoshoting from other planes. However, the characteristics of data from the remote-piloted vehicles board often do not allow the use of automatic procedures for standard packets. Some operations, for example, alignment of connecting points must be done manually.

It is emphasized that airphotoshooting from the remote-piloted vehicle board is carried out with increased blending. Instability of the flight of the aircraft sometimes can lead to very large overlaps between neighboring images, which causes complexity in standard photogrammetric packages. That is why it is necessary to investigate such processes.

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