THEORY AND METHODS OF SIGNAL PROCESSING

UDC 629.735.051:004.932 (045)

[1]M. P. Mukhina,
[2]T. A. Yeremeieva

INFORMATIVITY ESTIMATION TECHNIQUE OF TEMPLATE GEOPHYSICAL FIELD DATA

[1,2]Educational-Scientific Institute of Information Diagnostic Systems,
National Aviation University, Kyiv, Ukraine
E-mails: [1]m_mukhina@inbox.ru, [2]eremeeva94@mail.ua

Abstract**—*This article presents an integral index for informativity estimation of geophysical field template. Informativity estimation algorithm and software for its realization are developed. The experiments on a series of pictures of different regions (field, forest, city, etc.) confirmed the effectiveness and accuracy of the given algorithm.*

Index Terms—Geophisical field; informativity; cartographic data; correlation-extreme navigation system.

I. INTRODUCTION

The correlation-extreme navigation system (CENS) principle of operation is based on a comparison of the Earth's surface image or set of topographic features (the current image) with the reference one, which is got in advance. Position mismatch of these images in the adopted coordinate system allows forming a command to retain control object on a predetermined path.

The current image is formed during the movement of controlled object, while reference is made in advance and introduced in control system as a route job (during navigation) or combination of target features, or transmitted to the aircraft during flight.

Correlation-extreme navigation system is perspective line of research, because it can be an alternative to the satellite system for INS (Inertial Navigation System) correction, but its accuracy significantly depends on the accuracy of cartographic information. The cartographic data requires to be pre-processed in order to increase the efficiency of CENS operation. Although it is necessary to estimate template informativity, to provide data in a compact form and improve accuracy and performance of CENS [1].

There are many methods and algorithms for informativity estimation of mapping information, but their accuracy is not sufficient. Therefore, it is advisable to use several parameters for more accurate and effective estimation.

II. PROBLEM STATEMENT

A. Detection of image informative areas

To compare the images by the correlation analysis method or to compare their specific features it is necessary to solve the problem of objects selection on the front plan in permanently unmoved ground. In case of using this principle aboard Unmanned Aerial Vehicle (UAV) the constant changing of objects and background takes place, so the detection of informative areas of image is needed. Consideration of small quantity of informative areas at the detection and recognition of objects decreases the requirements to computational costs of CENS realization aboard UAV. At the same time, during the process of elimination of non-informative areas, the areas containing objects may be not considered. So, the problem of detection methods application to find informativity of image areas and to select more informative areas for further consideration is present. Respectively [2] such problem is not solved nowadays at full degree.

The mathematical problem statement consists of the following. Let it be necessary to find the correspondence of some point (x_0, y_0) of current image with reference one. Let's designate $f(x, y)$ as initial reference image. Consider a fragment of the image with center at (x_0, y_0) and the size $(2N+1)\cdot(2N+1)$ pixels. We introduce the function of the information content of the fragment $I\,(x_0, y_0, N)$.

It is necessary to determine:

1) whether a given fragment informative;

2) if the fragment is not informative, if is possible to change its size so that it becomes informative.

To answer these questions, a simple criterion can be used based on a comparison of information content function I with a numerical threshold T. If $I < T$, then the fragment is considered non-informative. In this case, the fragment size is increased by a some constant n until either not executed until the opposite condition, or fragment size reaches a maximum value $N_{\max}$.

B. Representation of image specific features

Image specific features can include feature points, lines (contours) and areas. The variety of methods are used to detect features and to compound descriptors

© National Aviation University, 2016
http://ecs.in.ua

which are unique for definite feature. The structure of descriptors may differ, however the basic principle used here can be easily expand for another method used to describe the image features. For further consideration, SURF descriptors are used [3].

The SURF detector is based on the determinant of the Hessian matrix:

$$\mathbf{H}(x,y,\sigma)=\begin{vmatrix} L_{xx}(x,y,\sigma) & L_{yx}(x,y,\sigma) \\ L_{xy}(x,y,\sigma) & L_{yy}(x,y,\sigma) \end{vmatrix}, \quad (1)$$

where $L_{xx}(x,y,\sigma)$ is convolution of the second order partial of Gaussian $\frac{\partial^2}{\partial x^2}g(\sigma)$ from the image in the point (*x*, *y*). The same is for $L_{xy}(x,y,\sigma)$ and $L_{yy}(x,y,\sigma)$. V¿6–ð U5$

The descriptor is calculated as the gradients for 4×4 = 16 quadrants around the feature point. Then each quadrant is divided further by 16 smaller quadrants. Four components on each quadrant must be computed that gives totally the 64 components of descriptor of area around the feature point.

The descriptor of feature point by SURF contains enough information to match the reference image and current one, but for reliable positioning some fields to the descriptor must be added and investigated.

C. Analyses of existing methods of cartographic data preparation

General requirements to unified template for CENS are formulated in [4], without any proposed structure and used methods of data processing. More detailed description of procedure of template data preparation and processing is given in [5]. The proposed presentation is based on technology of computer vision where the template is given as a scene. However, such representation has a significant drawback, namely the procedure of its formation cannot be fully formalized. And therefore it has no posibility to be fully automatized.

There are several methods of informativity determination.

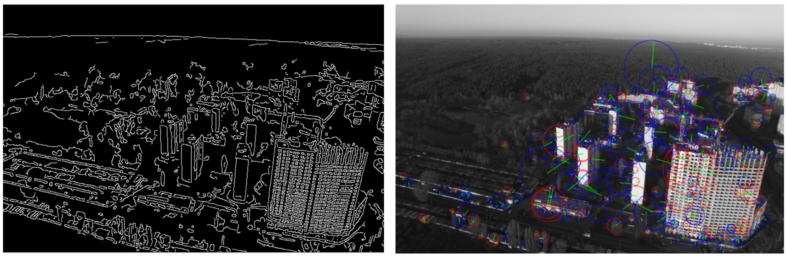
Calculation of signal variance. More homogeneous the brightness signal is, the more area is informative.

$$\sigma^2(x_0,y_0,N)=\frac{1}{(2N+1)^2}\sum_{x=-N}^{N}\sum_{y=-N}^{N}\left(f(x+x_0,y+y_0)\right)^2-\left(\frac{1}{(2N+1)^2}\sum_{x=-N}^{N}\sum_{y=-N}^{N}f(x+x_0,y+y_0)\right)^2 \quad (2)$$

where (x_0, y_0) is the point of the image, for which the informativity is defined; *N* is the selected size of (x_0, y_0) neighborhood [2].

Signal-to-noise ratio (SNR). Using signal-to-noise 1
ratio for determination of image area informativeness is suggested, more homogeneous area is, there will be less deviations of signal and, correspondently, less

G bald&Pe4 O



a b c

Fig. 1. Features descriptors (a) Blob analysis; (b) Hough transform; (c) SURF detector

Among computationally simple indexes of non-homogeneity (uniqueness or, correspondently, informativity) of reference fragment is variance of image intensity, signal-to-noise ratio, correlation radius, etc [2], mentioned above.

Such indexes are used for correlation approach to compare current and reference images. But many researchers, especially [5], define separately correlation-extreme methods of images comparison and methods of comparison of images characteristic features.

In such way, for estimation of fragment informativity the integral index H is proposed to use:

$$H = w_{\sigma^2}\sigma^2 + w_{\mathrm{SP}}\mathrm{SP} + w_{\mathrm{SNR}}\mathrm{SNR} - w_K K, \qquad (4)$$

where σ^2, SP, SNR, K are variance, number of SURF points per image area, signal-to-noise ratio and covariance indexes; w_{σ^2}, w_{SP}, w_{SNR}, w_K are weight coefficients.

Research was done on the examples of different regions images (field, forest and city). If the image is represented as a structure by descriptive features of special points type, found by SURF method, then instead of informative feature – image intensity, that is used in formula (2), the descriptors of point, which are represented in the mentioned above form, will be used.

On intuitive level it is clear, that high quantity of feature points, found in fragment, corresponds to better informativity, and correspondingly their uniqueness and distinctness one from another will provide higher reliability of comparison. Let's estimate the uniqueness through covariance of correspondent pairs of feature points on the fragment. Since the descriptors of points are centered and not displaced with final second moment, then the expression of covariance of pairs of random descriptors would be:

$$K = \mathrm{cov}(D, D) = M\left[\mathbf{D}^{\mathrm{T}} \cdot \mathbf{D}\right] = \frac{1}{m^2}\begin{bmatrix} D_1(1) & \dots & D_1(m) \\ \vdots & \ddots & \vdots \\ D_{64}(1) & \cdots & D_{64}(m) \end{bmatrix}^{\mathrm{T}} \cdot \begin{bmatrix} D'_1(1) & \dots & D'_1(m) \\ \vdots & \ddots & \vdots \\ D'_{64}(1) & \cdots & D'_{64}(m) \end{bmatrix}. \qquad (5)$$

The greater the difference between descriptors is, the smaller the value of covariance (5) will be. It is also necessary to mention that descriptor matrix is already normalized due to peculiarities of SURF method.

III. Experimental Researches of Image Fragments Informativity

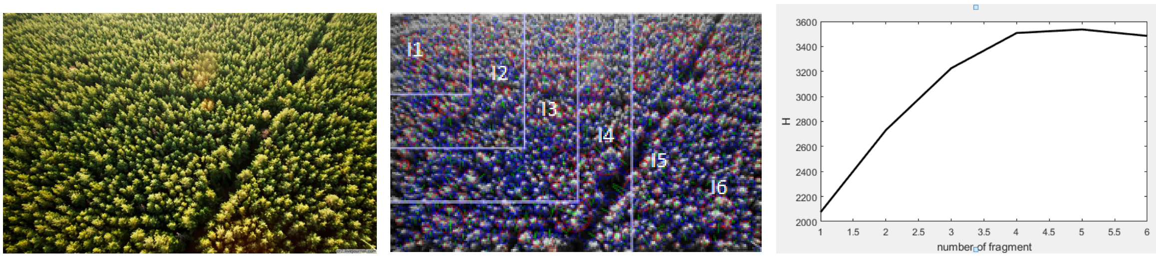
To research the proposed technique of informativity estimation and reliability of image matching three images (field, forest and city) were taken.

In Figure 2a initial image is shown, there are mainly textural features. For image optimal size determination we calculate integral indexes for fragments I1, I2, I3, I4, I5, I6, which are illustrated in Fig. 2b. In Figure 2c it is well illustraded, that up to fragment I5 informativity increases and then begin decreasing. Therefore, maximal informativity (3536,241) for this image corresponds to fragment 600×450 pixels (I5) and this is its optimal size.

In graph (Fig. 3b) it is well illustraded, that with fragment increasing, informativity increases to. Therefore, to find adequate informativity for field, we must increase image size till infinity, and stop when it will has enough informativity. So, field region has low informativity.

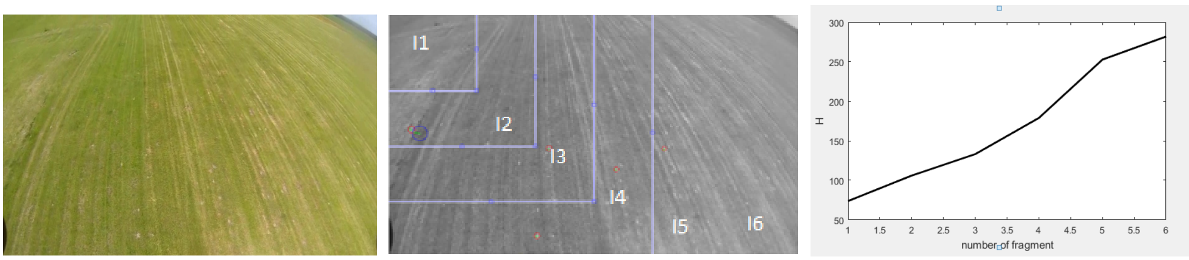
In Figure 4a it is shown areas with different informativity: sky – low, forest – medium and city – high one, therefore, with fragment increasing the parameters heterogeneity is observed. Particularly it can be seen that the peak is on the fragment 2 (250×250), the informativity is the highest one because this region includes different pieces, piece of sky, forest, and city, such fragment really has a high informativitty and it easy to recognize among other ones. At the same time fragment I3 losses its uniqueness because the horizon line takes lower area then in I2, city has high informativity, but other parameters (variance) nullify this. From this we can conclude that our method is relevant because the fragment I2 from the viewpoint of an operator really have the higher informativity.

Table 2 shows calculated integral indexes for different regions.



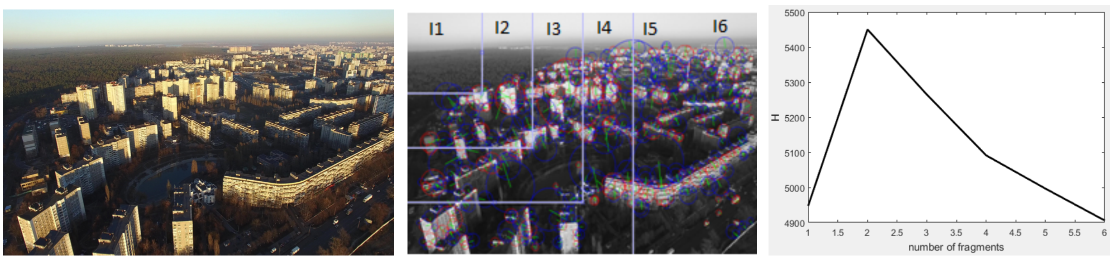
a b c

Fig. 2. Results of forest image processing (a) initial photo, taken from UAV board; (b) image of forest converted into grayscale, divided on several fragments and processed by SURF descriptor; (c) graph of integral index *H* value with respect to fragment size



a b c

Fig. 3. Results of field image processing (a) initial photo, taken from UAV board; (b) image of field converted into grayscale, divided on several fragments and processed by SURF descriptor; (c) graph of integral index *H* value with respect to fragment size



a b c

Fig. 4. Results of city image processing (a) photo of city, taken from UAV board; (b) image of city area converted into grayscale, divided on several fragments and processed by SURF descriptor; (c) graph of integral index *H* value with respect to fragment size

TABLE II

EXPERIMENTAL RESULTS

	I1	I2	I3	I4	I5	I6
H(forest)	2075.029754	2731.862577	3226.77959	3507.95128	3536.241	3484.5674
H(field)	73.8218335	106.038502	133.114033	178.963907	252.880844	281.921648
H(city)	4947.8998	5450.32493	5264.74364	5091.4835	4996.708997	4905.810

IV. CONCLUSIONS

To improve the accuracy and performance of CENS we proposed to evaluate the informativity of cartographic information using an integral index. Experiments on the series of different regions photos have shown that field region has very low informativity, forest – medium and city – high one. These results confirmed that optimal informativity equals to 3000. From the viewpoint of the operator this index gives us a correct estimate of informativity, and is relevant. Although, we have determined that the image can be divided into different informative sections such as field, sky, forest, city and others. This separation allows us to select the most informative parts and thus, present data in a more compact form.

REFERENCES

[1] V. K. Baklitskii, Correlation extreme methods of navigation and guidance, Tver', Knizhnyi klub press, 2009, 360 p.

[2] M. N. Krasilshchikov, and G. G. Serebriakov, Control and guidance of unmanned manuevered aerial vehicles on the basis of modern infromation technologies, Moscow, Fizmatlit press, 2003, 263 p.

[3] H. Bay, T. Tuytelaars, and L. Van Gool. SURF: Speeded up robust features. European Conference on Computer Vision, vol. 1, pp. 404–417, 2006.

[4] M. P. Mukhina, andI. V. Seden, "Analysis of modern correlation extreme navigation systems", *Electronics and Control Systems*, vol. 1 (39), 2014, pp. 95–101.

[5] M. V. Medvedev, and T. A. Sinichkina, "Objects classification on the basis of data taken from images", *Information technologies in economics, education and bussiness,* Proceedings of V International science practical conference, Saratov, February 2014, pp. 64–65.

Received January 12, 2016

Mukhina Maryna. Ph.D. Associate professor.
Educational-Scientific Institute of Information Diagnostic Systems, National Aviation University, Kyiv, Ukraine.
Education: National Aviation University, Kyiv, Ukraine (2002).
Research area: images processing, navigation and control.
Publications: 33.
E-mail: m_mukhina@inbox.ru

Yeremeieva Tetiana. Bachelor.
Educational-Scientific Institute of Information Diagnostic Systems, National Aviation University, Kyiv, Ukraine.
Education: National Aviation University, Kyiv, Ukraine, (2016).
Research interests: the extremal control systems.
Publications: 2.
E-mail: eremeeva94@mail.ua

М. П. Мухіна, Т. А. Єремєєва. Метод оцінювання інформативності еталонних даних геофізичного поля

Запропоновано інтегральний параметр для оцінювання інформативності еталонних даних геофізичного поля. Розроблено алгоритм та програмне забезпечення для його реалізації. Експерименти на наборі зображень різних місцевостей (поле, ліс, місто) підтвердили ефективність та точність даного алгоритму.

Ключові слова: геофізичне поле; інформативність; картографічні дані; кореляційно-екстремальна навігаційна система.

Мухіна Марина Петрівна. Кандидат технічних наук. Доцент.
Навчально-науковий інститут інформаційно-діагностичних систем, Національний авіаційний універститет, Київ, Україна.
Освіта: Національний авіаційний універститет, Київ, Україна, (2002).
Напрямок наукової діяльності: обробка зображень, навігація та керування.
Кількість публікацій: 33.
E-mail: m_mukhina@inbox.ru

Єремєєва Тетяна Анатоліївна. Бакалавр.
Навчально-науковий інститут інформаційно-діагностичних систем, Національний авіаційний університет, Київ, Україна.
Освіта: Національний авіаційний університет, Київ, Україна, (2016).
Напрямок наукової діяльності: екстремальні системи управління.
Кількість публікацій: 2.
E-mail: eremeeva94@mail.ua

М. П. Мухина, Т. А. Еремеева. Метод оценки информативности эталонных данных геофизического поля

Предложен интегральный параметр для оценки информативности эталонных данных геофизического поля. Разработаны алгоритм и программное обеспечение для его реализации. Эксперименты на наборе изображений разных местностей (поле, лес, город) подтвердили эффективность и точность данного алгоритма.

Ключевые слова: геофизическое поле; информативность; картографические данные; корреляционно-экстремальная навигационная система.

Мухина Марина Петровна. Кандидат технический наук, доцент.
Учебно-научный институт информационно-диагностических систем, Национальный Авиационный Университет, Киев,Украина.
Образование: Национальный авиационный универститет, Киев, Украина, (2002).
Направление научной деятельности: обработка изображений, навигация и управление.
Количество публикаций: 33.
E-mail: m_mukhina@inbox.ru

Еремеева Татьяна Аналоьевна. Бакалавр.
Учебно-научный институт информационно-диагностических систем, Национальный авиационный университет, Киев, Украина.
Образование: Национальный авиационный университет, Киев, Украина, (2014).
Направление научной деятельности: экстремальные системы управления.
Количество публикаций: 2.
E-mail: eremeeva94@mail.ua