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ZASTOSOWANIE KLASTRÓW ZDJĘĆ LOTNICZYCH W STRUKTURALNYCH SYSTEMACH MONITOROWANIA

Streszczenie: W artykule przedstawiono koncepcję związaną z algorytmem grupowania oraz anlizy zdjęć. W przypadku zdjęć lotniczych wykorzystuje się podział na mniejsze spójne bloki, które poddawane są dalszej obróbce w klastrach zgodnie z charakterystycznymi cechami. W artykule zaproponowano zastosowanie algorytmu grupowania K-means, który pozwoli na rozprowadzanie badanych bloków zdjęć lotniczych na podstawie ich charakterystycznych cech na klastrach.

Keywords: transformata, fotografia lotnicza, zdjęcia powierchni, niezidentyfikowane obiekty, bloki, klastry

CONCEPTUAL APPROACH OF AERIAL PHOTOGRAPHS CLUSTERING IN THE AERO MONITORING SYSTEM STRUCTURAL SPACE

Abstract: In article the main questions which are connected with the cluster analysis, namely algorithms of a clustering of digital photographs in system of processing and information transfer are considered. At a stage of a clustering of aerial photographs, there is a splitting of the image into one-coherent blocks. Here blocks of aerial photographs are exposed to various algorithms of a clustering, for the purpose of their distribution on clusters, and further definition of degree of a semantic saturation of blocks in clusters according to indicational characteristics. Therefore, within researches, in article it is offered to use algorithm of a clustering of K-means which will allow to distribute the studied blocks of aerial photographs, on the basis of their indicational characteristics on clusters.

Keywords: transformant, aero monitoring, aerial photographs, unmanned aerial vehicle, blocks

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1. Introduction

Today the tendency of growth of emergency situations in the modern world imposes serious requirements to system of aero monitoring. One of the main requirements in system of aero monitoring, is transfer of digital pictures from a board of the unmanned aerial vehicle (UAV) on a land complex, and also their decodifying in real time. It will allow to provide in due time system of aero monitoring with data on strategic objects, and also objects of military industrial complex, boundary territories, the airports, power and water highways on which territories armed conflict is possible [1, 7]. However significant increase in amount of information, and also limited characteristics of onboard data transmission channels don't allow to carry out fully delivery of information in real time. Thus, need of ensuring timely delivery of digital pictures, with the set quality, with use of unmanned onboard means of aero monitoring, is an actual task.

The analysis of the existing technologies for processing of digital aerial photographs [1-3] shows that methods of onboard processing of images don't consider a semantic component of the last and bring considerable distortions in the processed fragments of pictures. At the same time there is a need of preliminary processing of aerial photographs onboard the UAV, taking into account allocation in a picture of semantic important fragments which will be transferred further with preservation of the greatest informational content and also with the set capacity of onboard communication channels.

Among various methods of the cluster analysis [2, 17] it is offered to use a method of K-means. The choice of such algorithm is connected with the fact that, first, this algorithm is simple in realization, has a high speed of processing of basic data (in our case, a set of blocks of an aerial photograph), secondly, process of a clustering of blocks of an aerial photograph can happen not according to one characteristic (indicator) of the block, and at the expense of several indicational characteristics. However in a type of limited power of the onboard equipment of processing and data transmission of the UAV, in our case, it is offered to use two indicators. It is obvious that use two the dual-indicational indexes in the course of a clustering of blocks of an aerial photograph will provide necessary result.

2. Technology of aerial photographs blocks coding in the system of aero monitoring

As we don't know to what classes of a semantic saturation aerial photograph blocks belong, characteristic blocks of aerial photographs [3] will allow to classify application of methods of a clustering by degree of a semantic saturation. Here it is also necessary to note that finally, productivity of process the decodifying of aerial photographs will depend on use of the most effective method of a clustering.

Within research we will consider one of statistical methods of the cluster analysis – a method of *K*-means. The main idea of algorithm consists in definition of accessory of blocks of aerial photographs (on a basis the indicational characteristics) to clusters by means of minimization of a difference concerning aerial photograph blocks in a cluster and maximizing distance between centroids of clusters.

The algorithm of a clustering on the basis of a method of K-means is described by the following steps:

***Step I.* It is offered to choose quantity of clusters of k=3.**

This results from the fact that within research blocks of aerial photographs of different types (planimetric, textural, uniform) are considered in which saturation degree is considered, namely: low saturated, middle saturated and high saturated. Initial blocks $b(p_{k,\ell})$, are characterized by an indicator of the saturation P_{dct} (further it is used as $p_{k,\ell}$), have the coordinates (k,ℓ) in an aerial photograph are also renominated according to their accessory as a cluster element.

Accessory to a cluster of the redistributed block of an aerial photograph will be defined as $b(p_{k,\ell}) \rightarrow m_{i,j}^{(\gamma)}$ with fact, that $p_{k,\ell} \in P_j$.

In case if the aerial photograph block, is characterized on two indicators:

$$b(p_{k,\ell}^{(1)}, p_{k,\ell}^{(2)}) \rightarrow m_{i,j}^{(\gamma)} \text{ with fact, that } p_{k,\ell}^{(1)}, p_{k,\ell}^{(2)} \in P(2)_j, \qquad (1)$$

Where: $b(p_{k,\ell}^{(1)}, p_{k,\ell}^{(2)})$ – (k,ℓ)-th block of aerial photograph, characterized by an index of the saturation $p_{k,\ell}^{(1)}$ and structural index $p_{k,\ell}^{(2)}$; $P(2)_j$ – dual-indicational structural space of j-th cluster.

Formula 1 shows that in the cluster analysis, distribution of blocks of an aerial photograph on clusters significantly depends on absolute values of basic data.

Transformation of source values of indexes is for this purpose carried out $p_{k,\ell}^{(1)}$, $p_{k,\ell}^{(2)}$ on the following ratios: for a saturation index $p_{k,\ell}^{(1)}$ rated index $p_{k,\ell}'^{(1)}$ will be calculated: $p_{k,\ell}'^{(1)} = \left. p_{k,\ell}^{(1)} - \overline{p}_{k,\ell}^{(1)} \middle/ \sigma^{(1)} \right.$; for a structural index $p_{k,\ell}^{(2)}$ rated index $p_{k,\ell}'^{(2)}$ will be calculated: $p_{k,\ell}'^{(2)} = \left. p_{k,\ell}^{(2)} - \overline{p}_{k,\ell}^{(2)} \middle/ \sigma^{(2)} \right.$. Where $p_{k,\ell}'^{(1)}$, $p_{k,\ell}'^{(2)}$ – rated values of an index of a saturation and structural index for (k,ℓ)-th block of aerial photograph; $\sigma^{(1)}$, $\sigma^{(2)}$ – mean square deflection (MSD) values of an index of a saturation $p_{k,\ell}^{(1)}$ and structural index $p_{k,\ell}^{(2)}$.

At the same time, by use of operation of addition of the standardized indexes $p_{k,\ell}'^{(1)}$ and $p_{k,\ell}'^{(2)}$ we receive a rated index $p_{k,\ell}'$ in dual-indicational structural space $P(2)_j$: $p_{k,\ell}'^{(1)} + p_{k,\ell}'^{(2)} \rightarrow p_{k,\ell}' \in P(2)_j$. The cluster is understood as a set $M(2)_j$, that consists of elements $m_{i,j}$, which are blocks $b(p_{k,\ell}')$ aerial photographs, values of rated indexes $p_{k,\ell}'$ of which belong to indicational structural space $P(2)_j$, according to the chosen metrics that is presented by a formula: $M_j = \{m_{1,j}^{(\gamma_3)}, ..., m_{i,j}^{(\gamma_3)}, ..., m_{n_j,j}^{(\gamma_3)}\}$, $i = \overline{1, n_j}$; $m_{i,j}^{(\gamma)} = b(p_{k,\ell}')$ with $p_{k,\ell}' \in P(2)_j$. Where $m_{i,j}^{(\gamma_3)}$ – i-th element of j-th cluster on a final step of process of a clustering; γ_3 – number of a final step of process of formation of a cluster set; n_j – quantity of elements in j-th cluster; $P(2)_j$ – dual-indicational structural space of j-th cluster.

It should be noted here that in our case, use of several indexes in the course of a clustering will lead to more exact results concerning distribution of blocks of aerial photographs of clusters. At the same time higher degree of similarity of blocks in each cluster is provided.

Step II. **On the second step initial centroids are defined** C_1, C_2, C_3**.**

Under a centroid $C_j^{(\gamma)}$ for j-th cluster on γ-th step of process of a clustering, in our case, we understand the value $\overline{p'}_j^{(\gamma)}$ of indicational characteristic – rated index, that is mean value among all elements of a cluster.

In case of use of a rated index $p'_{k,\ell}$ in dual-indicational structural space $P(2)_j$ by centroid $C_j^{(\gamma,)}$ at a final stage of a clustering, the value of the indicational characteristic of a rated index corresponding to mean value of all elements of the created cluster is: $C_j^{(\gamma,)} = \overline{p'}_j^{(\gamma,)}$. Centroids of clusters are necessary for calculation on each step of process of a clustering of a measure of proximity of elements. It is necessary for definition to what of clusters this element belongs. Centroid $C_j^{(\gamma)}$ on an initial step of process of a clustering the first element will be, which is chosen as the initial block of a cluster. Then, centroid $C_j^{(0)}$ on an initial step corresponds to the first element of j-th cluster, what is presented by a formula: $C_j^{(0)} = m_{1,j}^{(0)}$. Where $C_j^{(0)}$ – centroid of j-th cluster on an initial step of process of formation of a cluster, γ=0; $m_{1,j}^{(0)}$ – first element of j-th cluster on an initial step of process of formation of a cluster, γ=0.

Initial elements of clusters are chosen taking into account a rated index $p'_{k,\ell}$ of initial blocks $b(p'_{k,\ell})$ of aerial photographs. It is obvious that rated indexes $p'_{k,\ell}$, depending on type of blocks, have to differ most from each other.

In our case at first we choose two elements, rated indexes $p'_{k,\ell}$ of initial blocks of aerial photograph will maximize initial distances between clusters. Further undertakes average value of rated indexes $p'_{k,\ell}$ of the chosen elements and on the basis of this finds intermediate elements, indexes of which will be close to this mean value. Thus. values of rated indexes $p'_{k,\ell}$ of the chosen initial blocks strongly will differ from each other.

Step III. **Third step defines to what of centroids this or that block of aerial photograph is closer** $b(p'_{k,\ell})$ **.**

We designate that value $\overline{p'}_j^{(\gamma)}$ corresponds a centroid $C_j^{(\gamma)}$ of j-th cluster on γ-th step of process of a clustering. Initial distribution of blocks of aerial photographs $b(p'_{k,\ell})$ on clusters occurs by the principle of proximity of a rated index $p'_{k,\ell}$ for (k,ℓ)-th block to value $\overline{p'}_j^{(\gamma)}$ of centroid $C_j^{(\gamma)}$. Here the selected blocks are characterized by the fact that has close values of rated indexes $p'_{k,\ell}$ to value $\overline{p'}_j^{(\gamma)}$ of centroid according to the chosen metrics.

As a metrics of determination of distance $d(2)_{\xi}^{(\gamma)}$ between the aerial photograph block $b(p'_{k,\ell})$ and to initial centroid $C_j^{(\gamma)}$ of j-th cluster on a rated index $p'_{k,\ell}$ – as the proximity measure is used $D(2)_{Ev}$ Euclidean distance:

$$d(2)_{\xi}^{(\gamma)} = \sqrt{\left|p'_{k,\ell} - \overline{p'}_{\xi}^{(\gamma)}\right|^2} = \left|p'_{k,\ell} - \overline{p'}_{\xi}^{(\gamma)}\right|, \qquad (2)$$

where: $\overline{p'}_{\xi}^{(\gamma)}$ – mean value on a rated index among all elements of ξ-th cluster on γ-th step of process of a clustering in dual-indicational structural space $P(2)_j$.

Then it is a finding of the minimum distance $d(2)_{min}^{(\gamma)}$ (where $d(2)_{\xi}^{(\gamma)} = d(2)_{min}^{(\gamma)}, \xi = \overline{1,3}$) from block $b(p'_{k,\ell})$ of aerial photograph relatively centroids $C_1^{(\gamma)}$, $C_2^{(\gamma)}$, $C_3^{(\gamma)}$ in dual-indicational structural space $P(2)_j$, on the basis of what decision concerning belonging of the current block to a cluster is made.

With that $p'_{k,\ell} \in \overline{p'}_{j}^{(\gamma)}$ and $p'_{k,\ell} = p'_{i,j}$ if:

$$d(2)_{min}^{(\gamma)} = \min_{1 \le \xi \le 3} d(2)_{\xi}^{(\gamma)}, \text{ such that } j = \xi \text{ for } d(2)_{\xi}^{(\gamma)} = d(2)_{min}^{(\gamma)}.$$

Expression $d(2)_{min}^{(\gamma)} = \min_{1 \le \xi \le 3} d(2)_{\xi}^{(\gamma)}$ means finding of the minimum distance $d(2)_{min}^{(\gamma)}$ between block $b(p'_{k,\ell})$ and one of three centroids in dual-indicational structural space $P(2)_j$, that is necessary for definition to what of clusters the current block belongs $b(p'_{k,\ell})$.

The generalized criterion of efficiency of all process of a clustering the centroid allows to carry out an assessment of extent of reduction of an error of rather intra cluster proximity $C_j^{(\gamma)}$ and blocks $b(p'_{k,\ell})$ of aerial photograph in dual-indicational structural space $P(2)_j$, and it can be calculated as the sum of square mistakes what is presented by expression:

$$E(2)^{(\gamma)} = [\sum_{j=1}^{k} \sum_{i=1}^{n_j^{(\gamma)}} (p'_{i,j} - \overline{p'}_{j}^{(\gamma)})^2], \qquad (3)$$

where $n_j^{(\gamma)}$ – quantity of elements $m_{i,j}^{(\gamma)}$, which refer to j-th cluster; with that $n_j^{(\gamma+1)} = n_j^{(\gamma)} + 1$.

Efficiency of process of a clustering of an aerial photograph is defined as function minimization $E(2)^{(\gamma)}$: $E(2)^{(\gamma)} \to \min$.

Obviously that the closer blocks $b(p'_{k,\ell})$ of aerial photographs relatively a centroid of the created cluster are, the more qualitatively the process of a clustering is carried out. At the same time value of functionality $E(2)^{(\gamma)}$ will go to a zero value.

Step IV. **Reassignment a centroid $C_j^{(\gamma+1)}$ for j-th cluster on ($\gamma+1$)-th step of process of a clustering is carried out.**

On each step of process of a clustering, taking into account addition of i-th element to j -th cluster, comes a reassignment of a centroid $C_j^{(\gamma)}$ in dual-indicational structural space $P(2)_j$.

In our case, centroid $C_j^{(\gamma+1)}$ on ($\gamma+1$)-th step of process of a clustering, with addition of i-th element to j -th cluster renominates with the accounting of the current value $\overline{p}_j'^{(\gamma)}$ and rated index $p'_{i,j}$ of element, being the closest to value a centroid $C_j^{(\gamma)}$.

As a result of process of a clustering of digital aerial photographs, in dual-indicational structural space $P(2)_j$, clusters with the distributed aerial photograph blocks on degree of a semantic saturation are created, namely: low saturated, middle saturated and high saturated.

3. Conclusions

The technology a clustering of blocks of an aerial photograph in dual-indicational structural space in system of information processing is developed. The concept is based on use of algorithm of a clustering of K-means by using of which distribution of blocks of an aerial photograph, in dual-indicational structural space, on clusters in which degree of a semantic saturation of characteristic blocks is considered is carried out. This results from the fact that within research blocks of aerial photographs of different types (planimetric, textural, uniform) are considered in which saturation degree is considered, namely: low saturated, middle saturated and high saturated.

REFERENCES

1. BARANNIK V.V., MUSIENKO A.P., YALIVETS K.S.: Method of the clustering of fragments of aerial photographs in spectral-frequency space. Science-Based Technologies, 29(2016)1, 23-30. DOI: 10.18372 / 2310-5461.29.10088.
2. BARANNIK V.V., MUSIENKO O.P., LEKAH A.A.: Technology of coding of blocks of an aerial photograph taking into account semanticaly important information to airborne systems for air monitoring. Science-Based Technologies. 31(2016)3, 274-278. DOI: 10.18372/2310-5461.31.10792.
3. BARANNIK, V.V., RYABUKHA, YU.N, PODLESNYI S.A.: Structural slotting with uniform redistribution for enhancing trustworthiness of information streams. Telecommunications and Radio Engineering. 76(2017)7, 607-615. DOI: 10.1615/TelecomRadEng.v76.i7.40.
4. GONZALES R.C., WOODS R.E.: Digital image processing, Prentice Hall, New Jersey, edition. II, 2002.

5. RICHARDSON I: H.264 and MPEG-4 Video Compression: Video Coding for Next-Generation Multimedia / Ian Richardson, 2005.
6. ZHANG Y., NEGAHDARIPOUR S., LI Q.: Error-resilient coding for underwater video transmission, OCEANS 2016 MTS/IEEE Monterey, Monterey CA, 2016, 1-7.
7. BARANNIK V., PODLESNY S., TARASENKO D., BARANNIK D, KULITSA O.: The video stream encoding method in infocommunication systems. Advanced Trends in Radioelecrtronics, Telecommunications and Computer Engineering (TCSET), International, Proceedings of the 14th International Conference on TCSET 2018 Lviv, 2018, pp. 538-541. DOI: 10.1109/TCSET.2018.8336259.
8. BARANNIK V., TUPITSYA I., SHULGIN S., SIDCHENKO S., LARIN V.: The application for internal restructuring the data in the entropy coding process to enhance the information resource security. International Symposium IEEE East-West Design & Test, (Yerevan, Armenia, oct. 14–17, 2016). Yerevan: 2016.
325 – 328. DOI: 10.1109/ewdts.2016.7807749.
9. BARANNIK V., KRASNORUTSKIY A., RYABUKHA Y., OKLADNOY D.: Model intelligent processing of aerial photographs with a dedicated key features interpretation. Modern Problems of Radio Engineering, Telecommunications and Computer Science (TCSET): 13th Intern. conf., (Lviv-Slavske, Ukraine, febr. 23–26, 2016). Lviv-Slavske: 2016. pp. 736-739. DOI: 10.1109/TCSET.2016.7452167.
10. BARANNIK V.V., RYABUKHA YU.N., TVERDOKHLEB V.V., BARANNIK D.V.: Methodological basis for constructing a method for compressing of transformants bit representation, based on non-equilibrium positional encoding. International Conference on Advanced Information and Communication Technologies (AICT): 2 Intern conf., (Lviv, Ukraine, 4-7 July 2017, 2017). Lviv: 2017. 188-192. DOI: 10.1109/AIACT.2017.8020096.
11. SHI YUN Q.: Image and video compression for multimedia engineering: fundamentals, algorithms, and standards / Yun Q Shi, Huifang Sun, NY, CRC Press, 2008, 576 p.
12. Rao K. R., HWANG J. J.: Techniques and Standards for Image, Video and Audio Coding. EnglewoodCliffs, NJ: Prentice-Hall, 1996.
13. ABLAMEJKO S.V., LAGUNOVSKIJ D.M.: Obrabotka izobrazhenij: tehnologija, metody, primenenie. - Minsk: Amalfeja, 2000. – 303 s.
14. DING Z., CHEN H., GUA Y., PENG Q.: GPU accelerated interactive space-time video matting. In Computer Graphics International P. 163–168. 2010.
15. CHRISTOPHE E., LAGER D.: Quality criteria benchmark for hiperspectral imagery. IEEE Transactions on Geoscience and Remote Sensing. 43(2005)9. 2103–2114.

16. LEE S.,YOON J.: Temporally coherent video matting. Graphical Models 72. 2010. 25–33.
17. ALIMPIEV A.N., BARANNIK V.V., SIDCHENKO S.A.: The method of cryptocompression presentation of videoinformation resources in a generalized structurally positioned space, Telecommunications and Radio Engineering, English translation of Elektrosvyaz and Radiotekhnika, 76(2017)6, 521-534, doi: 10.1615/TelecomRadEng.v76.i6.60.
18. CHIGORIN A., KRIVOVYAZ G., VELIZHEV A., KONUSHIN A.: A method for traffic sign detection in an image with learning from synthetic dat, 14th International Conference Digital Signal Processing and its Applications, 2012, pp. 316-335.