INFORMATION TECHNOLOGY

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Philip Prystavka[1]
Eugen Nichikov[2]

VIDEO STABILIZATION INFORMATIONAL TECHNOLOGY FOR UNMANNED AERIAL VEHICLE

[1,2]National Aviation University
Kosmonavta Komarova avenue 1, 03680, Kyiv, Ukraine
E-mails: [1]chindakor@mail.ru, [2]jk@47.kiev.ua

Abstract. *We developed an information technology for stabilization of video from the board of unmanned aerial vehicle that allows compensating influence of macromotions and micromotions of video camera, i.e. removing the fluctuations of separate video frames and increasing their sharpness. Above mentioned methods and means could be used in video processing in real time.*

Keywords: digital video; stabilization; unmanned aerial vehicle.

1. Introduction

At the beginning of the 21st century more than 60 countries developed and manufactured unmanned aerial vehicles (UAV) of various types. Apart from questions directly related to design and performance of aircraft, there is an important question of processing video data from the board of UAV for military and civil purposes, including patrolling of long objects, tracking of forest fires, target fixation, etc. Scientific and production centers and other organizations are developing UAV experimental prototypes in Ukraine. These companies more focused on the development and usage of small and medium types of UAV. More than 60 km/h speed and insignificant flight altitude are specific for small and medium types of UAVs. Due to influence of these factors it is complicated for an operator to analyze a video, obtained directly from the board of aircraft. An operator gets tired from quick change of a shooting scene. Camera movement does not allow focusing on objects that could be interesting for the observer.

The reasons that lead to a reduction in visual quality of the video are macromotions and micromotions of camera. Macromotions may be caused by the movement of an aircraft, turns, wind influence, etc. Through this type of distortion occurs frame "shake". Micromotions of the camera occur as the result of a work of the engine, and so on. Distortions such as defocus or streaks appear in weakening the top spatial frequencies images.

Outcome following noise can be reduced by mechanical devices (gyrostabilized cameras, etc.). However, apart from high cost of these devices, they can have more weight, consume more energy, which can be critical when limited size and payload volume of an aircraft. Therefore there is a need to use mathematical treatment procedures that allow eliminating the impact of macro- and micromotions of the camera.

The need for data in real-time, reliability and versatility are a significant obstacle for constructing high-performance processing systems digital video stream. This is due to the fact that known approaches are typically algorithmically difficult. This leads to extra time and hardware costs. In addition, the algorithms of used methods should allow to perform parallel calculations in the implementation in the software and also video processing system must be integrated into complex ground control station UAV. So actual is the development of information technology, which would allow removing fluctuations of individual video frames and increasing their sharpness in real time and would be part of this complex.

2. Analysis of publications

Processing the video data from the board of UAV requires choosing technology that allows the processing of streaming video in real time and would be flexible enough for the implementation of the developed algorithms and does not require special equipment.

There is a popular in software development for UAV [2, 6] library of computer vision, image processing and numerical algorithms for general purpose open source - OpenCV. It is implemented in C/C++, is also being developed for Python, Java, Ruby, Matlab, Lua and other languages [3].

Significantly increase productivity through the usage of computer graphics processors of NVIDIA company [11] allows hardware and software architecture of parallel computing CUDA [4]. The disadvantage of this technology is binding to the specific type of graphics processors.

OpenCL [18] framework can be used for writing computer programs associated with parallel computing in various graphics and central processors and FPGA. OpenCL includes a language based on C99 [7], plus application programming interfaces (APIs) that are used to define and then control the platforms. OpenCL provides parallel computing using task-based and data-based parallelism. OpenCl is an implementation of the GPGPU technology [12].

Existing video stabilization tools (for example, Warp Stabilizer [1], VirtualDub Deshaker [5], proDAD Mercalli [9], and so on) allow to process already captured video (only postprocessing). In addition, as already noted, the information technology should be a part of the UAV ground control station. Usage of third-party software does not allow integrate a video processing procedure to the complex.

The aim of this work is the development of information technology (IT) video stabilization from the UAV, which allows respond to changes captured by hardware to operators of decision-making systems in real time.

Record and data transmission channels of communication beyond the scope of this article, so here the term "video" will refer to the video in digital format.

In fact, digital video is a temporal sequence of frames; therefore, not decreasing generality, we shall use the term "digital image" in the sense of the video frame when describing frame processing methods.

For definiteness, we assume that the digital image represented as raster in RGB color model. We denote $p_{i,j}$, $i=\overline{0,W-1}$; $j=\overline{0,H-1}$ - the intensity of the color component of the pixel (R, G, or B), where W, H - linear dimensions of the image.

3. Stabilization of video from UAV

As already noted, the reasons leading to the reduction of visual quality of the video are macromotions and micromotions of video camera. Consider the procedure of compensation of disturbances in the processing of data from the board of UAV.

4. Camera macromotions compensation

Macromotions of camcorder causes to trembling of the frame of a video from the board of UAV on a small altitude. That significantly affects the quality of information perception of the video operator.

The procedure of elimination of the negative impact of macromotions can be used in solving of the following tasks:

1. Stabilization in planar aerial filming.
2. Fixing the object of observation.

Video stabilization in planar aerial filming can take place the following algorithm, illustrated in the flowchart (Fig. 1). In this case, the camera is pointed down perpendicular to the earth surface. Shooting scene is constantly changing.

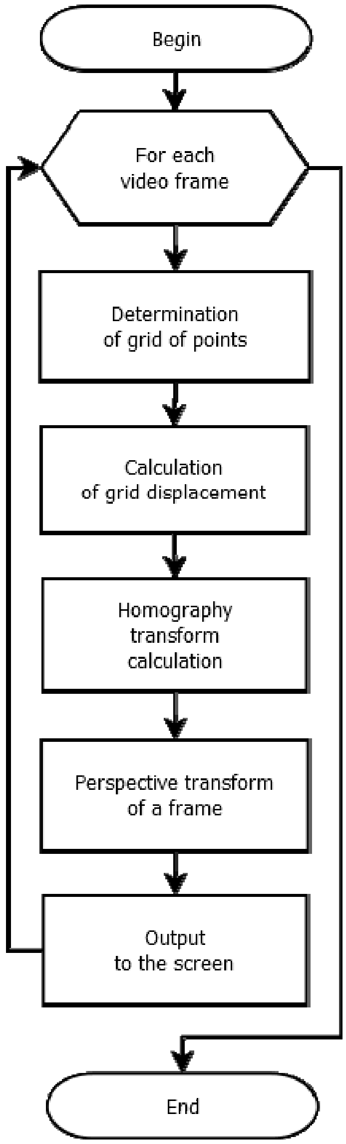

Fig. 1. Flowchart compensation algorithm for macromotions camera fixing

To stabilize the video, you must define a regular grid of points that will be detecting. Next to each video frame will be determined offset of these points relative to the previous frame. Lucas-Kanade algorithm [8] can be used in this task.

The figure (Fig. 2) shows an example of the shift points of the frame. Shift that corresponds to the general direction marked by arrows. If shift is not consistent with the general direction, a point would not be taken into account when calculating homography transformation. Such situation is possible due to falling to the scene foreign object, or in case wrong direction calculated. Points which do not have the right fit for the previous frame are marked by squares These points will also not be included.

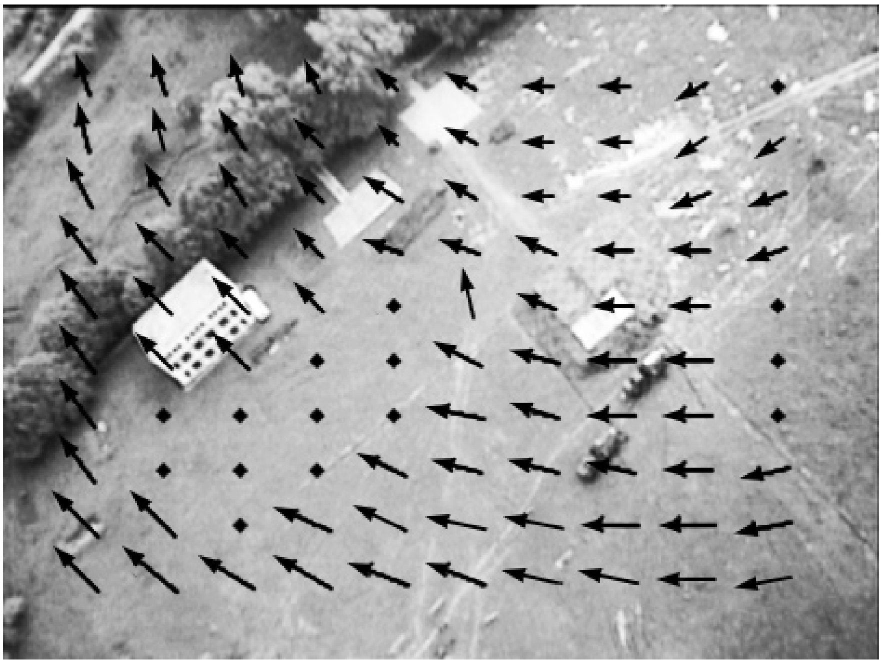

Fig. 2. Determining of offset points relative to the previous frame

Next, calculate homography transform of frame based on landslides series of frames. Shake compensation is through the perspective transformation of the current frame. In this case, the coordinate transformation for any pixel (i, j) output coordinates are given by the formula [17]:

$$i' = \frac{a_{11}i + a_{21}j + a_{31}}{a_{13}i + a_{23}j + 1}, \quad j' = \frac{a_{12}i + a_{22}j + a_{32}}{a_{13}i + a_{23}j + 1}.$$

where conversion factors $a_{m,n}$; $m = \overline{1,3}$; $n = \overline{1,3}$ determined using a minimum of four reference points. In this case, under reference points we understand pair of points of the current frame and related to them the points of the previous frame.

5. Fixing the object of observation

In task of fixing object of observation camera pointed in this object. Shooting scene is constant. However, through the movement of an aircraft, objects can approach and depart, viewed from different angles. Correcting unwanted camera vibrations may occur by the algorithm shown on the flowchart (Fig. 3).

It is necessary to define feature points [16] for the initial frame of the video to compensate macromotions in solving the problem of fixing the target. Next calculate the offset of these points for each frame using the Lucas-Kanade method [8]. If the offset of some point is not defined these points are discarded and not further considered. If not enough points left, the image quality may be impaired. Therefore, you can list feature points for the current frame manually or configure automatic recalculation, for example, if number of points is less than 5.

The next step is calculating the average value of the offset feature points relative to the previous frame. In this case, rotation of the camera is not taken into account. In order to compensate rotation of the camera, you should to calculate homography transformation [17] relative to the previous frame instead of offset.

On the processed video motion of the control points appears more smoothly. It can be illustrated on the chart (Fig. 4), which shows the coordinates of the control point at 25 frames of original and processed videos. In this example, the length of a curve which is defined by moving the control points, after processing decreased 5.5 times.

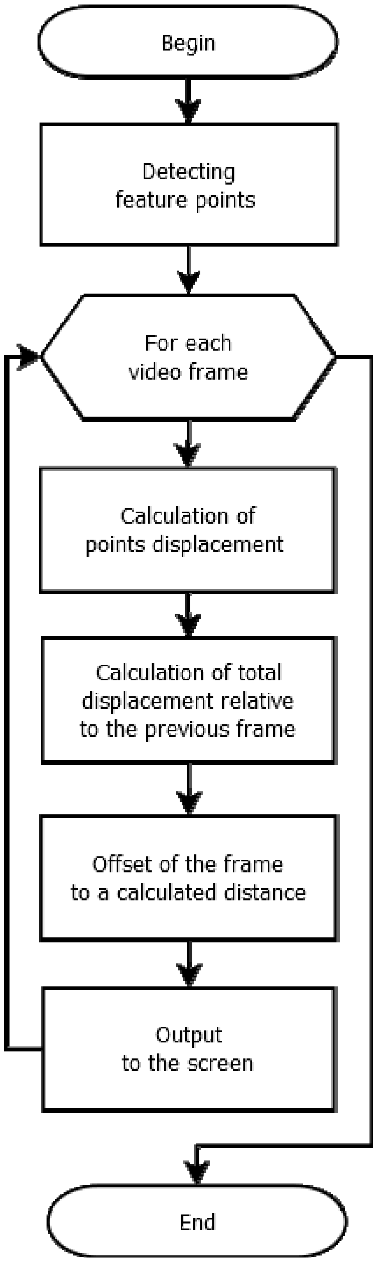

Fig. 3. Flowchart of the algorithm compensation of macromotions of camera in fixation of the target

6. Compensation micromotions of camera

When implementing procedures digital stabilization (sharpening of the digital image), which actually spend processing in real time, preference is given to those that reach the target processing functions with a minimum of computing operations. In fact such linear operators obtained in the form of a discrete convolution non-ferrous components and raster mask filters-stabilizers [13].

Suppose that the distortion of the original image caused camera micromotion. Then can be considered

$$p_{i,j} = L\left(p_{i,j}\right) = \sum_{ii=i-r_i}^{i+r_i} \sum_{jj=j-r_j}^{j+r_j} \gamma_{ii-i,jj-j}\, p^{o}_{ii,jj},$$

$$i = \overline{-\frac{k_i}{2}, \frac{k_i}{2}},\quad j = \overline{-\frac{k_j}{2}, \frac{k_j}{2}},$$

where $p_{i,j}$ - pixel color component (red, green or blue); $L\left(p_{i,j}\right)$ - linear low filtering operator; (i, j) - pixel index; k_i, k_j - image frame size; $p^{o}_{ii,jj}$ - color component of the ideal undistorted image; $\gamma_{ii-i,jj-j}$ - element of low-pass filter mask; $\left(2r_i+1\right)\times\left(2r_j+1\right)$ - size of the low-pass filter mask. Note that the mask γ is not known in advance and can be considered as a random.

We denote $\left\{p^{*}_{i,j}\right\}_{i,j\in Z}$ - sequence corresponding raster color component after stabilization. We introduce for consideration linear operators $C\left(p_{i,j}\right)$ such that

$$p^{*}_{i,j} = C\left(p_{i,j}\right) = \sum_{ii=i-r_i}^{i+r_i} \sum_{jj=j-r_j}^{j+r_j} \gamma^{*}_{ii-i,jj-j}\, p_{ii,jj},$$

quality of stabilization will be considered acceptable if it is carried out $p^{*}_{i,j} = p^{o}_{i,j}$, $i, j \in Z$,

for random mask γ. For example:

$$\gamma^{*} = \frac{1}{3136}\begin{pmatrix} 1 & 8 & -74 & 8 & 1 \\ 8 & 64 & -592 & 64 & 8 \\ -74 & -592 & 5476 & -592 & -74 \\ 8 & 64 & -592 & 64 & 8 \\ 1 & 8 & -74 & 8 & 1 \end{pmatrix}.$$

In [14] analyzed such linear operators and experimentally proved their effectiveness in the tasks of increasing the sharpness of a digital images distorted by camera micromotions in the real-time.

7. Information Technology

Thus we can offer the following IT video stabilization from the UAV, which allows respond to changes captured by hardware to operators of decision-making systems in real time.

It is possible to highlight two main stages of the processing video from UAV. First is macromotions compensation. Depending on the type of filming and tasks occur during processing, the user can choose one of the modes: stabilization of the frame or fixation of the target. The second stage is micromotions compensation can run in parallel to macromotions compensation.

For realization of stated mathematical aspects of information technology that is proposed, developed an automated system intended for stabilization of the video from the UAV. OpenCV computer vision library is used in the implementation of the automated system. Used methods [10, 13-15] and tools allow you to make calculations in several threads; it allows to carry out processing of video in real time.

"Activity Diagram" (Fig. 5) shows video processing. In the first step, the user can have only one option "Load video" from which we need to start working. This video can be in streaming format, or as a file. After opening the source video, the user can choose one of the parallel actions: compensation of macro- and micromotions. To compensate macromotions select one of two modes: video stabilization or target fixation.

Automated system was tested using data obtained from the board of UAV M-10 "EYE", development of scientific-production center of unmanned aviation "Virage", National Aviation University. Testing conducted on the recorded video with a resolution of 320x240 pixels at 30 fps. Video processing in real time was spent on the Dell Latitude E5530 Intel will be Core i5-3320M CPU @ 2.60 GHz and 8 GB. RAM. Video processing of larger size is possible in not real time or with lesser fps.

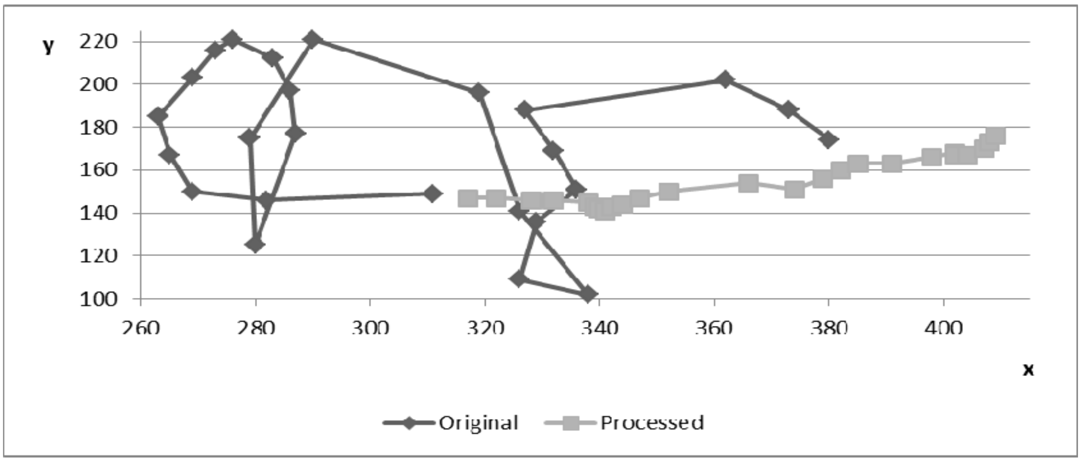

Fig. 4. Coordinates of the position of the control point on the original and processed videos

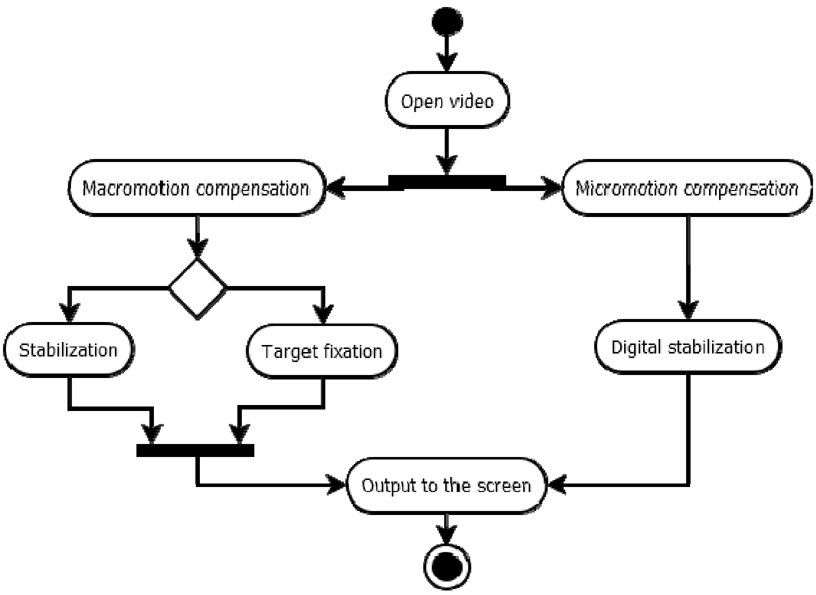

Fig. 5. Activity Diagram

8. Conclusions

The information technology of stabilization of the video from UAV developed. IT allows operators of decision-making systems to respond to changes captured by hardware in real time.

Used methods and means allow you to make calculations in several threads, which significantly increases the speed of data processing and allows video processing in real time.

Implementation of information technology can be used to create a workplace of the second external pilot of unmanned aircraft.

Further studies suggest the implementation of a multi-threaded processing by means of the GPU, increase the frame size of the processed video, usage of the additional data transferred from UAV etc.

References

[1] Adobe Premiere Pro CC (Online resource): http://www.adobe.com/products/premiere.html (in English).

[2] *Alpatov B.A., Babayan P.V., Koblov Ju.S., Muraviev V.S., Strotov V.V., Fel'dman A.B.* Software package for the automation of scientific research in the field of advanced navigation systems drone surveillance data. Vestnik RGRTY. 2012. ISSN 1995-4565. № 2 (vol. 40). – P. 9-15 (in Russian).

[3] *Bradsky G., Kaehler A.* Learning OpenCV. O'Reilly. 2008. ISBN 978-0-596-51613-0. – P. 580 (in English).

[4] CUDA ZONE (Online resource): https://developer.nvidia.com/category/zone/cuda-zone (in English).

[5] Deshaker video stabilizer for VirtualDub (Online resource): http://www.guthspot.se/video/deshaker.htm (in English).

[6] *Hing, J.T., Sevcik, K.W., Oh P.Y.* Improving Unmanned Aerial Vehicle Pilot Trainingand Operation for Flyingin Cluttered Environments. Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on 10-15 Oct. 2009. – P. 5641-5646 (in English).

[7] ISO/IEC 9899:1999/Cor 3:2007 от 2007-11-15 (Online resource): http://www.iso.org/iso/home/store/ /catalogue_ics/catalogue_detail_ics.htm?csnumber=50510 (in English).

[8] *Lucas B. D., Kanade T.* An iterative image registration technique with an application to stereo vision. Proceedings of Imaging Understanding Workshop. 1981. – P. 121-130. (in English).

[9] MercalliI EASY fixing shaky videos (Online resource): http://www.mercallieasy.com/ (in English).

[10] *Nichikov E.P.* Ortorectification of photos from unmanned aircraft of small and medium-type, with binding to reference points. Problems of informatization and monitoring. 2012. № 4(40). – P. 67-70 (in Ukrainian).

[11] NVIDIA (Online resource): http://nvidia.com/ (in English).

[12] *Owens J. D., Luebke D., Govindaraju N., Harris M., Krüger J., Lefohn A.E., Purcell T. A.* Survey of General-Purpose Computation on Graphics Hardware. Computer Graphics Forum. 2007. vol. 26. number 1. – P. 80-113 (in English).

[13] *Prystavka P.O.* Apply a filter based on polynomial splines in the processing of raster images. Visnyk NAU. 2008. № 4. – P. 104-107 (in Ukrainian).

[14] *Prystavka P.O., Cholyskina O.G.* Research of combined filter for sharpening images. Actual problems automation and informational technologies : Collection of scientific works. 2009. vol. 13. – P. 39-53 (in Ukrainian).

[15] *Prystavka P.O.* Polynomial splines in data processing. Publishing Dnipropetrovsk University Press. 2004. – P. 236 (in Ukrainian).

[16] *Shi J., Tomasi. C.* Good Features to Track. Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition. June 1994. – P 593-600. (in English).

[17] *Temiz M. S., Külür S.* Rectification of digital close range images: sensor models, geometric image transformations and resampling. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B5. Beijing 2008. – P. 89-94 (in English).

[18] The open standard for parallel programming of heterogeneous systems (Online resource): http://www.khronos.org/opencl/ (in English).

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Приставка П.О.[1], Нічіков Є.П.[2] Інформаційна технологія стабілізації відео з борту безпілотного повітряного судна

[1,2]Національний авіаційний університет, просп. Космонавта Комарова, 1, Київ, Україна, 03680
E-mails: [1]chindakor@mail.ru, [2]jk@47.kiev.ua.

Розроблено інформаційну технологію стабілізації відео з борту безпілотного повітряного судна, що дозволяє компенсувати вплив макроруху та мікроруху камери фіксації, тобто прибрати коливання окремих кадрів відео та підвищити їх різкість. Показано можливість використання наведених методів та засобів при обробці відео в режимі реального часу.

Ключові слова: безпілотне повітряне судно; стабілізація; цифрове відео.

Приставка П.О.[1], Ничиков Е.П.[2] Информационная технология стабилизации видео с борта беспилотного воздушного судна

[1,2]Национальный авиационный университет, просп. Космонавта Комарова, 1, Киев, Украина, 03680

E-mails: [1]chindakor@mail.ru, [2]jk@47.kiev.ua

Разработана информационная технология стабилизации видео с борта беспилотного воздушного судна, которая позволяет компенсировать влияние макроколебаний и микроколебаний камеры фиксации, т.е. убрать колебания отдельных кадров видео и повысить их чёткость. Показана возможность использования указанных методов и средств для обработки видео в режиме реального времени.

Ключевые слова: беспилотное воздушное судно; стабилизация; цифровое видео

Prystavka Philip

Doctor of Technical Sciences, Professor, head of the department of Applied Math, National Aviation University, Kyiv, Ukraine.

Education: Dnipropetrovsk National University, Dnipropetrovsk, Ukraine.

Research area: applied mathematics and information technologies.

Publications: 117.

E-mail: chindakor@mail.ru

Nichikov Eugen

Graduate Student, dept. of Applied Math, National Aviation University.

Education: National Aviation University, Kyiv, Ukraine.

Research area: Information Technology.

Publications: 13.

E-mail: jk@47.kiev.ua