# VISION-BASED APPROACH TO UAV VIBRATION ANALYSIS[1,2]

**David Asatryan, Samvel Hovsepyan**

***Abstract**: It is known that the vibration of the board of unmanned aerial vehicles (UAVs) leads to distortions of information received from UAV. An important task is to determine the vibration parameters of the UAV board in real flight conditions at the absence of special measuring equipment on the board. The source of the necessary information for this can serve as a video sequence taken by the on-board video camera, since vibration leads to blurring of the image. In this paper, a technique for estimation of vibration parameters by a method of the analysis of the degree of blurring of the images in the frames of a video sequence is proposed. In this paper, we use the method proposed earlier, based on the determination of the Weibull distribution shape parameter, calculated from the set of gradient magnitudes of the image. The frequency of vibration is determined by analyzing the spectral density of the sequence of estimates of the blur. An example of real measurements carried out with the help of UAV is given.*

**Keywords**: UAV, Vibration, video, Weibull distribution, spectral density.

***ACM Classification Keywords**: Image Processing and Computer Vision*

## Introduction

Unmanned aerial vehicles (UAVs) have become an active research topic in photogrammetry in problems of determining the position, orientation and geometric dimensions of certain ground objects, etc. [1].The successfulness of this task is due to the possibility of obtaining high-quality digital photos and applying effective image processing algorithms. Modern UAVs are equipped with high resolution cameras, in principle, sufficient for solving many photogrammetric problems.

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[1] This work was supported by the RA MES State Committee of Science, in the frames of the research project № 15T-1B274.

[2] This work was supported by Russian-Armenian (Slavonic) University, in the frames of the research project, financed by the RF State Committee of Science.

However, images obtained from on-board equipment are distorted due to a number of factors inevitably accompanying the flight of any UAVs such as the influence of weather conditions (in particular, winds), random deviations from the intended flight path, turbulence of the atmosphere, vibration of the board from running engines, etc. As a result, the image is blurred, noised and distorted in an unexpected manner, which significantly affects the accuracy of the photogrammetric measurements. According to [2] a one-pixel shift in a 0.8 mega pixel resolution captured from a UAV operating at 1000ft will correspond to about 2.5m measurement error on the ground. Therefore, studies related to the assessment and reduction of the effect of vibration on the quality of decisions taken on the information delivered by UAVs has found great attention in the scientific literature.

One of the important tasks in this area is to assess the impact of vibration of the UAV position in space and, consequently, the position of the video camera on the degree of blurring of images in the video sequence. In general, vibration can be regarded as a special type of motion, which has the form of periodic oscillations. Consequently, the above estimation problem can be reduced to determining the parameters of these oscillations.

The task of evaluating the vibration parameters of a UAV by photographing certain objects is considered in different formulations. The most common approach is to develop and perform experiments using shaker stands. For example, in [3] the problem of Automatic isolation of blurred images from UAV image sequences is considered. A "shaking table" was used to create images with known blur during a series of laboratory tests. Once defined for a sequence of images, a user defined threshold can be used to differentiate between "blurred" and "acceptable" images.

As for image processing based methods, video stabilization is attained through image processing techniques to estimate the camera motion by computing the degree of geometric transform parameters between consecutive frames of video, smooth the parameters and compensate the deviation of images [4].

Another approach is used in [5], in which to study the characteristics of the vibration of the UAV side, the most significant sources of vibration are selected and the effects of individual components and total vibration are simulated. However, this approach involves performing work to assess the degree of vibration influence only for a certain type of UAV and the possibility of distributing the results obtained to other types of products remains unclear.

We are interested only in those methods that allow us to solve the above-mentioned problem with a real UAV flight or in conditions as close as possible to real flight. It is clear that the use of expensive measuring stands and other special equipment on board the UAV is impractical, even if it is possible. Therefore, we are interested in methods that use video equipment, with which certain objects are photographed and on the images obtained the corresponding decisions are taken.

The main idea of the proposed approach is based on the fact that the images in frames of the video sequence obtained during real UAV flight are subject to blurring, the degree of which fluctuates from frame to frame and can fluctuate according to the camera position at each moment of time. This circumstance makes it possible to estimate the frequency of the vibration of the bead, and also to carry out relative measurements of its amplitude. The proposed approach is applied for the first time and can be applied in other related fields.

## Technique for estimating the frequency of vibration

A method for estimating the frequency of vibration is based on the use of the image blur measure proposed in [6] to analyze the frames of the video sequence obtained from the UAV. This measure represents the value of the form parameters of the two-parameter Weibull distribution (1),

$$f(x;\eta,\sigma)=\frac{\eta}{\sigma}\left(\frac{x}{\sigma}\right)^{\eta-1}\exp\left[-\left(\frac{x}{\sigma}\right)^{\eta}\right],\ x\geq 0, \tag{1}$$

adjusted to the set of gradient magnitudes of the image, calculated using the Sobel operator [7], where $\eta > 0$ is the shape parameter, and $\sigma > 0$ is the scale parameter. We note that the Weibull model of the gradient magnitude is useful for other problems of image processing (see, for example, [8-11]).

In [2], a sufficiently sharp monotonically increasing dependence of this measure on the degree of blurring of the image is shown, approaching the value of "2", and in some cases slightly exceeding this value.

We give an example illustrating what was said for a particular image. In Fig. 1 is shown an example of an image blurred with a fixed smoothing algorithm with different values of the blur factor. The values of the shape parameter $\eta$ are shown below the corresponding images. It can be seen that the dependence of the evaluation of the form parameter on the degree of blurring is consistent with what was said above and visual perception.

Numerous experiments with the processing of video sequences obtained in real UAV flight have shown that fluctuations of the blur measure are actually observed. Let us give an example. In Fig. 2, a fragment of the fluctuation dependence of the blur measure from number of the video sequence frames obtained with the real drone of the Ar Drone 2.0. Here the shooting frequency is 30 frames per second. Numerous experiments with the processing of video sequences obtained in real UAV flight have shown that the fluctuations of the blur measure are actually observed.

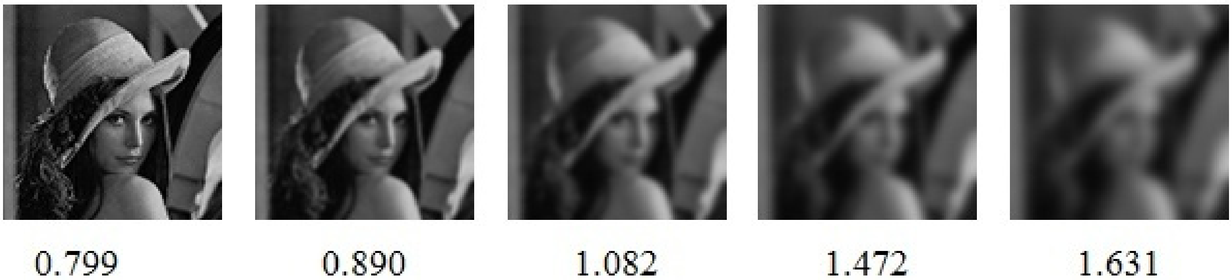



Fig. 1. Estimates of the shape parameter $\eta$ for the blurred Lena image

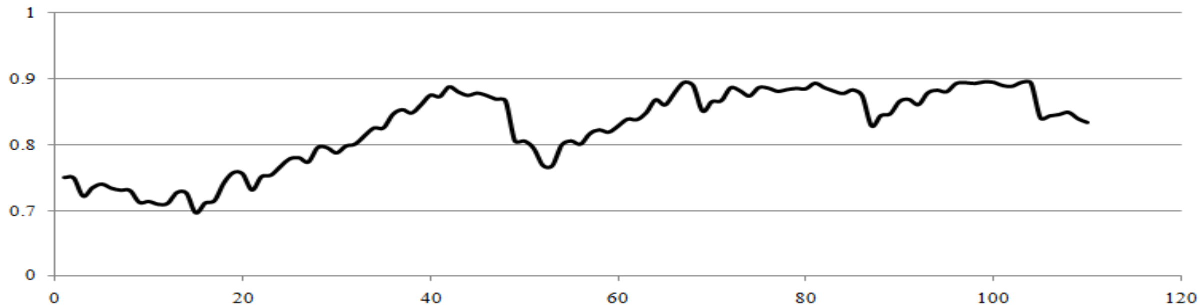



Fig.2. Fragment of the curve of the blur measure changing in real video frames.

High-frequency oscillations observed on the curve correspond to changes in blur due to vibration, while low-frequency variations represent a change in the degree of blurriness of the observed frames during the movement of UAVs on the terrain.

To estimate the vibration frequency, a spectral analysis of this curve was carried out. In Fig. 3 is shown the spectral density curve calculated along this curve by means of Fast Fourier Transform algorithms (processing is performed using the STATISTICA10 package). The curve shows two spectral density peaks corresponding to frequencies of about 5 Hz and 15 Hz.

In order to verify the correctness of the experiment, spectral density calculations were made for 10 consecutive segments of the video sequence containing 30 frames (i.e., with a duration of 1 second).

Two fragments of this experiment are shown in Fig. 4. It turned out that the estimation of the vibration frequency is approximately the same for all segments, which confirms the correctness of the experiment and allows the evaluation to be carried out for the entire video sequence.

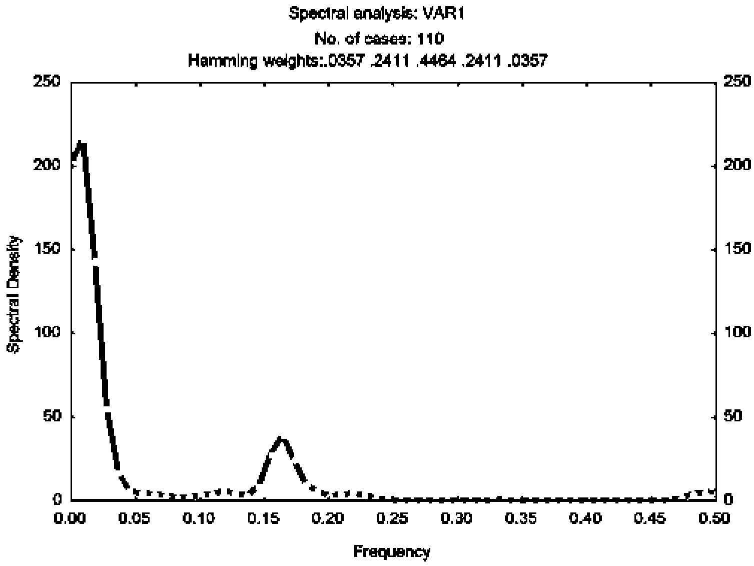
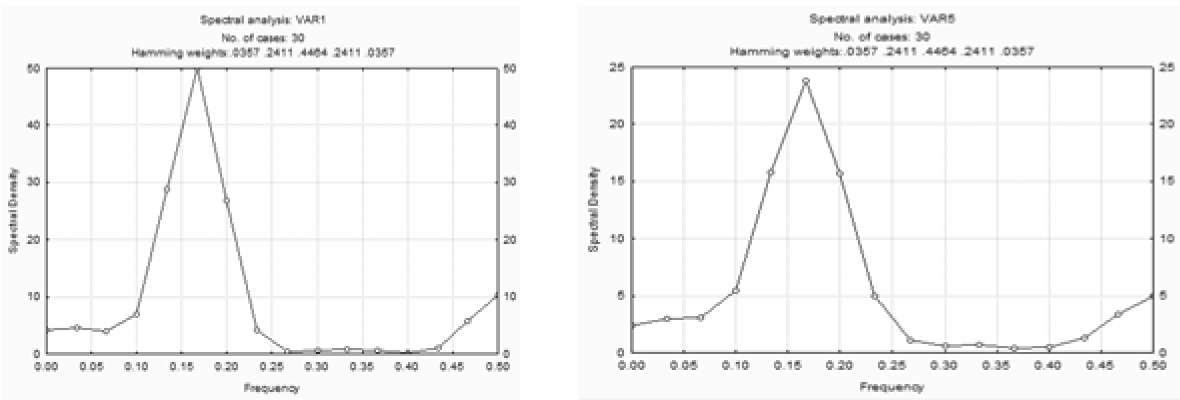



Fig.3. The spectral density calculated for the data of Fig. 2.




a) b)

Fig. 4. Spectral density for different segments of the video sequence.

a) For frames with numbers 1-30; b) For frames with numbers 91-120.

In conclusion, we describe one side, but important application of the proposed methodology. When photogrammetric measurements performed on video images obtained from the UAV board, it becomes necessary to select the most suitable frame for further processing. The purpose of this choice is to improve the accuracy of photogrammetric measurements. One of the criteria for selecting the desired frame is the degree of motion blur caused by the movement of the UAV. A similar problem was posed in [9], and, as pointed in the introduction of this paper, it is solved using measurements on a shake table. The same methodology allows to solve this problem in those cases when there is no such data and the only source of information is the video sequence obtained from the UAV. Then the application of the considered technique for the choice of the required frame is proposed based on the magnitude of the image blurriness in the frame.

## Conclusion

In this paper, a technique is proposed for estimating the vibration frequency of the UAV side by properly processing the images of the video sequence. A technique for determining the blurriness of images in frames by the value of the Weibull distribution shape parameter, estimated from the set of the gradient magnitudes, was realized. The advantage of the proposed approach is the possibility of estimating the vibration parameters based on the results of video shooting in real flight conditions. The developed technique can be used in various photogrammetric problems, as well as in problems of monitoring conditions and flight processes of UAV.

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# ERRATUM

## David Asatryan, Karen Egiazarian, Vardan Kurkchiyan

In the paper: David Asatryan, Karen Egiazarian, Vardan Kurkchiyan. Orientation Estimation with Applications to Image Analysis and Registration (International Journal "Information Theories and Applications", Vol. 17, Number 4, pp. 303-311, 2010) was made an error.

Formula (5) must be as follows $$tg\alpha = \frac{2 * \sigma_H \sigma_V \rho_{HV}}{\sigma_H^2 - \sigma_V^2 - \sqrt{\left(\sigma_H^2 - \sigma_V^2\right)^2 + 4\sigma_H^2 \sigma_V^2 \rho_{HV}^2}}.$$

Reminder is right.