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The Problems of Constructing Optimal Onboard Colored RGB Depicting UAV Systems

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Abstract:-The problems of constructing optimal adaptive onboard color RGB depictingUAV systems have been analyzed. The problem of optimal formation of color signals of RGB color system has been formulated and solved by implementing the adaptive flight mode of UAVs containing an onboard imaging system. An adaptive UAV mode with an imaging system on board is proposed, which consists of adaptive changes in flight altitude depending on the wavelength of the received color signal. As a result of the optimization of the proposed operating mode of the UAV imaging system, an analytic formula for adaptive device control has been obtained. Recommendations have been given on the practical implementation of the proposed method.

Keywords:-adaptation, aerosol, filtration, optimization,RGB image system, UAV

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I. INTRODUCTION

It is common knowledge that color images of terrestrial land objects obtained via various flying devices, including UAVs, are usually exposed to atmospheric color-searching factors. First of all, such factors should be delivered bythe atmospheric aerosol in its various manifestations, from a fine aerosol to particles of giant sizes reaching tens of micrometers. One of the main tasks of obtaining high-quality color images of various ground objects is to eliminate or compensate the effect of atmospheric aerosol consisting of both color distortion and the decrease in the signal-to-noise ratio. For example, in order to eliminate chromaticity distortionspartially, it was suggested in [1, 2, 3] to use a noise canceling filter, and in [2] it was suggested to achieve maximum visibility along the optical path. In [3], the combination of a “dark” channel and a local contrast enhancement is used to remove chromaticity distortion. Other methods have been proposed [4-6], on the base of filtering the signal and using the signal coming from the “dark” channel. At the same time, in the known methods, the existing possibility of optimizing the operating mode of the color imaging system installed on the aircraft for filtering undesirable color gamma at certain wavelength sections is almost not used. Investigating the conditions for achieving optimum operation of the color imaging system would increase the signal-to-noise ratio at the output of the color RGB imaging system in the respective wavelength bands and thereby new opportunities are used for the further use of such systems to detect and identify remote color objects.The article is devoted to the investigation of the possibility of the optimal RGB mode synthesis of a color imaging onboard system, in the above sense.

II. THE PROPOSED METHOD

The distribution of radiation flows in the formation of an image of an adaptive imaging system is shown in Fig.1.

The mathematical model of remote imaging at wavelength λ has the following form [7]using the imaging system:

$$g(\lambda) = f(\lambda)\cdot T(\lambda) + A(\lambda)\cdot(1-T(\lambda)) \qquad (1)$$

where: g (λ) is a noisy image.

$$f(\lambda) = f_{sun}(\lambda) + f_{sky}(\lambda) \qquad (2)$$

where: f (λ) is the glow of the scene being investigated or the original noiseless image; A (λ) is the glow of the atmosphere; T (λ) is the transmission of the atmosphere.

Equation (1), f (λ) · T (λ) represents the image component subjected to direct attenuation; A (λ) · (1-T (λ)) - is a component expressing air glow, i.e. the result of light scattering by an aerosol in the atmosphere.

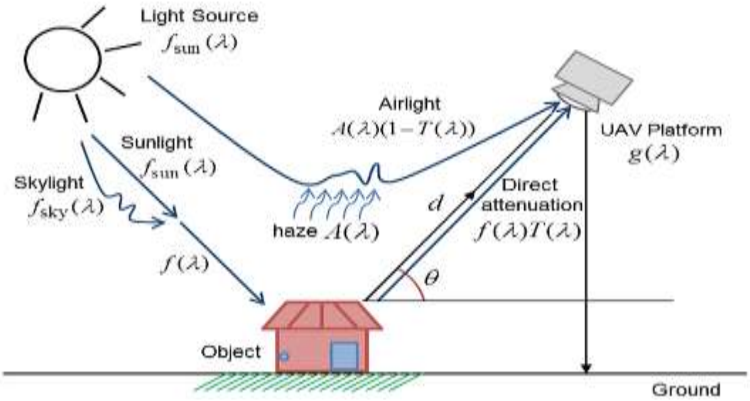

Figure 1.Model representation of an imaging system on the base of a UAV located in an aerosol-contaminated atmosphere. F_{sun} (λ) - the glow of the Sun; F_{sky} (λ) is the glow of the sky, i.e. the light dispersed in the atmosphere; λ is the wavelength [7]

According to [8], the transmission T (λ) is defined as:

$$T(\lambda) = e^{-\beta \cdot l} \tag{3}$$

where: β is coefficient of atmospheric scattering at the wavelength of the investigated color; l is the distance to the object.

Thus, in the classical case, the problem of eliminating the impact of aerosol is to restore f (λ) using the data on g (λ), T (λ) and A (λ) [7]. In this article, the possibility of optimizing the process of forming RGB color images by introducing additional constraints and restrictions on the integral values of newly introduced dependenciesis considered.

For the adaptive control of the impact of external factors on the RGB colored side images, the introduction of a control function for adaptive flight altitude control or the dependence of l on λ, is proposed in the work.

$$l = l(\lambda) \tag{4}$$

The introduction of function (4) means the transition of the system to the first proposed adaptive mode, i.e. changing the distance to the object being investigated depending on the value of the wavelength λ RGB component of the color image.

The mathematical model of the proposed adaptive mode of UAV operation with an RGB color imaging systemshould be considered in detail.

The integral functional Fi,determining the signal of the i-th component of the RGB color system, to be optimized in the adaptation mode in the continuous wavelength range 0 ÷ λmax has the following form:

$$F_i = \int_0^{\lambda_{\max}} \gamma(\lambda)_i \, g(\lambda) d\lambda = \int_0^{\lambda_{\max}} \gamma(\lambda)_i \left[f(\lambda) \cdot e^{-\beta \cdot l(\lambda)} + A(\lambda) \cdot (1 - e^{-\beta \cdot l(\lambda)}) \right] d\lambda \tag{5}$$

where: γ (λ)$_i$ is the stimulus function for the i-th component of the RGB chromaticity system $i = \overline{1,3}$.

The problem of optimizing the adaptive regime of the color onboard imaging system is solved by finding a function l (λ) at which in the above-mentioned wavelength range F1 would reach a maximum value, which is equivalent to the optimal generation of signals of the specified range. For the accurate solution of this problem, it is necessary to limit the class of admissible functions l (λ), the realization of which is technically possible.

Assume that, the restriction of the class of possible adaptive control functions l (λ) is determined according to the condition:

$$\int_0^{\beta_{\max}} F_0(\lambda) d\lambda = \int_0^{\beta_{\max}} \lambda \cdot l(\lambda) d\lambda = C; \; C = const \tag{6}$$

where function F0 (λ) can be chosen from a bounded set of functions

$$\{F_{0j}\} = \{F_{01}(\lambda); F_{02}(\lambda)\}; \; j = \overline{1,2} \tag{7}$$

$$F_{01}(\lambda) = a_1 - a_2\lambda \tag{8}$$

$$F_{02}(\lambda) = a_3 + a_4\lambda \tag{9}$$

In this case, the set of admissible functions is restricted to two functions

$$l_1(\lambda) = \frac{a_1}{\lambda} + a_2 \quad (10)$$

$$l_2(\lambda) = \frac{a_3}{\lambda} - a_4 \quad (11)$$

where: a_1, a_2, a_3, a_4 =const.
The function graphs F21 (λ) and F22 (λ) are shown in Fig. 2

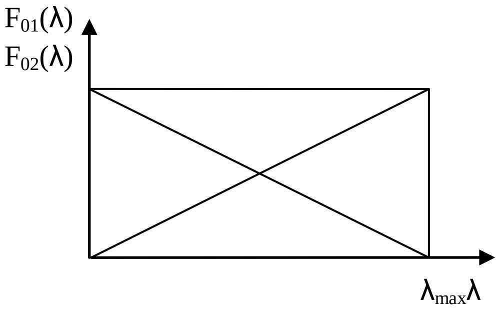

Figure2.The function graphs F21 (λ) and F22 (λ)

The function graphsl 1 (λ) and l2 (λ) are shown in Fig. 3

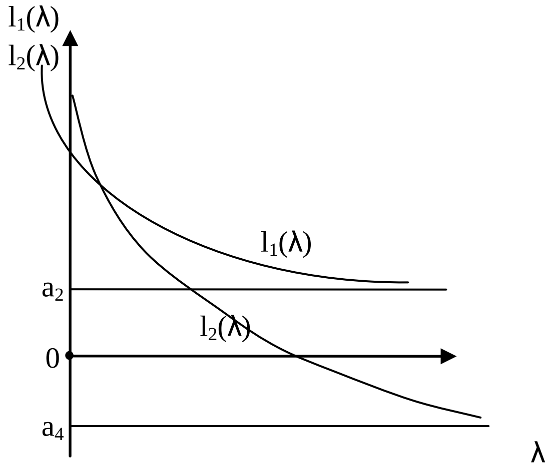

Figure3.The function graphsl 1 (λ) and l2 (λ)

Taking into account expressions (5), (6), the complete functional of unconditional variation optimization is formulated:

$$F_i = \int_0^{\lambda_{max}} \gamma(\lambda)_i \cdot \left[f(\lambda) \cdot e^{-\beta \cdot l(\lambda)} + A(\lambda) \cdot \left(1 - e^{-\beta \cdot l(\lambda)}\right)\right] d\lambda - \chi \left[\int_0^{\lambda_{max}} \lambda \cdot l(\lambda) d\lambda - C \right] \quad (12)$$

where: $i = \overline{1,3}$.

According to Euler's equation, the optimal function l (λ) should meet the condition:

$$\frac{d\left\{\gamma(\lambda)_i \left[f(\lambda) \cdot e^{-\beta \cdot l(\lambda)} + A(\lambda) \cdot \left(1 - e^{-\beta \cdot l(\lambda)}\right) - \chi \cdot \lambda \cdot l(\lambda)\right]\right\}}{dl(\lambda)} = 0 \quad (13)$$

Taking into account condition (13), the followings are obtained:

$$-\beta f(\lambda) \cdot e^{-\beta \cdot l(\lambda)} + A(\lambda) \cdot \beta \cdot e^{-\beta \cdot l(\lambda)} - \chi \cdot \lambda = 0 \quad (14)$$

From expression (14) the followings are found out:

$$e^{-\beta \cdot l(\lambda)} \left(A(\lambda) \cdot \beta - f(\lambda) \cdot \beta \right) - \chi \cdot \lambda = 0 \quad (15)$$

$$l(\lambda)=\frac{1}{\beta}\ln\left[\frac{-f(\lambda)\cdot\beta+A(\lambda)\cdot\beta}{\chi\cdot\lambda}\right] \quad (16)$$

Taking into account expressions (6) and (16), the followings are obtained:

$$\int_0^{\lambda_{\max}}\frac{\lambda}{\beta}\ln\left[\frac{f(\lambda)\cdot\beta-A(\lambda)\cdot\beta}{\gamma\cdot\lambda}\right]d\lambda=C \quad (17)$$

$$\chi=\exp\left\{\frac{2CB}{\lambda_{\max}}-\frac{2}{\lambda_{\max}^2}\int_0^{\lambda_{\max}}2\ln\left[-f(\lambda)\cdot\beta+A(\lambda)\cdot\beta\right]d\lambda-\ln\lambda\right\}=\gamma_0 \quad (18)$$

Taking into account expressions (16) and (18), the following equation can be obtained

$$l(\lambda)_{opt}=\frac{1}{\beta}\ln\left[\frac{-f(\lambda)\cdot\beta+A(\lambda)\cdot\beta}{\chi_0\cdot\lambda}\right] \quad (19)$$

Thus, when the condition (19) is implemented, the functional (12) reaches an extremal value.

In order to determine the type of the extremum, it is sufficient to calculate the second derivative integral in expression (12) and the followings should be verified:

$$A(\lambda)>f(\lambda) \quad (20)$$

The functional F2 reaches the minimum, and when

$$A(\lambda)<f(\lambda) \quad (21)$$

it reaches the maximum. However, as it can be seen from the expression (18), the Lagrange multiplier cannot be negative. Consequently, according to (19) inequality (21) is not satisfied, the inequality (20) showing the target functional (12) reaching its maximum valueis true.

Thus, the optimization and synthesis of the optimal RGB mode of the imaging system allows to generate the optimal signals R, G and B of the chrominance component in the following form:

$$F(R)=\int_0^{\lambda_{\max}}\gamma_R(\lambda)\cdot\left[f(\lambda)\cdot e^{-\beta\cdot l_{opt}(\lambda)}+A(\lambda)\cdot\left(1-e^{-\beta\cdot l_{opt}(\lambda)}\right)\right]d\lambda$$

$$F(G)=\int_0^{\lambda_{\max}}\gamma_G(\lambda)\cdot\left[f(\lambda)\cdot e^{-\beta\cdot l_{opt}(\lambda)}+A(\lambda)\cdot\left(1-e^{-\beta\cdot l_{opt}(\lambda)}\right)\right]d\lambda$$

$$F(B)=\int_0^{\lambda_{\max}}\gamma_B(\lambda)\cdot\left[f(\lambda)\cdot e^{-\beta\cdot l_{opt}(\lambda)}+A(\lambda)\cdot\left(1-e^{-\beta\cdot l_{opt}(\lambda)}\right)\right]d\lambda$$

where: γR (λ), γG (λ), γB (λ) is the stimulus function of the color image components.

III.CONCLUSIONS

Thus, the proposed method for optimizing the adaptive control of the process of forming RGB color images under the impact of an aerosol allows to achieve the maximum value of chrominance components in a continuous wavelength range. The technical realization of the optimal mode concludes in the mode of UAV lifting or descent in the measurement of R, G, B components of a separate image of a ground object in the further synthesis of a colored object by applying colors.

In conclusion, the main conclusions and provisions of the research are formulated as follows:

1. The problem of optimization and synthesis of RGB signal components of an onboard color imaging system is formulated by realizing the adaptive mode of onboard imaging systems.
2. An adaptive UAV mode with an imaging system on board is proposed, which concludes in adaptive measurement of flight altitude, depending on the color component of the color image being formed.
3. As a result of optimization of the proposed operating mode of the UAV imaging system, an analytic formula for adaptive device control is obtained.

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