UDC 656.71.057 (045)
DOI:10.18372/1990-5548.58.13519

Yu. M. Kvach

MODELING THE INFLUENCE OF FACTORS ON THE MONITORING OF THE LIGHT-SIGNAL FIRES OF THE CIVIL AVIATION AERODROME IN MATLAB ENVIRONMENT

Educational & Research Institute of Information and Diagnostic Systems,
National Aviation University, Kyiv, Ukraine
E-mail: juli_k74@ukr.net

Abstract*—The use of the created toolkit using the Matlab interface for determining the influence of factors on the monitoring of light-signal fires of the civil aviation aerodrome is proposed. The tools are used for defining visual information for the spatial orientation of the aircraft. It covers the difference in informing pilots about the visibility conditions and the ones really overcame by the pilot in the search for landmarks. Underestimation of reported visibility leads to a violation of the flight regularity, while the overestimation of information on visibility leads to more severe consequences – reducing landing safety. The investigation of the process of aerodrome fires recognition on the decline glide path in complicated meteorological conditions is of particular importance since it allows to obtain information for a pilot about the orientation of the aircraft relative to the earth's surface in the coordinate system of the observer. The process of recognizing the set of far light sources is currently the least studied area of atmospheric physics and physiological optics. The metric of the pilot's visual sensations during the approach in difficult meteorological conditions remains a topical problem. Therefore, it is possible to simulate a light-signal picture in the Matlab interface for the convenient use of tools for determining the visual search of aerodrome fires at civil aviation aerodromes, taking into account coordinates of the observer approach during the landing approach and atmospheric transparency.*

Index Terms—Observation; visual search; aerodrome fires recognition.

I. INTRODUCTION

The determination of the effectiveness of the visual search of aerodrome fires of the light-signaling equipment during the approach, taking into account the glide planning angle, the individual characteristics of the observer, and complicated meteorological conditions is of great importance. Various methods were used to solve the problem: theoretical calculations, experiments, flight checks. At present, more attention is paid to the estimation of the visual search effectiveness using simulation tools with the reduction of the full-scale experiment. Recognition of aerodrome fires of light-signal systems affects the formation of a visual picture that can be determined by simulation in the MATLAB environment.

II. OVERVIEW OF EXISTING CLASSIFICATION SYSTEMS

Current normative documents [1] give recommendations for the determination of the limiting illumination values on the retina of the eye and the law on determining the visibility range taking into accounts the complex meteorological conditions.

The circular ICAO [2] contains instructions on the practice of observing the range of visibility on the runway and the transmission of information about it with specified unresolved questions regarding the total effect of a set of lights caused by their fusion through the intervals and angles under which they are observed by the pilot.

III. PROBLEM STATEMENT OF AIDED CLASSIFICATION

To reduce the financial cost, it is proposed to use simulation during the evaluation of visibility of aerodrome fires of light-signal systems.

The brightness mode of aerodrome fires substantially affects safety during approach of aircraft in difficult meteorological conditions. The visual observation depends on the range of visibility and the clear perception of the aerodrome light-signal picture. To establish the light-signal picture, it is necessary to determine the optimal value of light intensity and color of the fires at any time of the day in all ranges of meteorological visibility range.

In accordance with [1], the visibility of the fires depends on the limiting illumination on the retina of the eye, which is determined by Alar's law:

$$E = (I/R^2)\,\tau^R, \qquad (1)$$

where E is the illumination created by the lighting device at a distance R; τ is specific transmittance coefficient of the atmosphere (transmittance of

atmospheric layer thickness of unit length); R is the distance between the light-signal device and the observer.

If the illumination of the retina of the eye is equal to the limiting illumination (it is the minimum illumination which causes the visual sensation), then the studied fire can be seen and the distance R is the visual range of the visibility of this fire. The value of the minimum illumination used to determine the visual range of the visibility of light signals depends on the brightness of the background against which a light signal is observed.

According to the current normative documents, the criterion of aerodrome fire failure of the light-signal system is a reduction of light intensity by more than 50%, which for different subsystems of aerodrome fires will be 10000 to 1250 cd (for categorical light-signal landing systems) and 100 to 50 cd (for non-categorical systems). At the same time, the values of light intensity, calculated by the expression (1) for the worst, but admissible observation conditions for this category of landing system will be lower. This means that light signals will be observed at the distance exceeding the distance of the required visual contact. It is clear that the excess of light intensity of fires beyond the limit value is explained by the desire to increase the safety of flights.

It is considered that the visual system gives a person up to 90% of all accepted information. Obtaining information about the outside world with the help of vision can always be considered as a sequential or simultaneous solution of the problem. Such problems may be related to search and location of the object. Under certain conditions, the eye cannot recognize the object. In this case, it is said that the object is below the threshold of visual perception

That is, the solution of the visual problem is possible in cases when the conditions of visibility exceed the threshold values of illumination on the eye apple of the observer, which in our case is the pilot of the aircraft.

The term "visibility" of the object has a fairly broad interpretation and is related to meteorological conditions, in particular, to atmospheric optics, light engineering, physiological optics, and others.

It is known that the visual perception of the point light sources, which include aerodrome fires of the light-signal system, is determined by their shine. The location of the aerodrome fire is most often known if the aerodrome fire is located in some line of sight. To find the object related with its search, the shine of the point object should be greater than the threshold value of $E_{thr} = 2 \cdot 10^{-8}$ lx at a brightness $L_{bgr.}$ of the background of 10^{-6} cd/m^2, and the more the probability of its finding, the less search time.

Dependence of threshold illumination E_{thr} from the brightness of the background is a continuous function approximated by the expression:

$$\log E_{thr} = 0.05(\log L_{bgr.})^2 + 0.57\log L_{bgr.} - 6.66, \quad (2)$$

where E_{thr} is threshold illumination, lx; L_{bgr} is the brightness of the background, cd/m^2.

It is believed that at the stage of visual piloting, for a sure visual contact of a pilot with a light-signal system, aerodrome fires should create in the plane of the eye apple the illumination which is not lower than the threshold. The distance to the fires at the beginning of visual piloting depends on many factors, but the number of these values is reduced to four depending on the category of radio-lighting landing equipment. The influence of the factors of atmosphere transparency is taken into account by the value of the specific transmittance, which varies from 0.9 to $10^{-3.4}$.

The obtained information with the help of vision can be considered as a series of problems of search and finding of the object, recognizing it by means of a number of features (form, color, presence of details, etc.), that is, visual problems.

It is clear that there is an area which can have a certain confidence degree for the correct solution of the visual problem. The main factors determining the visibility of aerodrome fires in their visual search in the atmosphere are:

- contrast of the object of observation with the background;
- light power of the fire;
- angular field of overview;
- search time; transparency of the atmosphere;
- object speed; probability of detection;
- state of observer adaptation.

Presence of other objects in the line of sight also affects the detection of the considered object etc.

It should be noted that the brightness of the atmospheric layer depends on the number of lights located according to the configuration of the light-signal system, and the brightness of the environment. The effect of light scattering, which is determined by the structure of the atmospheric layer, is also significantly affected.

IV. Proposed Algorithm of Aided Classification of Ground Objects

A toolkit was created using the Matlab interface [3], [4] to determine the visual search for individual and aerodrome firewall groups of aerial light signal systems, depending on entering the input field data (Fig. 1):

1) coordinates (X, Y, Z) and angles (V, G) of the location of light signal aerodromes on the runway;

2) photometric data of aerodrome light-emitting diode lights by retrieving ies-files of corresponding lights [5];

3) the position of the observer in relation to the light-signal pattern for determining the length of the trajectory between the light emitter and the receiver;

4) parameters characterizing the complexity of meteorological conditions indicating the background luminance (L_f), atmospheric transparency and meteorological range of visibility (MDV) allow you to get:

– illumination, taking into account the cosine dependence created by aerodrome lights on the pupil of the observer (E_0);

– illumination in compliance with Allard's law, created by aerodrome lights at the observer's pupil (E_A);

– total illumination created by aerodrome lights at the pupil of the observer (E) with the definition of minimum, average and maximum value;

– probability of observation of aerodrome lights (R);

– the threshold value of illumination, which allows to estimate the visibility of aerodrome lights, depending on adverse weather conditions;

– displaying a graphic illumination image from each individual aerodrome fire;

– graphic image output of radiation direction of aerodrome lights.

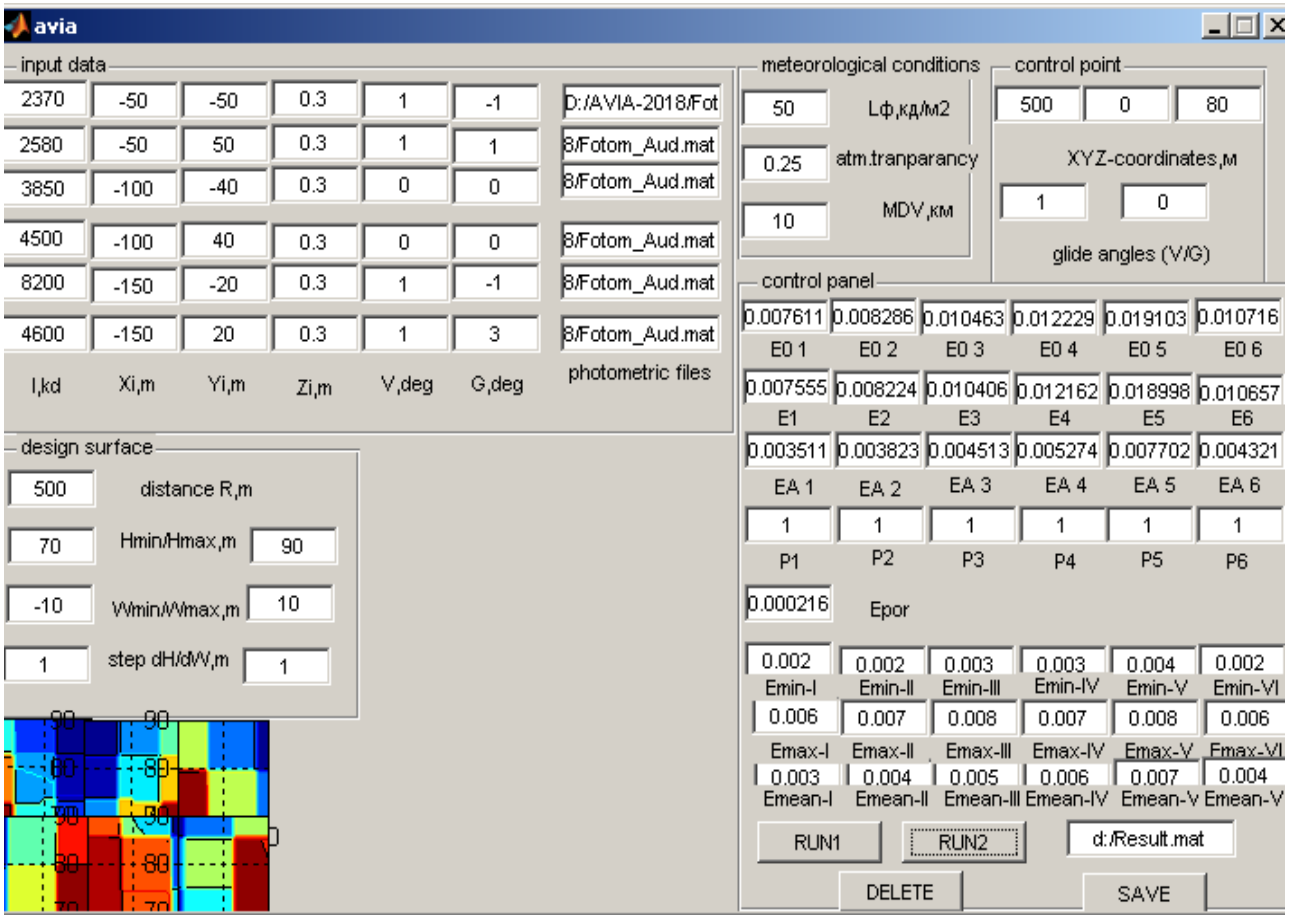

Fig. 1. Instruments for determining the visual recognition of light-signal systems elements of aerodromes, depending on the glide path angle of piloting, individual characteristics of the observer, transparency of the atmosphere

Thus, in order to simulate the illumination on the pilot's retina, it is necessary to determine the brightness of the background on which the recognition of individual aerodrome fires or their groups is carried out in accordance with their location in the light-signal systems and to determine their photometric characteristics.

The created graphic image of the targeting of individual fire (Fig. 2) or a group of fires with corresponding light intensity at the observer allows to make the respective conclusions with respect to their contribution into the overall picture of visual perception by the pilot.

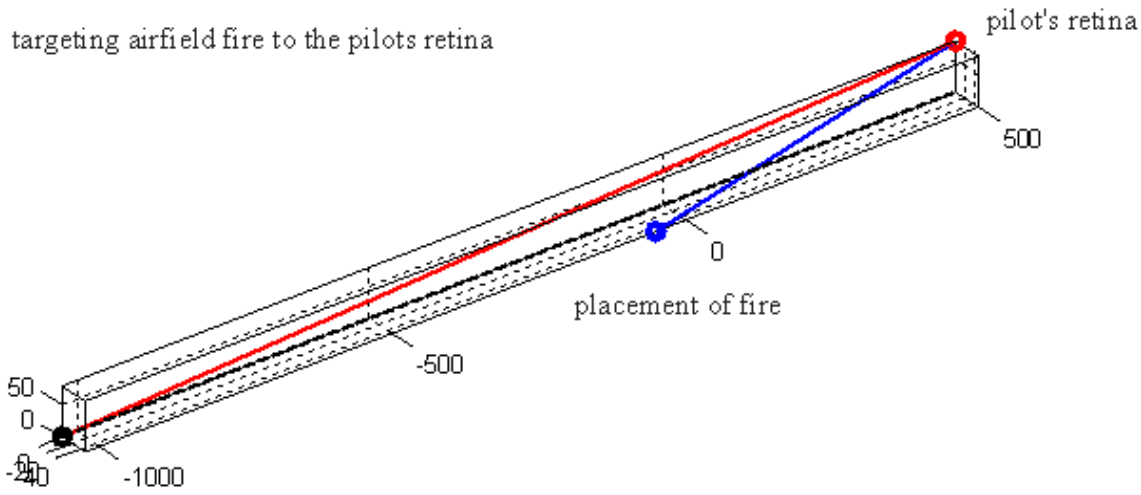

Fig. 2. The created graphic image of contribution of targeting individual fire with corresponding light intensity at the observer

V. CONCLUSIONS

The aerodrome lights are visible as a result of the simulation of the effect of the atmosphere transparency, coordinates and angles of the location of aerodrome lights on the observation of light-signal lights at a distance of 500 meters, since the value of the illumination created at the pupil of the observer exceeds the threshold value of illumination.

The dominant factors that influence the perception of the visibility of light-signal fires are determined. The developed toolkit in the Matlab environment takes into account the factors influencing the observation during the visual search of aerodrome lights of light signal systems depending on the meteorological visibility range, which reduces the time to determine the illumination from aerodrome fire on the retina of the eye, to determine the contribution of far sources of light to the general picture for obtaining pilot's visual sensations during the landing in adverse meteorological conditions.

REFERENCES

[1] Doc 9157-AN / 901 ICAO Aerodrome Design Guide. Part 4. Visual means. 4th ed. ICAO, 2004, 182 p.

[2] ICAO Doc 9328-AN / 908 "Guide on the Practice of Tracking and Tracking Visibility on Runway Tracking" *3rd ed., ICAO*, 2005, 124 p.

[3] V. Kondrashov, and S. Korolyov, *MathLab as a system of programming of scientific and technical calculations*, Moscow: Mir, Institute of Strategic Stability of the Ministry of Atomic Energy of the Russian Federation, 2002.

[4] I. B. Badriev, V. V. Banderov, and O. A. Zadvornov, *Develop a graphical user interface in the MathLab environment*, *Tutorial*, Kazan: Kazan State University, 2010, 113 p.

[5] Kvach Yu.M. "Modeling of aerodrome light-signal lights in simulators of the visual environment of aviation simulators," *Bulletin of the National Aviation University*. Issue 1, 2007, pp. 55–58.

Received October 17, 2018

Kvach Yuliia. Candidate of Science (Engineering). Associate Professor.
Department of Computerized Electrical Systems and Technologies, Educational & Research Institute of Information and Diagnostic Systems, National Aviation University, Kyiv, Ukraine.
Education: National Aviation University, Kyiv, Ukraine, (2004).
Research area: Mathematical modeling and monitoring of visual aids.
Publications: more than 40 papers.
E-mail: juli_k74@ukr.net

Ю. М. Квач. Моделювання впливу факторів на спостереження світлосигнальних вогнів аеродрому цивільної авіації в середовищі Matlab

Запропоновано реалізацію створеного інструментарію з використанням інтерфейсу Matlab для визначення факторів, що впливають на спостереження за світлосигнальними вогнями аеродрому цивільної авіації. Розглянуто використання інструментарію для визначення візуальної інформації в просторовому орієнтуванні повітряного корабля. Часто відбувається розбіжність інформації одержуваної пілотами про умови видимості і таких, що реально можуть здолати пілоти в пошуку наземних орієнтирів. Різниця в бік заниження повідомленої видимості призводить до порушення регулярності польотів, а розбіжність у бік завищення інформації про

видимість призводить до ще більш тяжких наслідків – зниження безпеки посадок. Досліджено процес розпізнавання аеродромних вогнів з глісади зниження в складних метеоумовах, який має особливе значення, оскільки дозволяє отримати інформацію для пілота про координати повітряного корабля щодо земної поверхні в системі координат спостерігача. Процес розпізнавання сукупності віддалених джерел світла в даний час мало вивчений в галузі фізики атмосфери і фізіологічної оптики. Метрика зорових відчуттів пілота під час заходу на посадку в складних метеоумовах залишається актуальною. Представлена модель світлосигнальної картини в інтерфейсі Matlab для зручного використання інструментарію у разі визначення візуального пошуку аеродромних вогнів на аеродромах цивільної авіації з урахуванням координат заходу на посадку спостерігача і прозорості атмосфери.
Ключові слова: спостереження; візуальний пошук; розпізнавання аеродромних вогнів.

Квач Юлія Миколаївна. Кандидат технічних наук. Доцент.
Кафедра комп'ютеризованих електротехнічних систем та технологій, Навчально-науковий інститут інформаційно-діагностичних систем, Національний авіаційний університет, Київ, Україна.
Освіта: Національний авіаційний університет, Київ, Україна, (2004).
Напрям наукової діяльності: математичне моделювання і моніторинг візуальних засобів.
Кількість публікацій: понад 40.
E-mail: juli_k74@ukr.net

Ю. Н. Квач. Моделирование влияния факторов на наблюдение светосигнальных огней аэродрома гражданской авиации в среде Matlab

Предложена реализация созданного инструментария с использованием интерфейса Matlab для определения факторов влияющих на наблюдение за светосигнальными огнями аэродрома гражданской авиации. Рассмотрено использование инструментария для определения визуальной информации в пространственной ориентировке воздушного корабля. Часто происходит расхождение информации получаемой пилотами об условиях видимости и реально преодолеваемых пилотом в поиске наземных ориентиров. Разница в сторону занижения сообщенной видимости приводит к нарушению регулярности полетов, а расхождение в сторону завышения информации о видимости приводит к еще более тяжелым последствиям – снижению безопасности посадок. Исследован процесс распознавания аэродромных огней с глиссады снижения в сложных метеоусловиях, который имеет особое значение, поскольку позволяет получить информацию для пилота о координатах воздушного корабля относительно земной поверхности в координатной системе наблюдателя. Процесс распознавания совокупности удаленных источников света в настоящее время мало изучен в области физики атмосферы и физиологической оптики. Метрика зрительных ощущений пилота во время захода на посадку в сложных метеоусловиях остается актуальной. Представлена модель светосигнальной картины в интерфейсе Matlab для удобного использования инструментария при определении визуального поиска аэродромных огней на аэродромах гражданской авиации с учетом координат захода на посадку наблюдателя и прозрачности атмосферы.
Ключевые слова: наблюдения; визуальный поиск; распознавание аэродромных огней.

Квач Юлия Николаевна. Кандидат технических наук. Доцент.
Кафедра компьютеризованных электротехнических систем и технологий Учебно-научный институт информационно-диагностических систем, Национальный авиационный университет, Киев, Украина.
Образование: Национальный авиационный университет, Киев, Украина, (2004).
Направление навигация и управление движением.
Количество публикаций: более 40.
E-mail: juli_k74@ukr.net