ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 9(29), DOI: 10.17485/ijst/2016/v9i29/99451, August 2016*

Colorimetric Features of Design and Production of Aircraft Display Systems in the Product Lifecycle

Maksim Olegovich Kostishin[1]*, Anatoly Vladimirovich Shukalov[1], Igor Olegovich Zharinov[1], Oleg Olegovich Zharinov[2] and Aleksandr Nikolaevich Ershov[3]

[1]Saint Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO University), Russia; maksim@kostishin.com, aviation78@mail.ru, igor_rabota@pisem.net
[2]Saint-Petersburg State University of Aerospace Instrumentation (SUAI), Russia; zharinov73@hotbox.ru
[3]JSC Elektroavtomatika Design Bureau n.a. P.A. Efimov, Russia; erschov_alex@mail.ru

Abstract

Background: The main attention is paid to the processes of design and production of the airborne display systems, the production specifics of which is associated with image colorimetric characteristics transformation. **Method**: This article reviews the product lifecycle diagram in the area of aviation instrument engineering. Transformation of color models, i.e., transition from the color coordinates of one color model to the color coordinates of another color model, is relevant for subject areas, in which various physical processes are used for color reproduction in the unified process cycle. **Findings**: The relevance of the research is determined by the necessity to reproduce identical colors in most cases without visible distortions in various color models and on various physical carriers specific to the real physical color reproduction process. The article shows that it is necessary to consider various color models describing the color rendition properties of various data carriers used in the avionics during creation of the display systems. The developed models and their varieties allow effective coding of information about color and brightness of the image in the communication channel and are used to describe the processes of the television image transmission trialed at the stage of the airborne equipment integration. **Improvements/Applications:** The materials of the article are of practical value in using the diagram of the end-to-end process cycle allowing the control of colorimetric shifts of color coordinates in the lifecycle of the aviation equipment.

Keywords: Aviation Instrument Engineering, Avionics, Color Models, Color Coordinates, Display Systems, Lifecycle

1. Introduction

The modern industrial production is inseparably linked with creation of products having color content. Illustrative examples are: Textile color in cloths manufacture; color of a car or road marking, color of road signs, buildings and structures in the manufacture of paint-and-lacquer coatings; color of displayed elements of the human-machine interface in computer programs or color of parameters on the screens of information and measurement, and control system displays.

Availability of colors imparts the industrial products the essential consumer qualities and also raises a number of procedural issues associated with documentary confirmation of the correspondence of the viewed color with that stated in the technical documentation. The color confirmation procedure is based on the colorimetrical standards, color atlases, control and measurement instru-

*Author for correspondence

mentation registering the distribution of the optical range radiation power within the visible wavelength range, and also physical processes of color reproduction within a certain subject area.

Transformation of color models[1,2] i.e., transition from the color coordinates of one color model to the color coordinates of another color model, are relevant for the subject, in which various physical processes are used in the unified process cycle for color reproduction. Such subject area, in particular, is aviation instrument engineering[3–6], where the developers create and certify samples of airborne display systems, design automation software, production technology, technical documentation, etc.

It is obvious that one type of the color models should be used for programming of the graphic controller executing preparation of an image in the video memory to be displayed on the detection device screen. Another type should be used for creation of paper prints of avionics indication frames provided in technical specifications, operation manuals and instructions (concerning data entry; verification, setting and adjustment, etc.), and the third type – in modeling optical diagrams in automated workplace instrumentation.

In this case, the identical colors provided in various color models and on various physical carriers that are specific to the real physical color reproduction process should be transmitted without visible distortions. In this regard, the relevant task is the development of a software tool allowing assessment and forecasting of colorimetric shifts in the “design-production” process cycle in creation of airborne display systems of aircraft.

2. Color Model as a Color Definition Method

In the traditional understanding, color is defined using common terms, which received names of colors: red color, yellow color, purple color, etc. Color standards, color scales and color atlases are used for exact color setting in colorimetrics.

However, due to the limited number of color names and the color naming unity for its different but close color shades, setting of the color at the name level (for example, “sky-blue-pink” color) is of little avail for use in the aviation machine engineering. For this reason, the avionics developers use various mathematical apparatuses allowing strict definition of rules for setting colors and color shades (color definition rules) within the framework of various color models.

Color model is a color-setting model mathematically defined as a set of numbers (color coordinates), and geometrically defined as a color body in the space of color coordinates.

Color models are used for mathematic description of certain color areas of the spectrum, and the color itself in the academic sense is a qualitative subjective characteristic of electromagnetic radiation of the optic range determined on the basis of the arising visual sensation and depending on a number of physical, physiological and psychological factors[1,2].

3. Results and Discussion

3.1 Transformation of Color Models

For mathematic description of technologic processes of color reproduction, various color models[1,2] were developed where any color can be presented in each one as a point (Figure 1.) belonging to the color body in the multidimensional color space, the axes of which are defined by the color coordinates.

In the color models that gained[3,4] the broadest practical application in the aviation instrument engineering, the color coordinates determine either basic colors out of which the observed color is formed on various physical carriers, or lightness, saturation and color tone – the properties consistent with the perception psychology of the viewer.

The simplified classification principle allows dividing all the color models relevant for the aviation instrument engineering into three individual groups:

- Hardware-dependent, i.e., such color models (*RGB*, *CMY*, *YIQ*, *YCbCr*), in which color reproduction is determined by the implementation specifics of the hardware platform of the used devices and process equipment.

- Hardware-independent, i.e., such color models (*XYZ*, *Yxy*, *Yuv*, *Lab*, *Luv*), in which color presentation is not dependent on the used airborne and process equipment, and determined exclusively by the abstract mathematical description of the colorimetric characteristics of color in the theoretical space of the color coordinates.
- Perceptional, i.e., such color models (*HSI*, *HSL*, *HSV*), in which color presentation is based on intuitively clear characteristics of color (color tone, saturation, lightness), agreed with the psychological peculiarities of perception of a standard colorimetric viewer.

Two types of objects – self-luminescent optical devices (liquid crystal or LED screens of information display devices, etc.) and non-self-luminescent objects reflecting light falling on them (for example, paper carriers of the indication frames of avionics presented in the technical documentation) are used for reproduction of color within the hardware-dependent color models in the aviation instrument engineering.

The additive principle of color reproduction description based on addition of the basic colors is used for self-luminescent devices in the hardware-dependent color models. The color of images presented on the paper carrier is formed on the subtractive principle based on the subtraction of the basic color coordinates. Hardware-dependent color models in the aviation instrument engineering are used at the stage of design and production of the equipment and documentation.

Hardware-independent color models are used in the aviation instrument engineering at the stage of theoretical research design and colorimetric calculations during the modeling of the optical diagrams on the instruments for design of avionics developers' automatic workstations (AWS)[7–9].

Perception color models are based on using some properties of the observed colors defined in the intuitively understandable categories as the color coordinates. Ultimately, color is defined in the perception models as a mixture of the set color shade, white and black colors. Perceptional color models are used at the stage of design of Airborne Electronics (AE) and technical documentation.

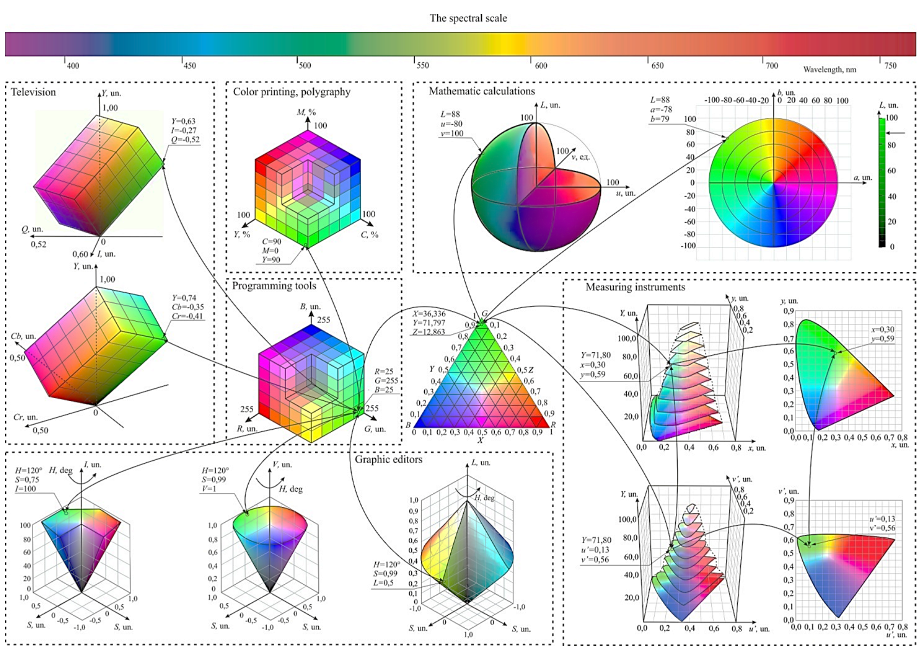


Figure 1. The conversion rules of color models relevant for the aviation instrument engineering.

3.2 Description of the "Design-Production" Process Cycle of Airborne Display Systems

The mathematical apparatus linking the color coordinates in various color models make up the basis for the developed dedicated software allowing assessment and forecasting of colorimetric shifts in the "design-production" process cycle in creation of aviation products (Figure 2).

The diagram shows the main design and production procedures carried out at an instrument engineering enterprise in the process of creating science-intensive products (items) for aviation indication systems. Examples of such products are the multifunctional indicator, control and display console, etc.

The development process of the navigation facility display systems of piloted aircraft is divided into the stages in accordance with their content:

- Design of structures, at which development of the composition of the functional elements of the future product and the physical nature of their interaction within the product is performed.
- Implementation of the product in the documentation package, at which the Design Documentation (DD) for the product is created according to the Unified System of Design Documentation (USDD).
- Product implementation at the software level when the specialists of the enterprise develop the test, operational (functional) and instrumental (required for the process targets of the production) Software (SW) according to the Unified System of Software Documentation (USSD).
- Development of Process Documentation (PD) according to the Unified Standards of Process Documentation (USPD), containing flow charts and description of process operations required for

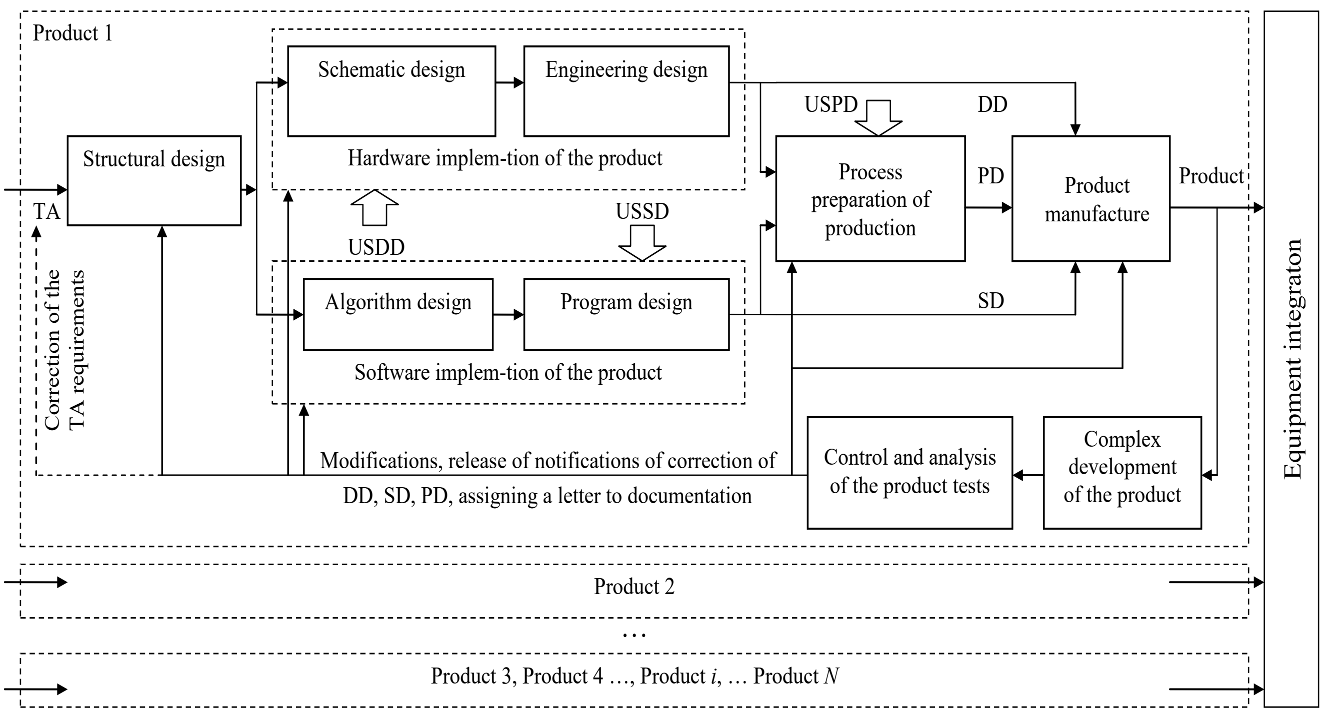


Figure 2. Equipment "design-production" process cycle.

manufacture of the products of the enterprise with account of the documentation for the by-products (non-standard process equipment).

- Product manufacture, in the process of which the design solutions proposed by the developers in the technical documentation are implemented in hardware.
- Adjustment and testing of the product used to assess the operability of the technical solutions proposed by the developers in the documentation, assessment of the product compliance with the requirements of the Technical Assignment to the product, assess the need in revising the documentation for the product (for example to remove mistakes in the received draft).
- Integration of the product, at which the interaction of miscellaneous equipment connected to the unified aviation system or a complex is tested, and functioning in accordance with the interaction logic coordinated by the special information communication protocols.

The key feature of the practical implementation of the process operations is standardization and unification of the design solutions proposed or introduced into the documentation and the production process of the enterprise. As it follows from Figure 3, the inconsistent Computer-Aided Design systems (CAD) combined into the unified information system of the enterprise allow automating separate design procedures of the general process cycle.

The practical experience in using the automated systems shows that activity results of the enterprise's employee who prepares individual design documents, for example a list of elements in MS Word text editor, are unsuitable for preparation of a specification by a designer, which he/she develops in the AutoCAD system. In this case, the designer has to manually move the entries of the hard copy of the document. The situation with development of the documents is similar: calcula-

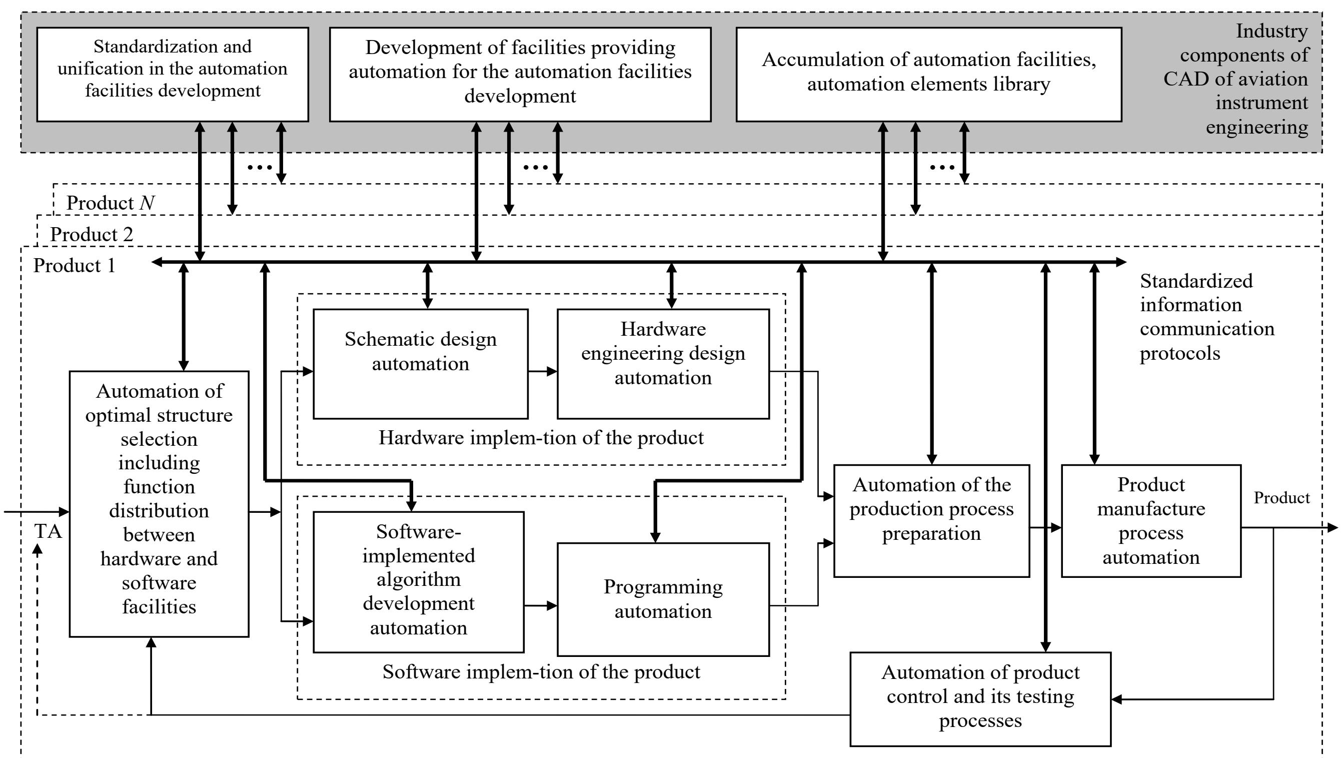


Figure 3. Automation of the design procedures of the "design-production" process cycle.

tions of non-ferrous and precious metals contained in the product accordingly, which cannot normally be prepared in AutoCAD. In the meanwhile, information about non-ferrous and precious metals is specified in the operation data-sheet of the product, which already pertains to the category of text documents.

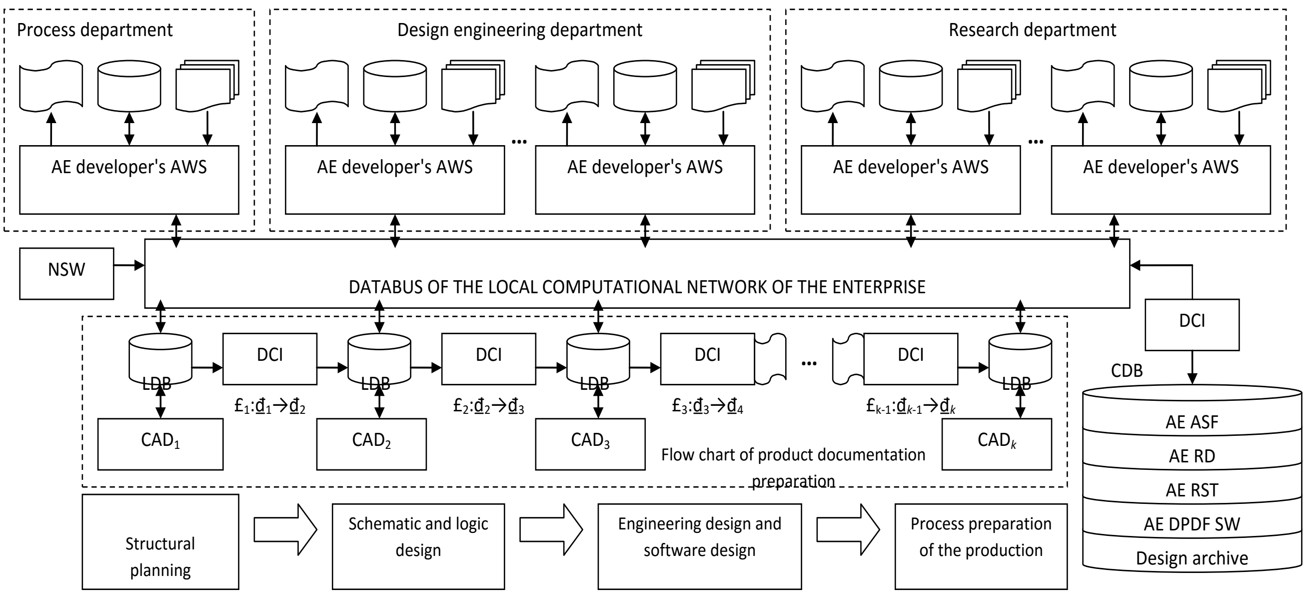
Thus, the use of inconsistent CAD, design results in which (transmitting CAD) cannot be unambiguously transferred to another CAD used at the next stage of the design (receiving CAD), dramatically decreases the effect of the information technologies introduction at the enterprise.

For this reason, the solution of the problem of developing the support information system for the end-to-end process of the design is relevant, in which the key role will be assigned to the interface of the informational interaction of the CAD components between each other.

The functional diagram of the end-to-end automated design system is shown in Figure 4. The basis for the end-to-end automated design system is three design units available at all enterprises of aviation instrument engineering: Research department; development department; process department.

Technical interaction of the departments is accomplished by means of a local databus of the enterprise, normally having no access to the Internet, which is determined by the need in meeting the requirements for compliance with the regime at the enterprise.

Subscribers of the local network of the enterprise are services ensuring control and account of the design motion at the enterprise, procedure for revision of the design (software, process) documentation, design archiving and creation of backup copies of the projects.



NSW – network software (automated data communiation between the subsystems of the industrial CAD implemented on inconsistent computational facilities).

DCI – Data conversion interface $\underline{đ}$ (non-standardized conversions of CAD_i design results to the form suitable for entry of this data into CAD_{i+1} and subsequent processing (process transitions $£_i$));

CDB – central data bank;

ASF – algorithm and software foundation of the AE;

RD – reference data (product description, material description, process description);

RSTI – reference scientific and technical information (description of author

Figure 4. Functional diagram of the end-to-end automated design system.

As it follows from the analysis of Figure 4, interaction of the CAD is carried out via the interface providing translation of ready designs (individual documents of the design) from one CAD to another without the need in using an additional manual labor of the designer.

Such interaction can be ensured either due to using additional converter programs allowing conversion of data files from one presentation format to another, or by a specialized structure of the new developed CAD considering the developers' need in such a conversion mechanism.

An example of the functional diagram of the automated documentation development support system is provided in Figure 4. The basis of the diagram is formed by the components ensuring interaction of the CAD and the user, components implementing the functional purpose of the CAD and the components ensuring interfacing of the design result (file) with other data storage and presentation standards accepted in other CAD systems.

3.3 Principle of Forecasting Calorimetric Shifts in the "Design-Production" Process Cycle

The principle of forecasting colorimetric shifts is based on the analysis of the used technologic processes and consistent conversion of color coordinates using profiles of devices involved in performance of each process operation. Most of such device profiles are standardized and approved by the International Color Consortium for each type of process equipment.

In particular, to describe the process of displaying color information on the indication device screen, the use of *RGB* additive color model is adequate at the software implementation stage of the product. *CMY* subtractive color model is utilized in order to describe the color reproduction process during display of the indication frame of the avionics on a color printer (documentation preparation).

Results of the colorimetric experiments obtained in the process of the control tests of the products, or results of theoretical calculations received at the structural design stage, are expressly set in the parameters of models *XYZ*, *Yxy*, *Yuv*, *Lab*. *YIQ*, *YCbCr* color models and their varieties allowing effective coding of information about color and brightness of the image in the communication channel are used in order to describe the processes of the television image transmission trialed at the stage of the airborne equipment integration.

HSI, *HSV*, *HSL* perceptional color models are used for color definition in applied software packages (in graphic editors) during creation of vector and bit images of the indication frames of the avionics (design documentation), which by the colorimetrical properties should meet the image observed on the screen of the airborne display or the same image printed on the paper carrier in technical specifications or instructions.

4. Conclusion

The necessity in transition between the parameters of color models (transfer of color from one color model to another) arises when the avionics developers need to describe complex production processes based on a set of various physical effects in the single process cycle. Such transition between the parameters of color models can lead to corruption of information about color (colorimetric shift), which is caused by a non-compliance of the color coverage of various color models used for description of color reproduction in certain process operations.

The color model has its color coverage. Color coverage of the model characterizes the spectral content of colors, which can describe the model. The hardware-dependence of the color model is the cause of its color coverage narrowing.

Obviously, color conversion within the range of various color models should be carried out through the standardized color models having the widest color coverage, for example *XYZ*. In this case, we can achieve the "ideal" conversion, because it gives the exact display of color coordinates and in various color models. Otherwise, the color presented by the color coordinates in one color model will differ from the color presented by equivalent color coordinates in another color model. Physically, such difference is determined by the transfer of color that is beyond the boundaries of the color coverage of the "receiving" color model to the boundary of the reproducible color spectrum.

5. References

1. Ibraheem NA, Hasan MM, Khan RZ, Mishra PK. Understanding color models: A review. ARPN Journal of Science and Technology. 2012; 2(3):265–75.
2. Hunt RW. The reproduction of color. Harrow: Kodak Limited; 2004.
3. Desjardins DD. Military displays: Technology and applications. SPIE Press; 2013.
4. Barber S, et al. US Patent 7,417,641 B1: Aeronautical chart display apparatus and method; 2008 Aug 26.
5. Livada B. Avionic displays. Scientific Technical Review. 2012; 62(3-4):70–9.
6. Schanda J. Colorimetry understanding the CIE system. Wiley-Interscience John Wiley and Sons INC Publication; 2007.
7. Gatchin YA, Zharinov IO, Korobeynikov AG, Zharinov OO. Theoretical estimation of Grassmann's transformation resolution in avionics color coding systems. Modern Applied Science. 2015; 9(5):197–210.
8. Aleksanin SA, Zharinov IO, Korobeynikov AG, Perezyabov OA, Zharinov OO. Evaluation of chromaticity coordinate shifts for visually perceived image in terms of exposure to external illuminance. ARPN Journal of Engineering and Applied Sciences. 2015; 10(17):7494–501.
9. Zharinov IO, Zharinov OO, Kostishin MO. The research of redundancy in avionics color palette for on-board indication equipment. Proceedings of International Siberian Conference on Control and Communications (SIBCON-2015); The Tomsk IEEE Chapter and Student Branch, Russia, Omsk. 2015 May 21-23. Art 7147313.