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Web-Based Architecture of a System for Design Assessment of Night Vision Devices

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***Abstract*—**Nowadays the devices of night vision are widely used both for military and civil applications. The variety of night vision applications require a variety of the night vision devices designs. A web-based architecture of a software system for design assessment before producing of night vision devices is developed. The proposed architecture of the web-based system is based on the application of a mathematical model for designing of night vision devices. An algorithm with two components – for iterative design and for intelligent design is developed and integrated into system architecture. The iterative component suggests compatible modules combinations to choose from. The intelligent component provides compatible combinations of modules satisfying given user requirements to device parameters. The proposed web-based architecture of a system for design assessment of night vision devices is tested via a prototype of the system. The testing showed the applicability of both iterative and intelligent components of algorithm.

***Keywords*—**Night vision devices, design modeling, software architecture, web-based system.

I. Introduction

NOWADAYS, production assets are under constant pressure for reducing operating costs, enhancing reliability and improving the quality of the product. Intelligent systems assist the cutting-edge direction by involving interdisciplinary methods and algorithms. Resent advances in computers and software developments have dramatically changed the practice of many disciplines including engineering. Now it is possible to test thousands of product designs and run thousands of trials without first building a prototype for each product or conducting an elaborate experiment for each trial. The impact of this new ability to simulate the real processes is revolutionizing the practice of engineering. This is why the recent trends in product design are based on modularization to facilitate global manufacturing. The modularization plays a critical role in component of global collaboration in product development [1]. Modularity allows the designer to control the degree to which changes in manufacturing processes affect the product design. Modularity arises from the division of a product into independent components. This independence increases the use of standardized components and allows designers to more easily create a wide variety of products using a much smaller set of components. Product variety is created by having several different versions of each component in the final product. The physical and functional interfaces between the components are the same. The result is that any combination of components can be assembled into different versions of the same product, or even a different product, with minor modifications [2], [3].

The product variety optimization includes three degree of optimization problems, i.e. attribute assignment, module combination, and simultaneous design of both, and when the possibilities of computational optimization for product variety design under fixed product architecture are explored, optimization is demanded to determine the contents of module and their combination under fixed product architecture [4].

Night vision applications for both military and civil applications have spread for night time viewing in numerous applications including: military, security, rescue actions, navigation, hidden-object detection, wildlife observation, hunting, tourism, entertainment, etc. [5]-[8]. The most popular and well known method of performing night vision is based on the use of image intensifiers. The image enhancement systems consist of an image intensifier tube, objective and ocular and are called night vision devices (NVDs). NVDs offer significant benefits for night time performed tasks over unaided vision [9]. The variety of NVDs modules with different parameters exist and different NVDs could be designed to satisfy different user requirements. The user requirements concern the device functionality, performance, price, weight, etc.

The current paper aims to propose architecture for intelligent web-based system to assist decision making in designing of NVDs. To achieve this goal, a mathematical model of NVDs design is proposed. The described mathematical model is used to develop an algorithm for assessment of NVDs parameters and is implemented in a Web-based architecture for NVDs parameters assessment. Distinction feature of the described system is the possibility to simulate the design process (including interactive user participation) and to assess the device parameters without real prototypes developing.

II. Problem Description

The variety of night vision applications require a variety of the NVDs designs. The best design for a particular user is a design that is created taking into account the requirements of this user. As the NVDs are not under mass production it is important to offer for user estimation different virtual designs before actual producing of the device. This can be done by a software system for virtual design of NVDs that will help a

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preliminary assessment and estimation of the design.

The basic modules of passive night vision devices (NVDs) can be reduced to objective, image intensifier tube (IIT), ocular and power supply (Fig. 1).

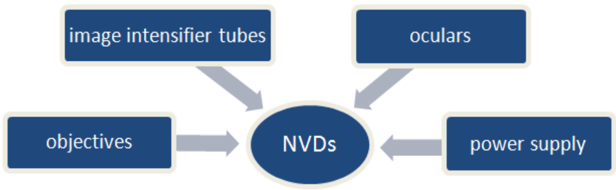

Fig. 1 Main NVDs modules

A combination involving an objective, IIT and ocular is called optoelectronic channel and is crucial for the NVDs performance.

To realize an innovative approach for NVDs parameters virtual assessment all modules with their parameters are to be considered. Moreover, there exist different types of devices by application such as NVGoggles (NVG), NVBinoculars (NVB), NVScopes (NVS) and all them has to be considered with their specific modules relations and compatibility. This can be done by developing of a proper generalized mathematical modeling of NVDs design. For the goal, the design process specific has to be described.

III. Description of Design Specifics

A well managed product development process is an important factor in order to stay competitive. When the repetitive nature of the development processes is recognized, the process can be modeled in order to predict the system performance. Design process modelling can be one course of action to discover key activities that have great impact on process lead-time and cost. The existence of variety of basic elements for NVDs requires a proper choice of modules to ensure the required device parameters. The optoelectronic channel is included into any NVDs device type (NVG, NVB, NVS) and parameters of the NVDs optoelectronic channel are representative indicators for NVDs functionality. The choice of NVDs optoelectronic channel components (objective, image intensifier tube and ocular) could be recognized as a combinatorial problem. When set of discrete design alternatives exists a combinatorial approach can be used to reduce the possible solutions by modelling of problem based on the characteristics of a specific situation. Considering NVDs design as a decision making problem means that there exist a decision-maker (DM) and the final solution depends on DM preferences. Practical experience shows the most essential parameters for the NVDs functionality are working range, field of view, magnification, electrical battery power supply lifetime, weight and price:

- *working range* – the main idea for the theoretical NVDs working range estimation is the proposed by the authors' formula [10],[11].

$$R = \left(\frac{0.07 D_{in} f_{ob} \tau_o \tau_a S_\Sigma \delta E K A'_{ob}}{M \Phi_{minph}} \right)^{1/2} \tag{1}$$

where: D_{in} – objective diameter inlet pupil in *m*; f_{ob} – objective focal length in *mm*; τ_a, τ_o – atmosphere and objective transmittance, dimensionless; $\Phi_{min.ph}$ – IIT photocathode limiting light flow in *lm*; δ – IIT limiting resolution in *lp/mm*, S_Σ – IIT luminous sensitivity in *A/lm*; M – IIT signal-to-noise ratio, dimensionless; E – ambient light illumination in *lx*; K – contrast, dimensionless; A'_{ob} – reduced target area in m^2.

The designer can use the estimation of the NVDs working ranges (1) for beforehand evaluation of this parameter of particular device design. This evaluation can be repeated for different optoelectronic channel modules combinations until the results became close enough to the desired values. Three types of the NVDs working ranges (detection, recognition and identification ranges) can be evaluated by Jonson criteria [12] and relation (1).

- *magnification* – the NVDs magnification α is represented by the relation of objective and ocular focal length and the magnification β of IIT (if exists)

$$\alpha = \beta \frac{f_{ob}}{f_{oc}} \tag{2}$$

In case of NVGs, the overall magnification $\alpha = 1$ (i.e. without magnification), while the NVBs and NBSs have magnification $\alpha > 1$.

- *field of view* – the NVDs field of view is defined by the relation of objective and ocular focal length taking into account the IIT screen diameter. The objective field of view can be determined by the ratio:

$$f_{ob} = D_{IITph} \left(2tg(\frac{\omega}{2}) \right)^{-1} \tag{3}$$

where f_{ob} is the objective focal length in millimeters, ω is field of view in degree, D_{IITph} is diameter of IIT photocathode in millimeters.

Similarly, the ocular field of view can be determined as:

$$f_{oc} = D_{IITscreen} \left(2tg(\frac{\omega}{2}) \right)^{-1} \tag{4}$$

where f_{oc} – ocular' focal length in millimeters, ω – field of view, $D_{IITscreen}$ – IIT' screen diameter in millimeters.

The typical value of NVGs field of view is about 40 degrees while NVBs and NBSs have limited field of view from 2 to 12 degrees.

To utilize IIT screen diameter D_{IIT} an appropriate ocular with corresponding field of view should is considered by the following dependency:

$$2\sin\frac{\omega_{oc}}{2} \geq D_{IIT} \quad (5)$$

- *electrical battery power supply lifetime* – limitation of the electrical battery power supply lifetime L_B depends on the electrical load of IIT I_{IIT} and on battery capacity C_B:

$$L_B = \frac{C_B}{I_{IIT}} \quad (6)$$

The typical supply voltage needed for the IIT is 3.0 V. There exists two basic categories that can be used – AA type batteries with supply voltage 1.5 V and button (coin) cell type with 3.0 V supply voltage. Different number of serial and/or parallel connected batteries can be used and the corresponding formula for battery capacity C_B, is

$$C_B = n\sum_{p=1}^{t} a_p \sum_{q=1}^{k_p} b_q^p C_B^q \quad (7)$$

where n – number of the parallel connected batteries accordingly to the capacity requirement, a_p – binary variable for battery p-type, b_q^p – binary variable for battery q-subtype of p-type battery, C_B^q – the capacity of the p-type and q-subtype battery.

- *weight and price* – an good approximation of the NVDs weight and price could be estimated as a sum of IIT, objective, ocular and electrical battery power supply as:

$$Weight_{NVD} = Weight_{IIT} + Weight_{ob} + Weight_{oc} + Weight_{battery} \quad (8)$$

$$Price_{NVD} = Price_{IIT} + Price_{ob} + Price_{oc} + Price_{battery} \quad (9)$$

Let us assume that there are t-type electrical batteries with supply voltage 1.5 V or 3 V. Each t-type battery could have k_p-subtypes with different capacity to choose from, so the electrical battery power supply weight could be defined as:

$$Weight_{battery} = n\left(\sum_{p=1}^{t} a_p \left(s_p \sum_{q=1}^{k_p} b_q^p H_B^q + \sum_{p=1}^{t} t_p\right)\right) \quad (10)$$

where H_B^q – weight of the p-type and q-subtype electrical battery, t_p – single p-type electrical battery power supply weight, s_p = 1 for 3 V batteries and s_p = 2 for the 1.5 V batteries.

The electrical battery power supply price $Price_{battery}$ depends on the chosen battery type and on the number of batteries n:

$$Price_{battery} = n\left(\sum_{p=1}^{t} a_p \left(s_p \sum_{q=1}^{k_p} b_q^p P_B^q + \sum_{p=1}^{t} k_p\right)\right) \quad (11)$$

P_B^p – price of the p-type and q-subtype electrical battery, k_p – single p-type electrical battery power supply price.

IV. Algorithm for NVDs Design Parameters Assessment

Algorithms and data structures are at the heart of every computer application [13]. Therefore, it is important to propose such algorithm that best fit the problem of NVDs design. An innovative algorithm for design of different NVDs is developed considering all of NVDs compatibility relationship and complying with DM requirements.

The proposed algorithm concerns integration between defined sets of modules as input data, processing data by the described formulae and delivering the output information – parameters for the device.

The proposed NVDs design algorithm involves two basic components – component for iterative design and component for intelligent design. Both components are responsible for obeying of the compatibility restrictions between modules. The generalized flowchart of the proposed NVDs design algorithm is shown on Fig. 2.

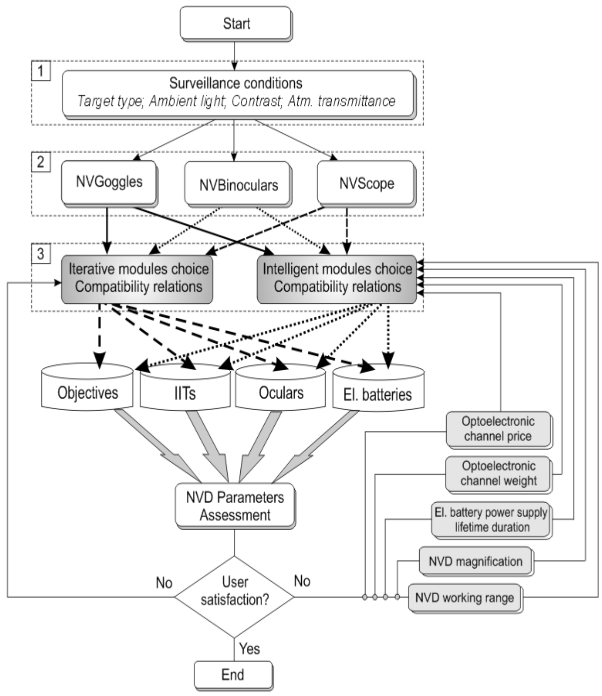

Fig. 2 Flowchart of the NVDs design algorithm

The proposed algorithm starts with defining of external surveillance conditions. Due the specifics of the NVDs it is important to take into account different external surveillance conditions in the design process. The most important NVDs parameter – the working range, is influenced by external surveillance conditions as ambient light illumination, target type, contrast between background and target, and atmosphere transmittance. Different values of external surveillance conditions are to be considered to reflect the different expected application surveillance conditions of the designed device. On the second stage the type of designed night vision device (NVG, NVB, NVS) is chosen. The third stage represents two algorithm branches – iterative and intelligent modules choice. The iterative modules choice allows the DM to make own selection of NVDs modules. Depending on the NVDs type chosen on stage 2 the corresponding formulae are used. Taking into account the chosen on the previous stages surveillance conditions, device type and particular modules, the designed device parameters are calculated and shown – the NVDs working range (calculated as detecting, recognition and identification ranges) weight, price, and electrical battery power supply lifetime duration. If the DM in not satisfied with some of calculated NVDs parameters he can select other modules via iterative branch of the algorithm. This interactive design process ends when the DM is satisfied of the designed device parameters estimations. The second branch of the algorithm is used when the DM does not want to continue searching of satisfactory modules combination but relies on the intelligent modules choice. This intelligent choice of modules allows the DM to set up some preliminary requirements about the designed device parameters. The main idea of intelligent modules choice is to find compatible modules combinations while satisfying DM requirements for some NVDs parameters. The algorithmic realization of the intelligent modules choice is based on determining of device parameters for all feasible modules combinations. Then the resulted arrays are sorted in increased order. If given values of working range (detection or recognition or identification range) or magnification are to be met the search goes toward increasing values of the sorted arrays until a value greater or equal to the given one is found. If weight or price required values are searched the search starts from the largest value and goes on until a smaller or equal to the given by DM value is found. If different parameters values required by DM are met by different modules combinations the corresponding messages are shown to DM to assist his further actions – to accept some combination or to modify some of the required parameters values.

V. Description of Web-based Architecture of System for Design Assessment of Night Vision Devices

To realize the assessment of designed NVDs parameters a Web-based architecture performing the proposed algorithm is developed (Fig. 3).

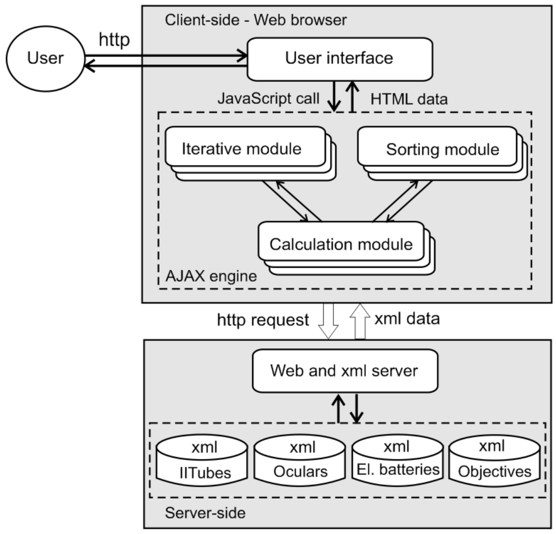

Fig. 3 Architecture of the intelligent Web-based system

The proposed architecture is based on using of AJAX technology on the client-side. AJAX (Asynchronous JavaScript and XML) is one of the most popular rich Internet application technologies [14]. The main idea behind the architecture of the AJAX engine is the reuse every time is needed some asynchronous processing or a smart way to refresh information on the current web page without reloading it [15]. Using the AJAX technology enables web applications to call the web server without leaving the actual page and in the background without notice of the user (through XMLHttpRequest). This avoids loading the same form or page including the html code multiple times, reduces the network traffic and increases the user acceptance. In practice, AJAX engine is realized as JavaScript functions that are called whenever information needs to be requested from the server. When the AJAX engine receives the server response, it goes into action, often parsing the data and making updates of the presented to the user information. Because this process involves transferring less information than the traditional web application model, user information updates are faster. The advantage of client-side is the independence from the server-side technology.

The server-side is realized by a mixture of technologies, such as HTML, script languages (JavaScript) and JSP technology. The databases for modules and their parameters, and all files of the web-based system for design assessment of NVDs are stored on the server-side. The server-side code creates and serves the page and responds to the client asynchronous requests.

The graphical user interface of a prototype of web-based system for design assessment of NVDs based on the described architecture is shown on Fig. 4.

Fig. 4 Screenshot of system user interface

Three radio buttons allow the DM to select only one type of NVDs (NVG, NVB or NVS). Drop-down lists allow DM to select NVDs modules. When a particular module is selected the lists of other modules are updated according their compatibility relation. Another group of drop-down lists are used to set external surveillance conditions. Each selection of a module visualizes its corresponding parameters within text fields. This information assists DM in process of selection. After device modules and external surveillance conditions are selected, the parameters of designed device are calculated and shown in corresponding text fields. This accomplishes the design of device via iterative branch of the developed algorithm. The intelligent design branch of the proposed algorithm is realized when DM enters some required values for the device parameters in the text fields of device parameters. These requirements are processed by module “calculation” to define feasible modules combination satisfying all given DM preferences. When such combination is found it is shown to the DM for approval or for another intelligent search. If a feasible module combination satisfying all given DM preferences does not exist a proper message is shown. The used JavaScript functions call AJAX engine which sends request to server’s databases and retrieves server response. Then passing the AJAX, the data on web page is displayed without reloading a page. After each request only small amount of data is transferred between client and web server.

VI. Conclusion

The paper describes an approach for Web-based architecture for design assessment of night vision devices. The variety of night vision applications demands for variety of the NVDs designs. As the NVDs are not under mass production a possible approach is to offer to DM different virtual designs before actual producing of the device for his preliminary estimation and approval. This can be done by a software system for virtual assessment and estimation of NVDs design. An algorithm for preliminary assessment of NVDs design is developed taking into account the NVDs design specific and complying with DM requirements. The proposed algorithm realizes choice of NVDs type; external surveillance conditions selection; iterative choice of feasible combinations of NVDs modules and assessment of device parameters or intelligent proposal of modules combinations to satisfy given NVDs requirements for values of device parameters. This algorithm is implemented within prototype of Web-based architecture for preliminary theoretical estimation of NVDs design. Two branches of algorithm are developed – iterative and intelligent. The iterative branch allows simulating virtually different designs of device by choice of different modules combinations. In contrast to iterative modules choice, the intelligent choice of modules tries automatically to satisfy given DM requirements for some of the designed NVDs parameters.

The proposed architecture uses scripting language JavaScript to facilitate the using of web-based application for design assessment of NVDs. An advantage of the proposed architecture model is using of AJAX technology. Currently web standards used in AJAX are well defined and supported by all major browsers, and are browser and platform independent. The AJAX technology is used to update web pages asynchronously by exchanging small amounts of data with the server behind the scenes. Another advantage of the proposed architecture model is that all operations and calculations results stay locked on the client-side and are not accessible for other users of the system.

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