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Detection of Aircraft Technical System Failuresor Malfunctionsby Using Image / Video Processing of Cockpit Panels

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Abstract: *In Aviation, the different Aircraft technical system Parameters are monitored for failures or malfunctions by different sensors and are indicated in several panels in the Cockpit in the form of steady / flashing lights of different shapes, sizes, and colors such as amber, red, blue, white, etc. Some of the thus detected failures are constantly being recorded in a Flight Data Recorder (FDR). The FDR records limited the critical number of parameters only due to several constraints. The number of parameters that an FDR records vary from Aircraft to Aircraft, a typical Aircraft FDR records approx. 80 parameters. This paper proposes a concept of "Detection of Aircraft technical systems failures or malfunctions by using Image / Video Processing of a Cockpit Panel in Aviation". A Video of an Airborne Image Recording System (AIRS) is used to process in obtaining the results. By using this method, there is a wide scope of detection of a much greater number of parameters, i.e., typically to the tune of 150 to 200. As of now, The Aircraft incidents/accidents are investigated based on the evidence provided by the two flight recorders, namely, Cockpit Voice Recorder (CVR) and FDR. CVR records audio conversations among the pilots in the Cockpit and also with air traffic controllers. At times, both CVR & FDR also fail in providing actual or sufficient information for the cause of an incident or accident. Using this concept of detection definitely provides more information in arriving at the correct cause of an incident/accident. Hence this concept could help in identifying the actual cause of an incident or accident, thereby providing an opportunity to correct or improve the relevant Aircraft Technology. This concept consists of two parts, the first part is of shape analysis of a cockpit panel, and the second part is the fault analysis of the cockpit panel. This paper presents only the first part, i.e., Shape Analysis of the Cockpit Panel.*

Keywords: *Airborne Image Recording System (AIRS), Aircraft Incident/accidents, Aircraft Technical system malfunctions/failures, Aircraft Technology, Cockpit Panel, Cockpit Voice Recorder (CVR), Flight Data Recorder (FDR), Image/Video Processing.*

I. INTRODUCTION

Nowadays, aviation control systems are highly improved with advanced sensors and complex avionics. The possibility of fault occurrence also increases with the advanced functionalities of the controllers.

The number of sensors provided to monitor different parameters of an Aircraft is limited due to several constraints. The chance of malfunction of indications also increases due to electrical transients and complexity. This work aims at detecting a greater number of aircraft system parameters than the sensors used to detect as well as detecting each malfunction of an indication in a cockpit panel. The basic knowledge of Flight Recorders and Airborne Image recording systems could help in better understanding of the concept as well as interpretation of the results.

A. FLIGHT RECORDERS

Global aviation regulatory authorities mandate that an Aircraft must be fitted with CVR and FDR [1]-[4]. The CVR and FDR data are some of the most important information sources available to help determine the causes of an Aircraft incident/accident. A typical CVR retains the last two hours of voice recording at any given point in time. FDR continuously records certain critical parameters of an Aircraft, such as the Aircraft flight path, speed, altitude, engine power, configuration, etc. The typical FDR is capable of retaining the Flight Data information of the last 25 hours of operation. The CVR and FDR together are popularly called Black Box.

B. AIRBORNE IMAGE RECORDING SYSTEM (AIRS)

Airborne Image Recording System [5]-[7] is now on the National Transportation Safety Board (NTSB)'s "MOST WANTED" list. "A PICTURE IS WORTH A THOUSAND WORDS".

In the past, it was only possible to hear what was taking place and compare the voice recordings to data extracted from the flight data recorder. In some cases, the audio was useless because it was garbled, drowned out by background noise, or the pilots were incapacitated.

Airborne Image Recorder (AIR) would eliminate all those problems by providing an actual account of the accident as seen by the crew on the flight deck.

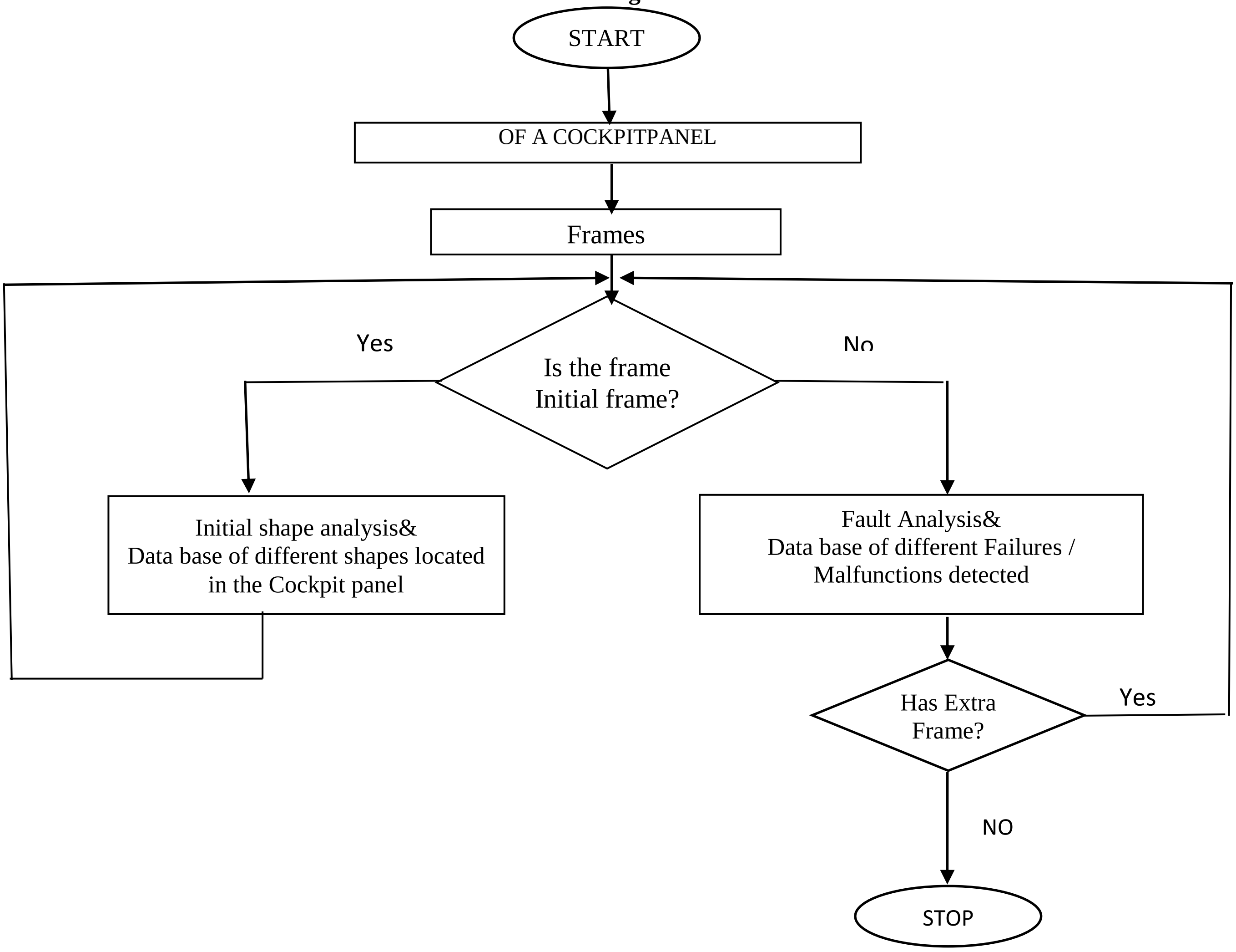
The detected failures through AIRShave a scope to give an additional alert to the cockpit crew and also may be compared with the data of FDR, CVR and are analyzed for concurrence with the Flight Data Recorder's failures detection. If concurrent, it is aircraft Technical System Failure; or else detector/indication failure or malfunction.

The proposed method of detection of Aircraft technical system failures or malfunctions by using Image / Video Processing of an Airborne Video Recording System consists of two parts. The first part is of shape analysis of a Cockpit Panel Video. The shape analysis of a Cockpit Panel Videoinvolvesthe process of a simulated video of a cockpit panel, including conversion of the Cockpit Panel video into frames of images, The initial frame is selected and analyzed for different shapes on the panel and prepares a database of different shapes located in the cockpit panel.

The second part is the fault analysis of the cockpit panel video, which involves the detection of technical systems failures or malfunctions by using Image / Video Processing. By using this method, there is a wide scope of detection of the much greater number of parameters, typically each and every parameter indicated in the Cockpit panel. It is vital to know the correct reason for the cause of an incident/accident so that the technology could be improved to eliminate future incidents/ accidents.

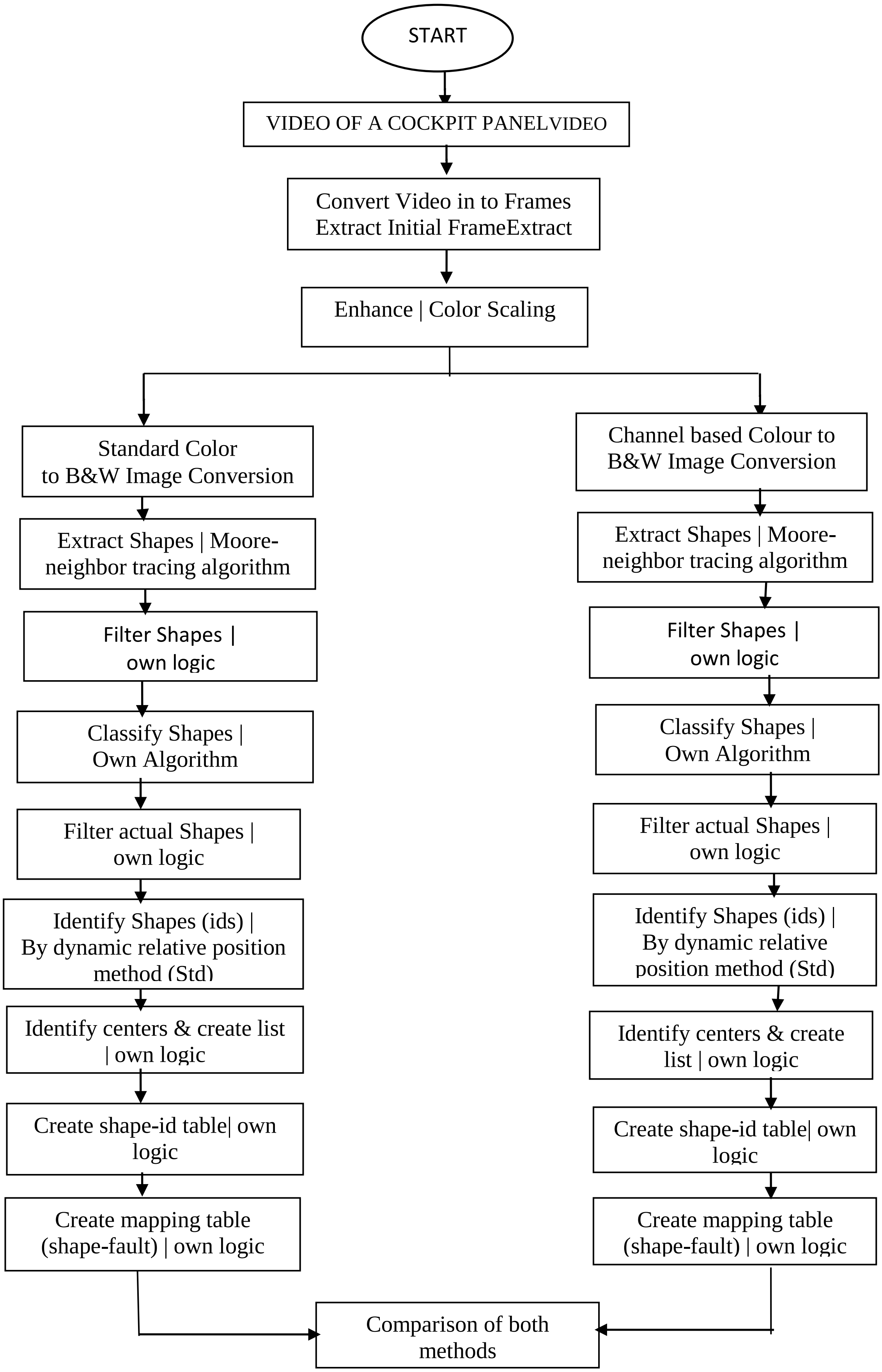
The Fig.1. below shows the flow chart depicting the total concept of detection of Aircraft technical system failures or malfunctions by using Image / Video Processing of a Cockpit panel.

Fig. 1. Conceptual Flow chart of detection of Aircraft technical system failures or malfunctions by using image / Video Processing in Aviation.



II. SHAPE ANALYSIS OF A COCKPIT PANEL VIDEO

Fig. 2. Flow chart of Shape Analysis of a Cockpit Panel by using Image/Video processing.



The Fig.2. shows the detailed flow chart of the process of Shape analysis of a Cockpit Panel Video. The shape analysis of the video of a cockpit panel involves different steps such as the input of a simulated cockpit panel video and converting it into image frames, selection of an initial frame, enhancing of the image by color scaling, extraction of different shapes, filtering of the shapes, classifying the shapes, filtering of the actual shapes of interest, identifying the different shape centers, creation of centers list, creation of shapes id table and mapping table. In this work, the total process is carried out by two different methods, i.e., converting a color image into a Black & White (BW) image by a standard direct conversion method and by converting a color image into a Black & White image by the Color Channel-based method and comparing both the methods adopted and finally arrive at the best-suited method for this application.

A. VIDEO OF A COCKPIT PANEL

A simulated video of a cockpit panel of an AIRS, consisting of several Aircraft technical system failures or malfunctions which are indicated in the form of steady / flashing lights of different shapes, sizes and indicating in different colors such as amber, red, blue, white, etc., is selected for testing.

B. CONVERSION OF VIDEO INTO IMAGE FRAMES

By using existing standard image tools, the different images from the video of the cockpit panel are extracted. The first frame of the video images is further processed to improve the quality of the image.

Here, the frame rate of the video is extracted first, and then using extracted frame rate, the video is converted into a sequence of frames or images.

C. ENHANCE THE IMAGE BY COLOUR SCALING

The image clarity could be affected due to lighting, weather, and imaging devices used to record the image. In case of poor illumination conditions, the images may appear darker or with low contrast. The first frame of the video images is selected and improved by using color scaling the quality of the image.

Color enhancement [8-13] is the preprocessing technique used to reduce the noise and thereby preserve the integrity of edges, and other useful contents of interest in the image are more easily identified. Color image enhancement plays a very important role in improving image quality, which is paramount in image processing.

The mean brightness of the initial frame and mean of all 3 RGB color channels are calculated, and the channel-based color scaling is applied using these mean values. Edge detection and blurring filters are applied in parallel to reduce the noise components and preserve the shape properties.

D. STANDARD COLOR TO BLACK AND WHITE IMAGE CONVERSION METHOD

The first method used is the standard color to Black and White image conversion method [14,15]; a color image is first converted into a grayscale image by taking the average of the individual RGB levels present at each pixel (using standard RGB to grayscale conversion ratio). These grayscale images are converted into black and white images using the image binarization method (thresholding method). Here the thresholding value is taken as the mean of the overall brightness of the grayscale image.

E. CHANNEL-BASED COLOR TO BLACK AND WHITE IMAGE CONVERSION METHOD

The second method used is the channel-based color to Black and White image conversion method [16-19]. In this work, a novel channel-based color to black and white image conversion method is developed to analyze each color component individually. Edge filters and average filters are applied in sequence on each channel, and all edges are extracted to construct channel-wise BW images. These channel-wise edges are averaged along with BW morphological operations to construct the actual BW image with all necessary edges/shapes.

F. EXTRACTING SHAPES

The different Shapes are extracted using Moore-neighbor tracing algorithm [20,21].

G. FILTERING OF ALL SHAPES

The flight panel has many unwanted edges/shapes like panel region borders, region names, region separators, control knobs, and other text indications. Around 60% of the extracted shapes are not related to indicators and unwanted in this work. These extra unwanted shapes are filtered out in order to reduce the computational effort during the fault analysis phase. Hence filtering of shapes is carried out by using own logic.

H. CLASSIFICATION OF SHAPES

In order to filter out the unwanted shapes, first, all the extracted shapes are classified into different categories depending on their shape. Here, each shape is analyzed using the standard algebraic logic and classified into standard shapes like squares, rectangles, circles, semi-circles, and others. This classification logic is completely customized for fault shapes present in the Cockpit panel.

I. FILTERING OF ACTUAL SHAPES OF INTEREST

After the shape classification of extracted shapes, all unwanted shapes like semi-circles, region borders, panel separators, and screws are filtered out using algebraic and geometrical calculations and logics. These logics are derived from the relative comparison of different shapes present in the Cockpit panel. Filtering of actual shapes of interest is performed using own logic.

J. IDENTIFICATION OF SHAPES

After extracting the actual fault shapes, all the interesting shapes should be assigned with proper identification like region names and identity numbers. This numbering adopted is unique as per panel region-wise.

K. IDENTIFICATION OF SHAPE CENTRES AND CREATION OF LIST

Here, the center coordinates of each shape are calculated using the mean coordinates of the sides, and a list of centers is created; numbered shapes are aligned with panel coordinates. This step highly improves the fault localization and also reduces the total time recurred to frame-to-frame fault analysis. Shape Identification phase will be completed after this step.

L. CREATION OF SHAPE ID TABLE

Shape centers list and Shape identity list are mapped, and a shape ID table is created to locate each fault on the panel using the shape identity number. This mapping is not fixed for all the layouts and varies with the panel region and fault indicator positions. This mapping table is customized for the cockpit panel layout considered.

M. CREATION OF MAPPING TABLE

This is the final mapping table which maps the fault locations with fault definitions. One fault location may map with multiple faults depending on fault color and state. Here state may be stable or blinking. So, the fault mapping table consists of fault location ID, fault color, fault state, and fault definition ID. This fault definition ID is used to extract the fault definition and region and other parameters from the fault definition table.

In this work, multiple tables are created to make the search algorithm unidirectional in order to increase fault analysis performance by reducing the time to localization of the fault and extraction of the fault data.

III. RESULTS AND DISCUSSION

In this work, multiple real-time flight faults are simulated, and the corresponding video is used to validate the proposed algorithms and workflow. Both the algorithms of converting a color image into standard direct Black & White image method and color channel-based method are developed using MATLAB-R2019A Software and results are compared in terms of total extracted faults and valid faults and also computational saving analysis. The Computational platform is an Intel Core-i7 workstation with 32GB RAM and an 8GB GPU card.

A. Results of Shape Analysis obtained by standard direct conversion of a color image into Black and White image method

Fig.3.Actual Panel of the Cockpit

Fig.3. shows the actual Cockpit Panel being subjected to Image/Video processing for the detection of Aircraft technical system failures or malfunctions.

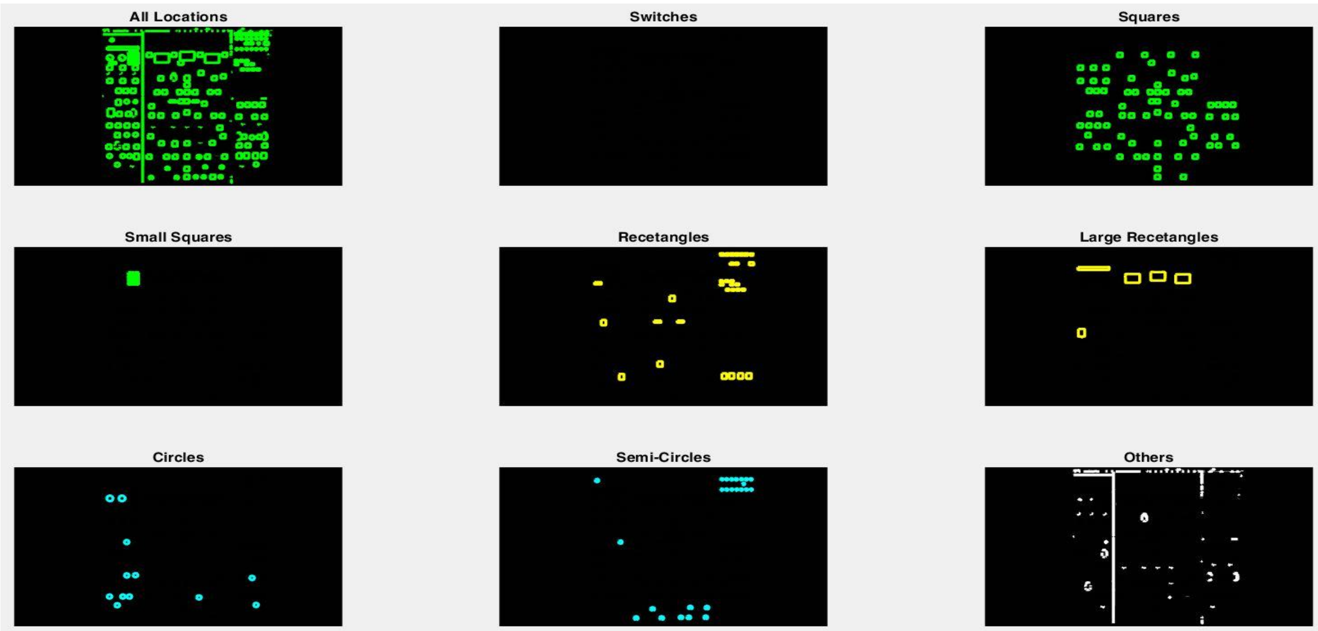


Fig.4. All locations & Shape-wise classifications extracted through standard direct color to BW image conversion method.

Fig.4. Shows all the locations of the cockpit Panel as well as different shapes extracted such as switches, squares, small squares, rectangles, circles, semi-circles, others, etc. Fig.5. shows all the locations in detail obtained by Standard direct color to Black and White image conversion method.

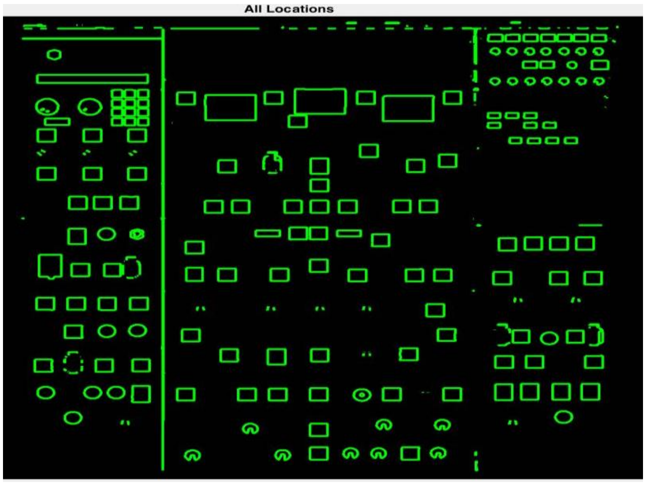


Fig.5. All locations extracted through Standard direct color to BW image conversion method.

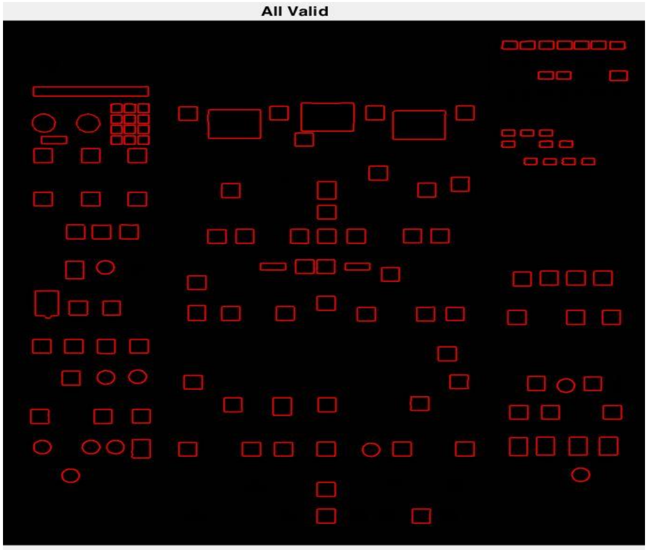


Fig.6. All valid shapes extracted through standard direct color to BW image conversion method.

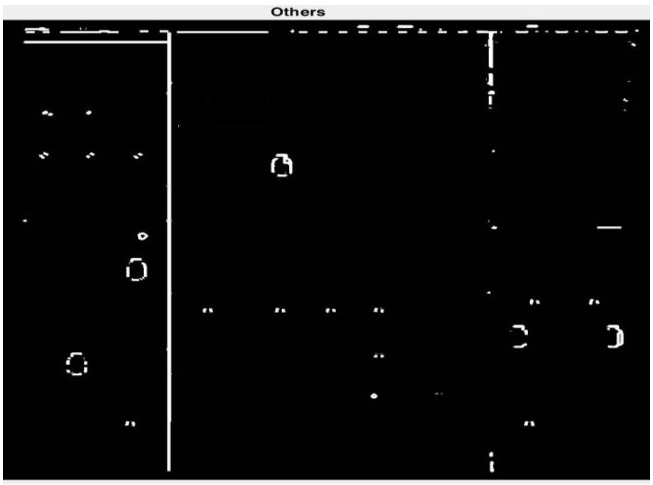


Fig.7.All invalid shapes extracted through Direct color to BW image conversion method.

Fig.6. and Fig.7. shows all the valid and invalid shapes respectively obtained by Standard direct color to Black and White image conversion method.

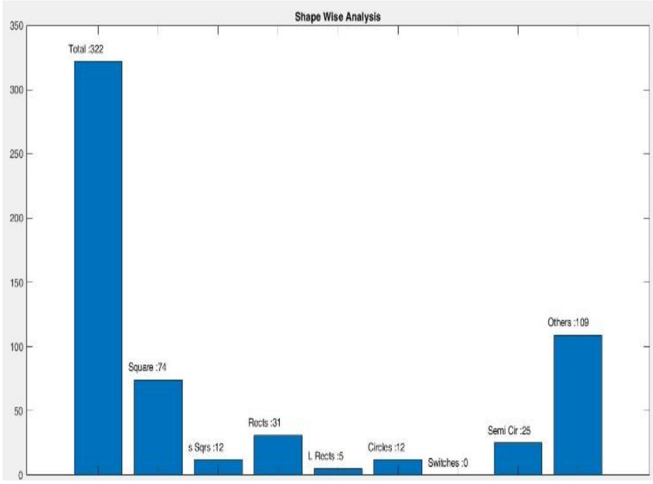


Fig.8. Shape-wise analysis of all extracted shapes in Standard direct color to BW image conversion method.

Fig.8. shows the shape-wise analysis showing the total no of shapes, squares, small squares, rectangles, large rectangles, circles, switches, semi-circles, others through the Standard direct color to BW image conversion method.

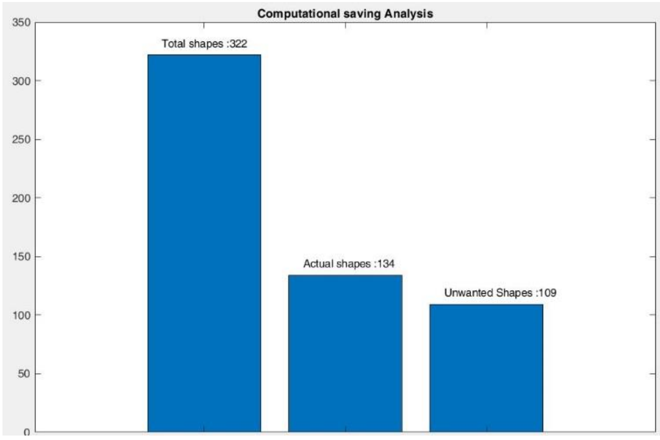


Fig.9.Computational saving analysis of all extracted shapes in Standard direct color to BW image conversion method.

Fig.9. indicates the computational saving analysis showing the total number of shapes detected, the total number of actual shapes of interest detected, the total number of unwanted shapes detected through the Standard direct color to BW image conversion method.

B. Results of Shape Analysis obtained by conversion of a color image into the Black and White image using Color Channel-based method

Fig.10.Shape Analysis obtained by conversion of a color image into a Black and White image using Color Channel-based method.

Fig.10.Indicates all the locations of the cockpit Panel as well as different shapes extracted such as switches, squares, small squares, rectangles, large rectangles, circles, semi-circles, others through the conversion of a color image into a Black and White Image using the color channel-based method.

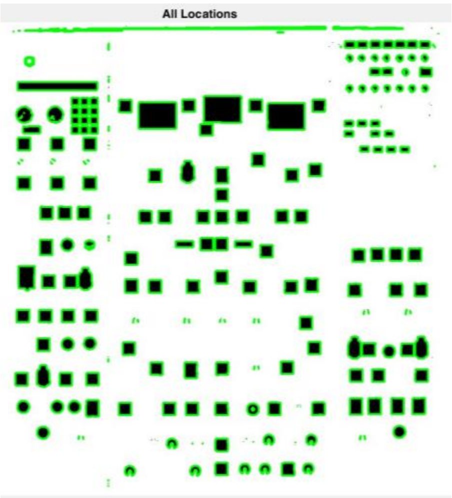


Fig.11.All locations were obtained by conversion of a color image into a Black and White image using the Color Channel-based method.

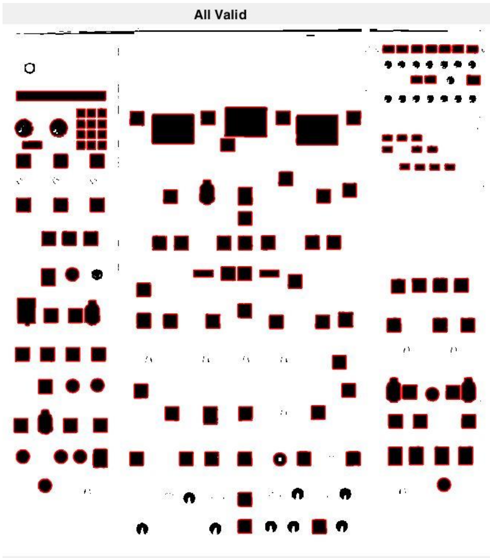


Fig.12.All valid shapes were obtained by conversion of a color image into the Black and White image using the Color Channel-based method.

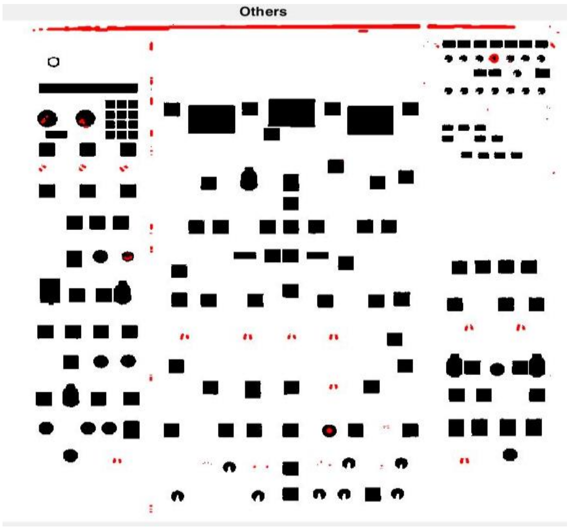


Fig.13. All other shapes were obtained by conversion of a color image into the Black and White image using the Color Channel-based method.

Fig.11.,12.,13., indicates all the locations in detail, all valid shapes, all other shapes respectively obtained through the conversion of a color image into a Black and White Image using the color channel-based method.

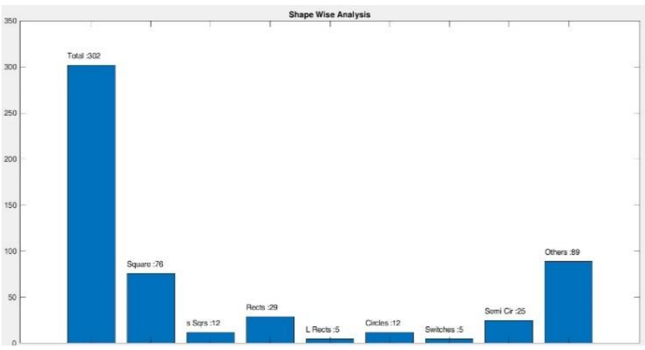


Fig.14.Shape-wise analysis of all extracted shapes obtained by conversion of a color image into the Black and White image using the Color Channel-based method.

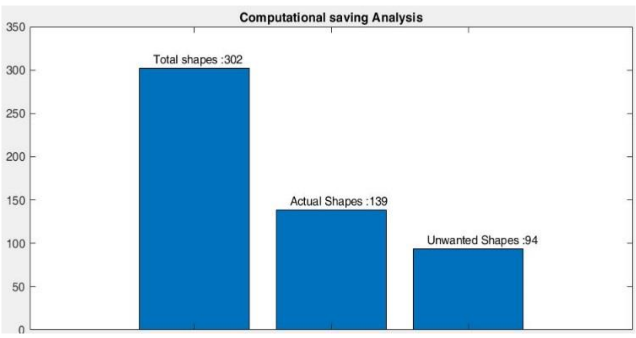


Fig.15.Computational saving analysis of all extracted shapes obtained by conversion of a color image into the Black and White image using the Color Channel-based method.

Fig.14. Indicates the shape-wise analysis showing the total no of shapes, squares, small squares, rectangles, large rectangles, circles, switches, semi-circles, others through the conversion of a color image into a Black and White Image using the color channel-based method.
Fig.15. indicates the computational saving analysis showing the total number of shapes detected, the total number of actual shapes of interest detected, the total number of unwanted shapes detected through the conversion of a color image into a Black and White Image using the color channel-based method.

From the above results, the standard direct conversion algorithm extracted a total of 322 shapes, out of which only 134 are the valid and wanted shapes, whereas the proposed Color channel-based algorithm extracted only 302 shapes, out of which 139 shapes are valid. The proposed algorithm extracted 5 more valid shapes than the standard direct conversion algorithm at the same time, filters out 20 unwanted shapes, which in turn increases the performance of the overall system. The valid shapes to total shapes ratio also increased by 5%.

IV. CONCLUSIONS

It is evident by comparing the results on shape analysis as well as computational saving analysis obtained by both Standarddirect color to Black & White image conversion method and by conversion of a color image into Black & White image using Color Channel-based method, Standard color to BW conversion is not suitable for the Cockpit panel shape analysis as dominant color shapes or blocks, which will reduce the performance of shape analysis.
Hence shape analysis by conversion of a color image into the Black and White image using the Color Channel-based method is more suitable for a Cockpit panel, as the actual number of shapes detected is less, as well as the shapes of interest detected are more. This could decrease the processing time and reach the speed of real-time analysis.

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V. REFERENCES

[1] DGCA, Civil Aviation Requirements, Section 2 – Airworthiness, Series 'I', Part V, Issue III, 30th October, Flight Data Recorders, Combination Recorders, Datalink Recorders, Airborne Image Recorders, Airborne Image Recording System and Aircraft Data Recording System, (2018). www.dgca.gov.in (Aircraft Rules-Civil Aviation Requirements).

[2] David E. Rapport and Paul D. Richter., Cockpit Video Recorders, 1051-1065, Issues in Aviation Law and Policy – 5211, (2005).

[3] Study on Flight Data Recorder Read-Out, Technical and Regulatory Aspects, BEA, www. bea. Aero / www.bea-fr.org.

[4] Australia's National Transport Safety Investigator, Black Box Flight Recorders Fact Sheet, www.atsb.gov.au

[5] Miles A. Cox, Erik P.Fantasia, Benjamin D.Rider, Timothy M.Rye Team 1, Feasibility of Airborne Cockpit Video Flight Recorders on Commercial Aircraft, (2000). http://www.iasa.com.au/folders/Safety_Issues/dfdr-cvr/DVDR1.htm

[6] National Transportation Safety Board, Washington, D.C. 20594, Safety Recommendation, in reply refer to A-15-1 through -8, (2015).

[7] Mike Horne, AD Aerospace Ltd, Manchester, UK, Future Video Accident Recorders.

[8] S. Again, Karen P Lentz and Artyom M. Grigoryanm A New Measure image Enhancement, January,(2000).:https://www.researchgate.net/publication/244268659.

[9] Ziaur Rahman, Muhammad Aamir, Yi-Fei Pu, Farhan Ullah, and Qiang Dai, A Smart System for Low-Light Image Enhancement with Color Constancy and Detail Manipulation in Complex Light Environments, 5th December,208, Symmetry 10, 718, (2018).

[10] Anish Kumar Vishwakarma, Agya Mishra., Color Image Enhancement Techniques: A Critical Review, Indian Journal of Computer Science and Engineering (IJCSE), 3(1) (2012). ISSN: 0976-5166.

[11] Jayanta Mukherjee and Sanjit K.Mitra., Enhancement of Color Images by Scaling the DCT Coefficients, IEEE TRANSACTIONS ON IMAGE PROCESSING, 17(10) (2008) 1783-1794.

[12] Dibya Jyothi Bora., Importance of Image Enhancement Techniques in Color Image Segmentation: A Comprehensive and Comparative Study, Indian J. Sci.Res.15(1) (2017) 115-131.

[13] Shefali Gupta and Yadwinder Kaur., Review of Different Local-Global Contrast Enhancement Techniques for a Digital Image , International Journal of Computer Applications (0975-8887), 100(18) (2014).

[14] Gonzalez, R., & Woods, R., Digital Image Processing (1st ed), New Delhi: Dorling Kindersley, (2014).

[15] Andrew P. King, Paul Aljabar., Chapter 10 – Signal and Image Processing, MATLAB Programming for Biomedical Engineers and Scientists, (2017) 221-253. https://doi.org/10.1016/B978-0-12-812203-7.00010-0.

[16] Ricardo L. de Queiroz and Karen M. Braun., Color to Gray and Back: Color Embedding into Textured Gray Images, IEEE TRANSACTIONS ON IMAGE PROCESSING, 15(6) (2006) 1464-1470.

[17] Samuel Macedo, Givanio Melo and Judith Kelner., A comparative study of grayscale conversion techniques applied to SIFT descriptors, SBC Journal on Interactive Systems, 6(2) (2015) 30-36. ISSN: 2236-3297.

[18] Saravanan Chandran., Color Image to Grayscale Image Conversion, Second International Conference on Computer Engineering and Applications,(2010). DOI: 10.1109/ICCEA.2010.192.Source: IEEE Xplore.

[19] Christopher Kannan and Garrison W. Cottrell., Color-to-Grayscale: Does the Method Matter in Image Recognition?, www.plosone.org, 7(1) (2012) e29740.

[20] Soumen Biswas, Ranjay Hazra., Robust edge detection based on Modified Moore-Neighbour, Optik-International Journal for Light and Electron Optics (Elsevier), 168 (2018) 931-943. https://doi.org/10.1016/j.ijleo.2018.

[21] G. Sai Sundara Krishnan, N. Vijaya., Algorithm on Tracing the Boundary of Medical Images Using Abstract Cellular Complex, International Conference on Machine Vision and Image Processing (MVIP), IEEE Xplore: (2012). DOI: 10.1109/MVIP.2012.6428780

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