Smart Navigation Equipment Monitoring System

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***Abstract*— Digital image processing is a processing of digital frames using digital computation. Image processing has been used in many sectors such as military, biomedics, and in this paper, the authors will implement it in the civil aviation sector by introducing a new method to monitor an aviation navigation equipment. It can be used on all LED-based Built-in Monitor navigation equipment, despite it is a low-cost system. The image processing of this research is done by doing perspective correction and then continue with BLOB detection in a segmentation stage. The final result will be displayed on a web page. Compared to its predecessor, this method gives better flexibility which does not need to be electrically connected with monitored equipment and not limited to certain brands.**

Keywords—Aviation, Remote Monitoring, RMS, RCMS

I. Introduction

Navigation services of civil aviation depends on navigation equipment availability or available services time. If failure count increases then the services time will decrease. Otherwise, if failure recovery time decreases then the services time will increase. Time delay between equipment failure to another failure is called Mean Time between Failure (MTBF) and the time delay needed to recover a failure is called Mean Time to Repair (MTTR). Thus, we expect a smaller value of MTTR and a larger value of MTBF [2].

Availability is impossible to achieve if the failure information does not deliver on time. The failures are caused by many factors that are not only about equipment quality but also could be environment effect.

II. Remote Monitoring System in Navigation Equipment

Navigation equipment were installed in Indonesia was NDB, VOR, ILS, DME. This equipment could vary with different brands and types. For instance, VOR manufactured by INDRA SISTEMAS, S.A. the types are VRB52 and VRB53 [5]. Thus, the navigation equipment variety keeps increase, and equipment monitoring is a challenge.

The equipment monitoring with technicians supervise the equipment at the equipment site location directly is called site monitoring. However, direct monitoring at the equipment site cannot be done all over the time. Normally operated equipment can be supervised at others locations. The monitoring where the location different from the equipment site is called remote monitoring [3].

Each navigation equipment provides a different type of communication then the data extraction method from each system is different too. That is why the remote monitoring system could be created by navigation equipment company but limited only for certain equipment. Moreover, each country has unique contour especially in Indonesia which consists of islands then connectivity is a big issue and data efficiency is a must.

A conventional remote monitoring system needs electrically connected with monitored equipment. This method has some weaknesses. Remote monitoring connection should be well adapted with a different topology such as RS232 or LAN. In addition, an equipment such as monitoring system that electrically connected could be suspected as failure source of the navigation equipment.

III. Proposed Solution

The proposed solution is using image processing algorithm. It utilizes a built-in monitor that includes in each navigation equipment. Built-in monitor "Fig.1" is a summary of equipment status and aerial parameters "Fig. 2" as LED indicators. These LEDs use high contrast colors like RED for alarm conditions or GREEN for normal conditions. Thus, the observer or technician can find out the equipment condition faster.

Fig.1. VOR SELEX Built-in Monitor [4]

Fig.2. Aerial Parameters

Main computation is handled by Raspberry pi 3 B+ and 640 x 480 pixel USB webcam uses as an image recorder. This resolution plays an important role because it will be used in digital distance measurement. Furthermore, we will use three references to improve accuracy. We could increase the resolution but it will hurt processing performance. Data train of the raspberry output feeds to databases for displaying on the web page. Complete diagram of the proposed solution could be seen in "Fig. 3".

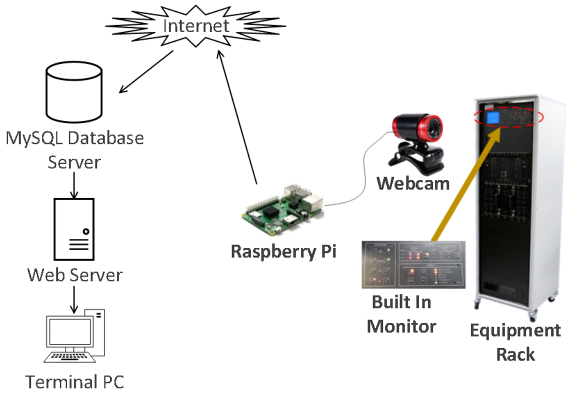


Fig. 3. The diagram of the proposed solution

The whole steps of the proposed image processing algorithm can be seen in “Fig. 4”. Defining the detection area should be done at first. The Built-in monitor frame is including in this area. A larger area will make the camera position further. Thus, if the area is out of camera coverage then dual cameras should be used. The detection area is defined by using AprilTag [1] markers.

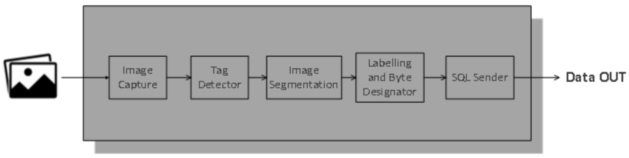


Fig. 4. The diagram of the detection step

A. Image capture and tag detector

Image capture uses OpenCV library and should be running on a separate thread to increase frame availability then data update will be faster. These image frames will be used for tag processing.

This research intended to be used for any equipment then AprilTag is used also as an equipment identifier. The difference between marker's AprilTag and equipment identifier's AprilTag as mentioned on “Fig. 5” is by the tag families where the markers are using Tag16h5 and the equipment identifier is using Tag36h10 families.

Over or under the intensity of light could affect to the tag detection. We could solve this by hardware such as a light dimmer. Another solution is using software such as gamma compensation. It could compensate either over or under intensity as shown on “Fig. 6” but noises will be more.

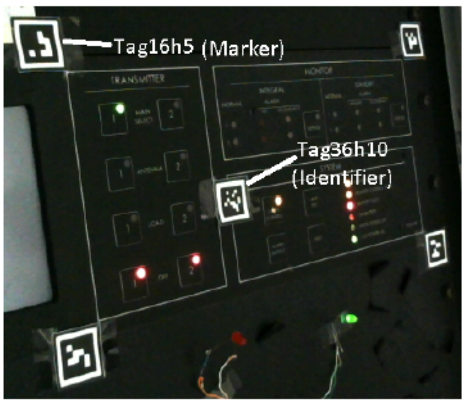


Fig. 5. Defining the detection area

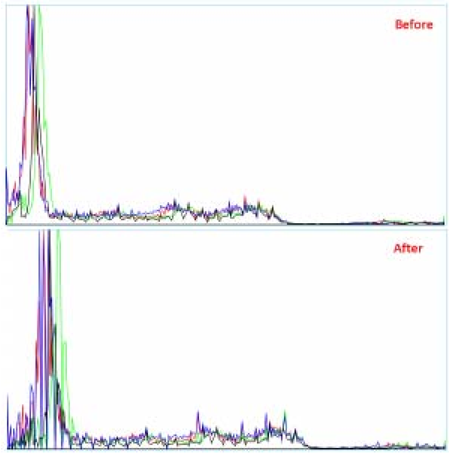


Fig. 6. Light intensity compensation with gamma correction

B. Image Segmentation

Keeping the camera position over the times will be difficult. If camera position is different then the distance of the detected object will be different too. To rectify this issue then four markers used [6].

We can access AprilTag properties “Fig. 7” and use it for markers needed. The benefit of AprilTag usage is it does not need an additional process to extract the tag coordinates. In addition, ID’s of the tag uses for marking each corner of the detection area to prevent swapped of the corner position.

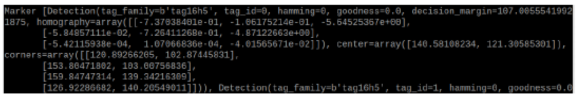


Fig. 7. AprilTag Properties

After four markers detected then we calculate these markers coordinate (x, y) of a frame. Software measures the coordinates then transform into fixed coordinates and crop it. The result after cropped is a corrected frame with four markers position exactly at the frame corners “Fig. 8”. Now, we are ready to detect the LED indicators on the corrected frame which are called BLOB.

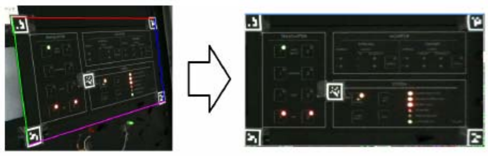


Fig. 8. Perspective correction

BLOB (Binary Large Object) is a group of connected pixels. BLOB detection is used to detect points or regions in a frame that has different properties and convert it to a binary frame. We can set to detect black or white based on some criteria such as size, circularity, convexity. To obtain a binary frame, we need to threshold a grayed image called binary threshold. All LED indicators could be well detected and eliminate unwanted objects with this step by changing the threshold value. High contrast object hard to remove especially for white color such as white line or white letter in white BLOB detection. For better detection, we need to remove this first.

A combination of erotion and dilation could be used. Not only for noise remover but also, we could use it to remove thin objects. We do erotion first to remove line and letter objects then we use dilation for thickening objects so the LEDs in the image frame will be clearer. A combination of erotion then continue with dilation is also called morphology open. Iteration number of morphology open parameters could be adjusted for process repetition.

A nearby object such as two illuminated LEDs could be confusing in detection because those LED emissions are merged. Another processing was conducted is called Distance Transform to split merged emissions. Distance Transform is normally applied to binary images. The result is an image that looks similar to the input, except that grey level intensities of foreground regions reduce gradually to the closest boundary to show distance as shown "Fig. 9". Even though LEDs emission merged, they have a focus point where it has greater intensity were detected by the Distance Transform algorithm. The Distance Transform outputs must be going through a binary thresholding step before processed in the BLOB detector.

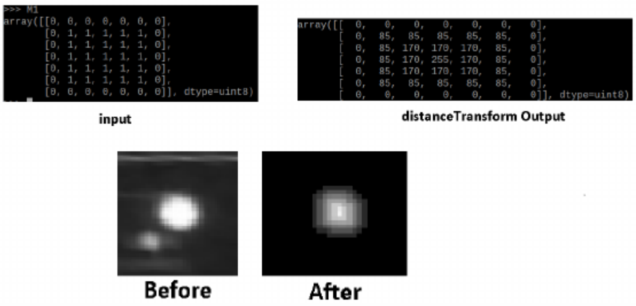


Fig. 9 Distance Transform

Detected BLOBs are called keypoints "Fig. 10". We need to determine of keypoint position by *x, y* coordinates. These coordinates are used to calculate the euclian distance to the references. Now we are going to create a label for each keypoints based on the distance. Label classification threshold set ± 5 points as distance calculation uncertainty compensation "Fig. 11".

Fig. 10. BLOB Keypoints

Fig. 11. Keypoints distance measurement

C. Labelling and Byte designator

In simple terms about the smart navigation equipment monitoring system is converting image frame sequence into data bits. For example in "Fig. 11", the main transmitter is set to transmitter No. 1 then the LED main transmitter No. 1 active with euclian distance is ± 104 from top left reference and ± 560 from top right reference. Based on that, we set data filter of the LED transmitter No. 1 with tolerance is ± 5 so that range for 104 (top left reference) is 99 to 109 and for 560 (top right reference) is 555 to 565. Any value inside of data filter tolerance will be produced bit 1 or TRUE and the rest value will be 0 or FALSE. So that if the main transmitter 1 LED is on then bit 1 will be produced. After all bits of LEDs have been collected, then they are wrapped into bytes for easier combining with the other data such as three alphabets of the equipment identification or IDENT.

D. SQL Sender

In this section, line programs have a responsibility to try to connect databases and insert SQL query then show a message if failed. The Databases will keep alive for one month.

IV. Result and Analysis

A. Tag response

An Undetected tag will raise an error and rest of the command will not execute. Here we will conduct a series of distance testing to help to decide camera position. The result could be seen in "Fig. 12". Based on the graph, maximum camera distance is not more than 90 cm with above 50% of the threshold. The detection range is limited by the camera focus point.

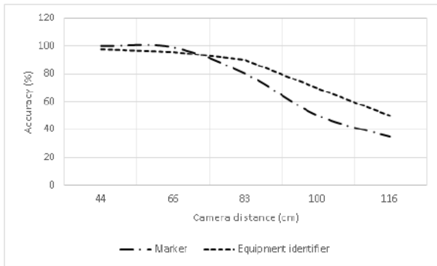


Fig. 12. Tag response related to camera distance

B. Length error

Length error tests will be conducted by varying camera position. The camera will be placed on angle 30, 60, 90, 120, 150 degrees related to Built-in monitor with 50 and 70cm away as shown on "Fig. 13". Three indicators are using as a measurement point which are main TX1 (A), local/remote (B), Standby bypass (C).

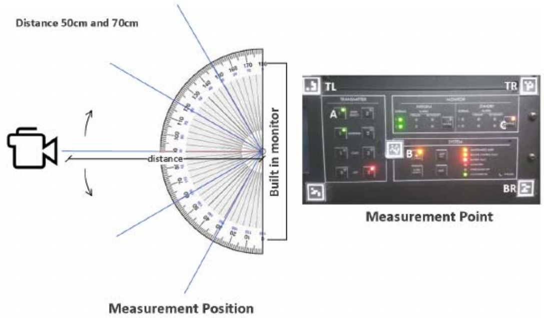


Fig. 13. Length error test scheme

We could see on the result "Fig. 14" that moving the camera away from Built-in monitor panel does not have length error significant effect. This fact is different with the camera moving around the panel. The authors are using three references which are top left (TL), top right (TR), and bottom right (BR). The more length comparison of each reference to an indicator then the error will be greater for angular movement. On "Table. I" to "Table. III" we could see of angular movement and distance effect compared to the real length.

TABLE I
INDICATOR TO REFERENCE REAL LENGTH

Indicator	Reference(cm)		
	TL	TR	BR
Main TX1 (A)	7	26.8	29.3
Local/Remote (B)	18.5	19.3	17.5
Stby Bypass (C)	29	6.8	11.5

TABLE II
LENGTH ERROR OF 50CM CAMERA AWAY

Indicator	Error for 50 cm away (pixel)		
	TL	TR	BR
Main TX1 (A)	2.23	5.92	5.39
Local/Remote (B)	5.39	3.05	2.4
Stby Bypass (C)	5.92	1.81	1.47

TABLE III
LENGTH ERROR OF 70CM CAMERA AWAY

Indicator	Error for 70 cm away (pixel)		
	TL	TR	BR
Main TX1 (A)	2.98	6.91	6.29
Local/Remote (B)	1.08	2.23	1.47
Stby Bypass (C)	2.94	1.82	1.22

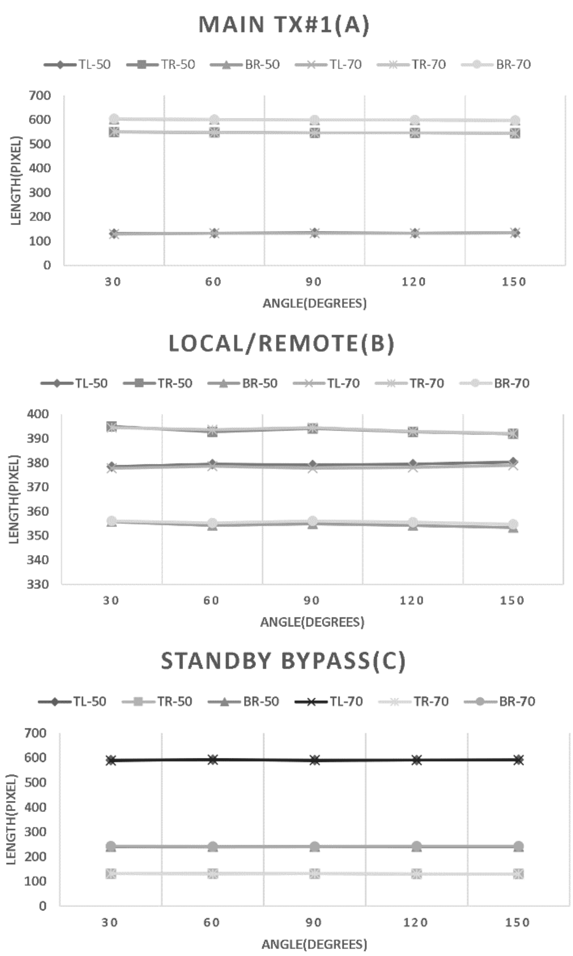


Fig. 14. Reference error for camera posisition 50 cm and 70 cm to indicators (a) Main TX1, (b) Local/Remote, (c) StandBy Bypass

C. Web and databases

The databases "Fig. 15" are designed in six columns. The first is raw data in binary format. ID stands for IDENT where the IDENT is unique for each equipment and stated by the government. ST is a quick view of equipment status as ALARM (bit 0) or NORMAL (bit 1) state. Eqtype is the equipment type where currently "1" is for SELEX 1150 and "2" is for INDRA VRB53. Warn column contained two conditions which are clear (bit 0) or warning (bit 1). Clear means everything is okay and warning means need to look forward. The last is timestamp contained databases server time and date, updated automatically with each of data inserted. Finally, observer could see the result over the webserver "Fig. 16" where the data obtained from the database "Fig. 15".

Fig 15. Built-in monitor database

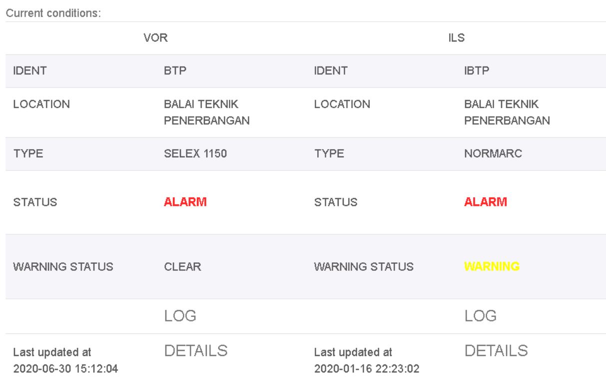
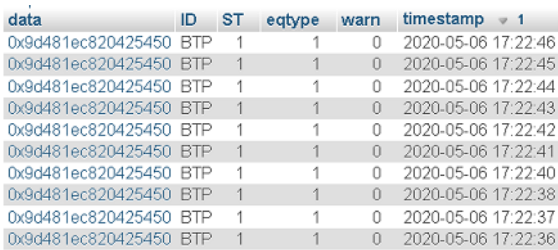


Fig. 16. Web view

D. Connection

The main goal of this research is it should be able to operate under limited speed connection then the connection tests was conducted.

Under full speed connection "Fig. 17", we could see the database filled every second under timestamp column and then we tried for set down connection speed under its limit. The critical speed is 100 Byte per Second. In "Fig. 18" we could see the datas are received even under 100 Byte per Second.



data	ID	ST	eqtype	warn	timestamp 1
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:46
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:45
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:44
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:43
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:42
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:41
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:40
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:38
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:37
0x9d481ec820425450	BTP	1	1	0	2020-05-06 17:22:36

Fig. 17. Testing under full-speed connection.

data	ID	ST	eqtype	warn	timestamp
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:15:29
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:15:21
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:15:14
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:15:06
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:14:58
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:14:51
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:14:43
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:14:35
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:14:28
0x9103fe4f20425450	BTP	0	1	1	2020-05-06 15:14:20

Fig. 18. Testing under critical speed

V. CONCLUSIONS

The Smart Navigation Equipment Monitoring System has been presented. This research has great flexibility to adapt over a remote area with limited connectivity. We could build it with a lower budget and no need to change the equipment electrical circuit. Camera placement is quite easy because the camera orientation and position related to objects does not affect the result. For better results, a camera with autofocus function could be used.

Data retrieval for a new dataset of equipment parameters does not require a long time and is only done once. It does not require special permissions to the equipment manufactures like the conventional method. Shifting the camera away from and closer to the built-in monitor panel does not have much difference in the reading of the indicator-reference distance because the LED indicators on the VOR SELEX SI 1150A are flat. If the shape of the LED is not flat, the result will be different and at least 10 pixels as a measurement tolerance or uncertainty compensation must be given.

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