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Estimation of Reliability Parameters of Vehicle Number Plate Recognition System

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Abstract : Vehicle Number Plate detection is an image processing technique to detect the vehicle number from the real time images. Reliability is an important factor accountable for every aspect of life. In this paper the author has considered a vehicle number plate recognition system. The system consists of four subsystems.Image acquisition, Extraction of plate region,Segmentation of characters and recognition of plate characters. The authors have used algebra of logics and Boolean function technique for the purpose of formulation of mathematical model and its solution. Reliability and M.T.T.F. for the system have evaluated. Some particular cases have also given to improve practical utility of the model.The findings of the present paper will be highly useful for developing proper strategies which can be implemented in order to enhance system performance.

Keywords : Vehicle Number Recognition, Boolean function technique, Reliability, Availability,Failure rate.

1 Introduction

Vehicle number plate detection is an image processing technology which is used to detect the license plate of avehicle from the real time image. There are four main subsystems in this system as shown in figure-1:

- Image Acquisition
- Plate Region Extraction
- Character Segmentation
- Character Recognition

This system consists of a digital camera which takes the image of the vehicle, find the location of the number plate, segment the characters of the number plate and finally template matching is used for characterrecognition. Vehicle number plate recognition can be used in many areas from speedenforcement and motorways to automation of parking lots, etc [1]. It plays a major role in automatic monitoringof traffic rules and maintaining law enforcement on public roads [2].

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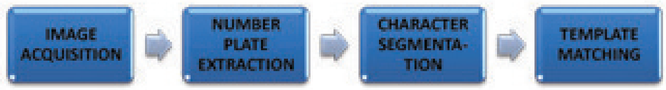

figure-1

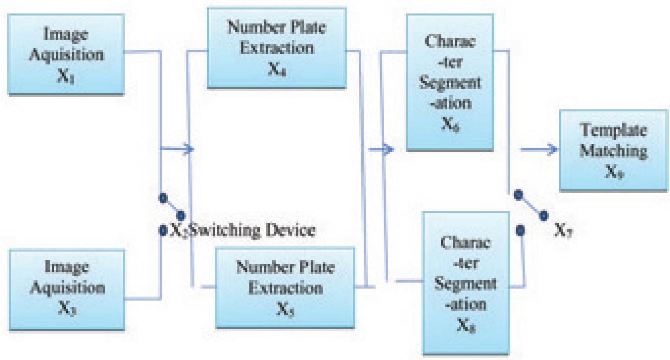

figure-2: Represents the system configuration of Vehicle number plate recognition system

Image Acquisition: In this sub system the system gets the image from the digital camera. The captured image is then passed from thecamera to the software module.

Plate Region Extraction: Image after median filtering is multiplied by grey scale image & then by applying horizontal and vertical scanning number plate is cropped and extracted.

Character Segmentation: In this characters & digits of the plate are segmented and each is saved as different image.

Character Recognition: For recognition of characters template matching is used. For matching the characters with Stored characters, input images must be equal sized with the stored characters. In the template matching each input character of the plate is correlated with all templates, then from the templates that character is selectedwhich has highest value of correlation coefficient with input character.

1.1 Assumptions

Assumptions associated with this model are as follows:

- At time t=0, all the units of the system are good.
- Reliability of every unit of the system is known in advance.
- System used is non-repairable.
- Transition from one unit to other is hundred percent reliable and takes no time.
- The state of every unit of system is either good or bad.
- The state of all components of the system is statistically independent.
- Thefailure times of all components are arbitrary.

1.2 Notations

x_1, x_3 : State of Image acquisition unit.

x_4, x_5 : States of Number plate extraction unit.

x_6, x_8	: States of Character segmentation unit.
x_9	: States of Template matching unit.
x_2, x_7	: State of switching device.
x_i $(i = 1, ..., 9)$	: 0, in bad state; 1, in good state.
x_i'	: Negation of x_i, $\forall\ i = 1, 2, ..., 9$.
$\wedge / \vee$	: Conjunction / disjunction.
$\vert\quad\vert$	: Logical Matrix.
R_i $(i = 1, ..., 9)$	: Reliability of i^{th} unit of the system.
Q_i $(i = 1, ..., 9)$	: Unreliability of i^{th} unit of the system and, $= 1 - R_i$.
a_i $(i = 1, ..., 9)$	: Failure rate of i^{th} unit of the system.
R_S	: Reliability of the Whole system.
$R_{SW}(t)/R_{SE}(t)$	: Reliability of the system as a whole when failures follow weibul / Exponential time distribution.

2 Formulation of Mathematical Problem

By employing Boolean function technique, the conditions of capability for successful operation of the considered system in terms of logical matrix are expressed as:

$$F(x_1, x_2, ..., x_9) = \begin{vmatrix} x_1 & x_4 & x_6 & x_9 & & \\ x_1 & x_4 & x_7 & x_8 & x_9 & \\ x_1 & x_5 & x_6 & x_9 & & \\ x_1 & x_5 & x_7 & x_8 & x_9 & \\ x_2 & x_3 & x_4 & x_6 & x_9 & \\ x_2 & x_3 & x_4 & x_7 & x_8 & x_9 \\ x_2 & x_3 & x_5 & x_6 & x_9 & \\ x_2 & x_3 & x_5 & x_7 & x_8 & x_9 \end{vmatrix} \tag{2.1}$$

3 Solution of the Problem

Applying algebra of logics, equation (2.1) may be rewritten as:

$$F(x_1, x_2, ..., x_9) = |x_9 \wedge f(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8)| \tag{3.1}$$

where

$$f(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8) = \begin{vmatrix} x_1 & x_4 & x_6 & & \\ x_1 & x_4 & x_7 & x_8 & \\ x_1 & x_5 & x_6 & & \\ x_1 & x_5 & x_7 & x_8 & \\ x_2 & x_3 & x_4 & x_6 & \\ x_2 & x_3 & x_4 & x_7 & x_8 \\ x_2 & x_3 & x_5 & x_6 & \\ x_2 & x_3 & x_5 & x_7 & x_8 \end{vmatrix} \tag{3.2}$$

Now substituting

$$A_1 = |x_1 \ \ x_4 \ \ x_6| \tag{3.3}$$

$$A_2 = |x_1 \;\; x_4 \;\; x_7 \;\; x_8| \tag{3.4}$$

$$A_3 = |x_1 \;\; x_5 \;\; x_6| \tag{3.5}$$

$$A_4 = |x_1 \;\; x_5 \;\; x_7 \;\; x_8| \tag{3.6}$$

$$A_5 = |x_2 \;\; x_3 \;\; x_4 \;\; x_6| \tag{3.7}$$

$$A_6 = |x_2 \;\; x_3 \;\; x_4 \;\; x_7 \quad x_8| \tag{3.8}$$

$$A_7 = |x_2 \;\; x_3 \;\; x_5 \;\; x_6| \tag{3.9}$$

$$\text{and } \; A_8 = |x_2 \;\; x_3 \;\; x_5 \;\; x_7 \quad x_8| \tag{3.10}$$

in the equation (3.2),it can be written as:

$$f(x_3, x_4, x_5, x_6, x_8, x_9, x_{10}) = \begin{vmatrix} A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \\ A_8 \end{vmatrix} \tag{3.11}$$

Using the process of orthogonalization, we can write equation (3.3) as:

$$f(x_3, x_4, x_5, x_6, x_8, x_9, x_{10}) = \begin{vmatrix} A_1 & & & & & & & \\ A_1' & A_2 & & & & & & \\ A_1' & A_2' & A_3 & & & & & \\ A_1' & A_2' & A_3' & A_4 & & & & \\ A_1' & A_2' & A_3' & A_4' & A_5 & & & \\ A_1' & A_2' & A_3' & A_4' & A_5' & A_6 & & \\ A_1' & A_2' & A_3' & A_4' & A_5' & A_6' & A_7 & \\ A_1' & A_2' & A_3' & A_4' & A_5' & A_6' & A_7' & A_8 \end{vmatrix} \tag{3.12}$$

Using algebra of logics, we may obtain the following:

$$A_1'A_2 = \begin{vmatrix} x_1' & & \\ x_1 & x_4 & \\ x_1 & x_4 & x_6' \end{vmatrix} \wedge |x_1 \;\; x_4 \;\; x_7 \;\; x_8| = |x_1 \;\; x_4 \;\; x_6' \;\; x_7 \;\; x_8| \tag{3.13}$$

Similarly,

$$A_1'A_2'A_3 = \begin{vmatrix} x_1 & x_4' & x_5 & x_6 \end{vmatrix} \tag{3.14}$$

$$A_1'A_2'A_3'A_4 = \begin{vmatrix} x_1 & x_4' & x_5 & x_6' & x_7 & x_8 \end{vmatrix} \tag{3.15}$$

$$A_1'A_2'A_3'A_4'A - 5 = \begin{vmatrix} x_1' & x_2 & x_3 & x_4 & x_6 \end{vmatrix} \tag{3.16}$$

$$A_1'A_2'A_3'A_4'A_5'A_6 = \begin{vmatrix} x_1' & x_2 & x_3 & x_4 & x_6' & x_7 & x_8 \end{vmatrix} \tag{3.17}$$

$$A_1'A_2'A_3'A_4'A_5'A_6'A_7 = \begin{vmatrix} x_1' & x_2 & x_3 & x_4' & x_5 & x_6 \end{vmatrix} \tag{3.18}$$

$$A_1'A_2'A_3'A_4'A_5'A_6'A_7'A_8 = \begin{vmatrix} x_1' & x_2 & x_3 & x_4' & x_5 & x_6' & x_7 & x_8 \end{vmatrix} \tag{3.19}$$

By making use of all these equations in equation (3.12), we get:

$$F(x_1, ..., x_{10}) = \begin{vmatrix} x_1 & x_4 & x_6 & & & & & \\ x_1 & x_4 & x_6' & x_7 & x_8 & & & \\ x_1 & x_4' & x_5 & x_6 & & & & \\ x_1 & x_4' & x_5 & x_6 & x_7 & x_8 & & \\ x_1' & x_2 & x_3 & x_4 & x_6 & & & \\ x_1' & x_2 & x_3 & x_4 & x_6' & x_7 & x_8 & \\ x_1' & x_2 & x_3 & x_4' & x_5 & x_6 & & \\ x_1' & x_2 & x_3 & x_4' & x_5 & x_6' & x_7 & x_8 \end{vmatrix} \tag{3.20}$$

Finally, the probability of successful operation, i.e., reliability of the system as a whole is give by

$$\begin{aligned} R_s &= P_r\{F(x_1, ..., x_9) = 1\} \\ &= R_9[R_1R_4R_6 + Q_6R_1R_4R_7R_8 + Q_4R_1R_5R_6 + Q_4Q_6R_1R_5R_7R_8 \\ &+ Q_1R_2R_3R_4R_6 + Q_1Q_6R_2R_3R_4R_7R_8 + Q_1Q_4R_2R_3R_5R_6 + Q_1Q_4Q_6R_2R_3R_5R_7R_8] \\ &= R_9[R_1R_4R_6 + R_1R_4R_7R_8 - R_6R_1R_4R_7R_8 + R_1R_5R_6 - R_4R_1R_5R_6 + R_1R_5R_7R_8 \\ &- R_4R_1R_5R_7R_8 - R_6R_1R_5R_7R_8 + R_1R_4R_5R_6R_7R_8 + R_2R_3R_4R_6 - R_1R_2R_3R_4R_6 \\ &+ R_2R_3R_4R_7R_8 - R_1R_2R_3R_4R_7R_8 - R_2R_3R_4R_6R_7R_8 + R_1R_2R_3R_4R_6R_7R_8 \\ &+ R_2R_3R_5R_6 - R_1R_2R_3R_5R_6 - R_2R_3R_4R_5R_6 + R_1R_2R_3R_4R_5R_6 + R_2R_3R_5R_7R_8 \\ &- R_1R_2R_3R_5R_7R_8 - R_2R_3R_4R_5R_7R_8 - R_2R_3R_5R_6R_7R_8 + R_1R_2R_3R_4R_5R_7R_8 \\ &+ R_2R_3R_4R_5R_6R_7R_8 + R_1R_2R_3R_5R_6R_7R_8 - R_1R_2R_3R_4R_5R_6R_7R_8] \end{aligned} \tag{3.21}$$

4 Some Particular Cases

Case i: If reliability of each component of the system is R
In this case, equation (3.21) yields:

$$R_S = 2R^4 + 3R^5 - 4R^6 - 3R^7 + 4R^8 - R^9 \tag{4.1}$$

Case ii: When all failures follow weibull time distribution
Let a_i $(i = 1, 2, ..., 9)$ be the failure rate of i^{th} component of the complex system and α be a positive parameter then in this case, reliability of the whole system, at instant t, can be obtained form equation (3.21) as :

$$R_{sw}(t) = \sum_{i=1}^{9} \exp\{-\lambda_i t^{\alpha}\} - \sum_{j=1}^{8} \exp\{-\mu_j t^{\alpha}\} \tag{4.2}$$

where λ_i and μ_j's are given as under:

$$\lambda_1 = c + a_3 + a_5 + a_8$$

$$\lambda_2 = c + a_3 + a_6 + a_8$$

$$\lambda_3 = c + a_3 + a_5 + a_9 + a_{10}$$

$$\lambda_4 = c + a_3 + a_5 + a_6 + a_8 + a_9 + a_{10}$$

$$\lambda_5 = c + a_3 + a_6 + a_9 + a_{10}$$

$$\lambda_6 = c + a_4 + a_5 + a_8$$

$$\lambda_7 = c + a_4 + a_6 + a_8$$

$$\lambda_8 = c + a_3 + a_4 + a_5 + a_6 + a_8$$

$$\lambda_9 = c + a_4 + a_6 + a_9 + a_{10}$$

$$\mu_1 = c + a_3 + a_5 + a_6 + a_8$$

$$\mu_2 = c + a_3 + a_5 + a_8 + a_9 + a_{10}$$

$$\mu_3 = c + a_3 + a_5 + a_6 + a_9 + a_{10}$$

$$\mu_4 = c + a_3 + a_6 + a_8 + a_9 + a_{10}$$

$$\mu_5 = c + a_3 + a_4 + a_6 + a_8$$

$$\mu_6 = c + a_3 + a_4 + a_6 + a_8$$

$$\mu_7 = c + a_4 + a_5 + a_6 + a_8$$

$$\mu_8 = c + a_3 + a_4 + a_6 + a_9 + a_{10} \text{ and}$$

$$c = a_1 + a_2 + a + 7$$

Case iii: When all failures follow exponential time distribution

Exponential distribution is a particular case of Weibull distribution for $\alpha = 1$. Hence, the reliability of whole system at an instant t, in this case, is given by:

$$R_{SE}(t) = \sum_{i=1}^{9} \exp\{-\lambda_i t\} - \sum_{j=1}^{8} \exp\{-\mu_j t\} \tag{4.3}$$

Also, the expression for M.T.T.F., in this case, is

$$\begin{aligned} M.T.T.F. &= \int_0^\infty R_{SE}(t)dt \\ &= \sum_{i=1}^{9}\left\{\frac{1}{\lambda_i}\right\} - \sum_{j=1}^{8}\left\{\frac{1}{\mu_j}\right\} \end{aligned} \tag{4.4}$$

5 Numerical Computation

For a numerical computation

(i) Setting a_i $(i = 1, 2, ..., 9) = 0.003$ and $\alpha = 2$ in equation (4.2);

(ii) Setting a_i $(i = 1, 2, ..., 9) = 0.003$ in equation (4.3);

(iii) Setting a_i $(i = 1, 2, ..., 9) = 0, 0.1, ..., 1.0$ in equation (4.4), one may compute the table-1 and 2. Corresponding graphs have shown through figure-2 and figure-3, respectively.

6 conclusion

In this study, the author has considered an industrial problem related to vehicle number plate recognition system for evaluation of some important reliability parameters by using algebra of logic and Boolean function technique. Some standby and parallel units are arranged in redundant position to improve systems performance. An imperfect switching device has used to online standby unit on failure of main unit. Reliability of whole system has computed in three different cases. Also, M.T.T.F. of the system, in cases failures follow exponential time distribution, has obtained. A numerical example together with graphical illustration has appended in the end to highlight important results. A critical examination of table-1 and figure-2 reveals that reliability of the system decreases rapidly in case, when failures follow Weibull time distribution, while it decreases smoothly and in better way when failures follow exponential time distribution. Study of table-2 and figure-3 yield that M.T.T.F. of the system decreases catastrophically in the beginning, as we make increases in the value of failure rate, but after that it decreases approximately in a uniform way.

t	$R_{SW}(t)$	$R_{SE}(t)$
0	1	1
1	0.99101	0.99101
2	0.96409	0.98202
3	0.9196	0.97305
4	0.85839	0.96409
5	0.78225	0.95515
6	0.69409	0.94623
7	0.59799	0.93733
8	0.49892	0.92845
9	0.40212	0.9196
10	0.31241	0.91077
11	0.293	0.90169
12	0.2203	0.89277
13	0.14761	0.88384
14	0.07491	0.87491

Table-1

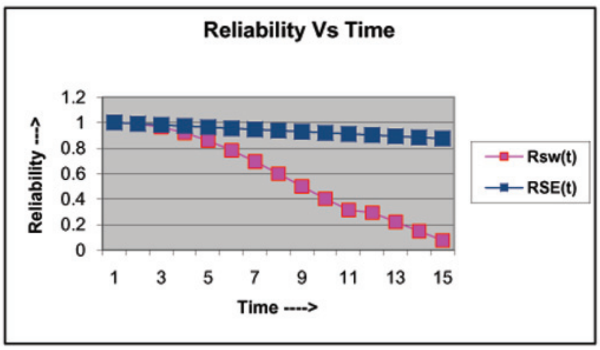

Figure-3

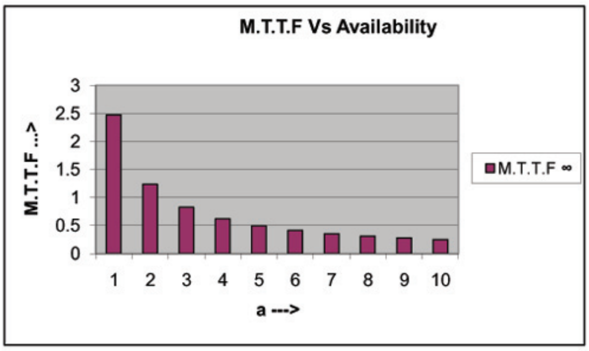

Figure-4

a	M.T.T.F
0	∞
0.1	2.472222
0.2	1.236111
0.3	0.824074
0.4	0.618056
0.5	0.494444
0.6	0.412037
0.7	0.353175
0.8	0.309028
0.9	0.274691
0.10	0.247222

Table-2

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