Cost-Benefit Analysis of Two- Identical Cold Standby Biometric System subject to Failure due to False rejection-Type I error and failure due to False acceptance- Type II error

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Abstract : In this paper we have taken Failure due to False rejection- Type I error and failure due to False acceptance- Type II error. Failure due to False rejection-Type I error then cold standby system becomes operative. Failure due to False acceptance- Type II error cannot occur simultaneously in both the units and after failure the unit undergoes Type-I or Type-II or Type-III repair facility immediately. Applying the regenerative point technique with renewal process theory the various reliability parameters MTSF, Availability, Busy period, Benefit-Function analysis have been evaluated.

Keywords: Cold Standby, Failure due to False rejection-a Type I error, failure due to False acceptance-a Type II error , first come first serve, MTSF, Availability, Busy period, Benefit -Function.

INTRODUCTION

CHARACTERISTICS OF BIOMETRIC SYSTEMS

These are the important factors necessary for any effective biometric system: accuracy, speed and throughput rate, acceptability to users, uniqueness of the biometric organ and action, resistance to counterfeiting, reliability, data storage requirements, enrollment time, intrusiveness of data collection, and subject and system contact requirements.

Accuracy

Accuracy is the most critical characteristic of a biometric identifying verification system. If the system cannot accurately separate authentic persons from impostors, it should not even be termed a biometric identification system.

False Reject Rate

The rate, generally stated as a percentage, at which authentic, enrolled persons are rejected as unidentified or unverified persons by a biometric system is termed the False reject rate. False rejection is sometimes called a Type I error. In access control, if the requirement is to keep the "bad guys" out, False rejection is considered the least important error. However, in other biometric applications, it may be the most important error. When used by a bank or retail store to authenticate customer identity and account balance, False rejection means that the transaction or sale (and associated profit) is lost, and the customer becomes upset. Most bankers and retailers are willing to allow a few False accepts as long as there are no False rejects.

False rejections also have a negative effect on throughput, frustrations, and unimpeded operations, because they cause unnecessary delays in personnel movements. An associated problem that is sometimes incorrectly attributed to False rejection is failure to acquire. Failure to acquire occurs when the biometric sensor is not presented with sufficient usable data to make an authentic or impostor decision. Examples include smudged prints on a fingerprint system, improper hand positioning on a hand geometry system, improper alignment on a retina or iris system, or mumbling on a voice system. Subjects cause failure to acquire problems, either accidentally or on purpose.

False Accept Rate

The rate, generally stated as a percentage, at which unenrolled or impostor persons are accepted as authentic, enrolled persons by a biometric system is termed the False accept rate. False acceptance is sometimes called a Type II error. This is usually considered to be the most important error for a biometric access control system.

Crossover Error Rate (CER)

This is also called the equal error rate and is the point, generally stated as a percentage, at which the False rejection rate and the False acceptance rate are equal. This has become the most important measure of biometric system accuracy.

All biometric systems have sensitivity adjustment capability. If False acceptance is not desired, the system can be set to require (nearly) perfect matches of enrollment data and input data. If tested in this configuration, the system can truthfully be stated to achieve a (near) zero False accept rate. If False rejection is not desired, this system can be readjusted to accept input data that only approximate a match with

enrollment data. If tested in this configuration, the system can be truthfully stated to achieve a (near) zero False rejection rate. However, the reality is that biometric systems can operate on only one sensitivity setting at a time.

The reality is also that when system sensitivity is set to minimize False acceptance, closely matching data will be spurned, and the False rejection rate will go up significantly. Conversely, when system sensitivity is set to minimize False rejects, the False acceptance rate will go up notably. Thus, the published (i.e., truthful) data tell only part of the story. Actual system accuracy in field operations may even be less than acceptable. This is the situation that created the need for a single measure of biometric system accuracy.

The crossover error rate (CER) provides a single measurement that is fair and impartial in comparing the performance of the various systems. In general, the sensitivity setting that produces the equal error will be close to the setting that will be optimal for field operation of the system. A biometric system that delivers a CER of 2% will be more accurate than a system with a CER of 5%.

Speed and Throughput Rate

The speed and throughput rate are the most important biometric system characteristics. Speed is often related to the data processing capability of the system and is stated as how fast the accept or reject decision is annunciated. In actuality, it relates to the entire authentication procedure: stepping up to the system; inputting the card or PIN (if a verification system); input of the physical data by inserting a hand or finger, aligning an eye, speaking access words, or signing a name; processing and matching of data files; annunciation of the accept or reject decision; and, if a portal system, movement through and closing the door.

Generally accepted standards include a system speed of 5 seconds from startup through decision annunciation. Another standard is a portal throughput rate of 6 to 10/minute, which equates to 6 to 10 seconds/person through the door. Only in recent years have biometric systems become capable of meeting these speed standards, and, even today, some marketed systems do not maintain this rapidity. Slow speed and the resultant waiting lines and movement delays have frequently caused the removal of biometric systems and even the failure of biometric companies.

Acceptability to Users

System acceptability to the people who must use it has been a little noticed but increasingly important factor in biometric identification operations. Initially, when there were few systems, most were of high security and the few users had a high incentive to use the systems; user acceptance was of little interest. In addition, little user threat was seen in fingerprint and hand systems.

Biometric system acceptance occurs when those who must use the system — organizational managers and any union present — all agree that there are assets that need protection, the biometric system effectively controls access to these assets, system usage is not hazardous to the health of the users, system usage does not inordinately impede personnel movement and cause production delays, and the system does not enable management to collect personal or health information about the users. Any of the parties can effect system success or removal. Uncooperative users will overtly or covertly compromise, damage, or sabotage system equipment. The cost of union inclusion of the biometric system in their contracts may become too costly. Moreover, management has the final decision on whether the biometric system benefits outweigh its liabilities.

In this paper we have taken failure due to False rejection - a Type I error and failure due to False acceptance-a Type II error. When the main operative unit fails then cold standby system becomes operative. Failure due to False acceptance-a Type II error cannot occur simultaneously in both the units and after failure the unit undergoes repair facility of Type- II by ordinary repairman or Type III by multispecialty repairman in case of failure due to False rejection - a Type I error immediately. The repair is done on the basis of first fail first repaired.

Assumptions

1. λ_1, λ_2 are constant failure rates for failure due to False rejection - a Type I error and failure due to False acceptance-a Type II error respectively. The CDF of repair time distribution of Type I, Type II and multispecialty repairmen Type-III are $G_1(t)$, $G_2(t)$ and $G_3(t)$.
2. The failure due to False acceptance-a Type II error is non-instantaneous and it cannot come simultaneously in both the units.
3. The repair starts immediately after failure due to False rejection - a Type I error and failure due to False acceptance-a Type II error and works on the principle of first fail first repaired basis.
4. The repair facility does no damage to the units and after repair units are as good as new.
5. The switches are perfect and instantaneous.
6. All random variables are mutually independent.
7. When both the units fail, we give priority to operative unit for repair.
8. Repairs are perfect and failure of a unit is detected immediately and perfectly.
9. The system is down when both the units are non-operative.

Notations

λ_1 , λ_2 - failure rates for failure due to False rejection - a Type I error , failure due to False acceptance-a Type II error respectively.

$G_1(t)$, $G_2(t)$, $G_3(t)$ – repair time distribution Type –I, Type-II, Type III due to False rejection - a Type I error , failure due to False acceptance-a Type II error, repair by the multispecialty repairman respectively.

p, q - probability of failure due to False rejection - a Type I error and failure due to False acceptance-a Type II error respectively such that p+ q=1

$M_i(t)$ System having started from state i is up at time t without visiting any other regenerative state

$A_i(t)$ state is up state at instant t

R_i (t) System having started from state i is busy for repair at time t without visiting any other regenerative state.

$B_i(t)$ the server is busy for repair at time t.

$H_i(t)$ Expected number of visits by the server for repairing given that the system initially starts from regenerative state i

Symbols for states of the System

Superscripts O, CS, FRTIF, FATIIF,

Operative, Cold Standby, failure due to False rejection - a Type I error, failure due to False acceptance-a Type II error respectively

Subscripts nfrtif, frtif, fatiif, ur, wr, uR

No failure due to False rejection - a Type I error , failure due to False rejection - a Type I error , failure due to False acceptance-a Type II error **,** under repair, waiting for repair, under repair continued from previous state respectively

Up states – 0, 1, 2, 3, 8,9 ; Down states – 4, 5, 6, 7

regeneration point – 0,1,2, 3, 8, 9

States of the System

0(O_{nfrtif}, CS_{nfrtif})

One unit is operative and the other unit is cold standby and there is no failure due to False rejection - a Type I error in both the units.

1($FRTIF_{frtif, urI}$, O_{nfrtif})

The operating unit fails due to failure due to False rejection - a Type I error and is under repair immediately of Type- I and standby unit starts operating with no failure due to False rejection - a Type I error.

2($FATIIF_{fatiif, urII}$, O_{nfrtif})

The operative unit fails due to Wrong assessment causes vehicle to crash into the Bay of Bengal and undergoes repair of type II and the standby unit becomes operative with no failure due to False rejection - a Type I error.

3($FATIIF_{fatiif, urIII}$, O_{nfrtif})

The first unit fails due to Wrong assessment causes vehicle to crash into the Bay of Bengal and under Type-III multispecialty repairman and the other unit is operative with no failure due to False rejection - a Type I error.

4($FRTIF_{frtif,uR1}$, $FRTIF_{frtif,wrI}$)

The unit failed due to FRTIF resulting from Failure due to False rejection - a Type I error is under repair of Type- I continued from state 1and the other unit failed due to FRTIF resulting from Failure due to False rejection - a Type I error is waiting for repair of Type-I.

5($FRTIF_{frtif,uR1}$, $FATIIF_{fatiif, wrII}$)

The unit failed due to FRTIF resulting from Failure due to False rejection - a Type I error is under repair of Type- I continued from state 1and the other unit fails also due to Failure due to False acceptance-a Type II error is waiting for repair of Type- II.

6($FATIIF_{fatiif, uRII}$, $FRTIF_{frtif ,wrI}$)

The operative unit fails due to Failure due to False acceptance-a Type II error and under repair continues from state 2 of Type –II and the other unit is failed due to FRTIF resulting from Failure due to False rejection - a Type I error and waiting for repair of Type-I

7($FATIIF_{fatiif ,uRII}$, $FRTIF_{frtif,wrII}$)

The one unit fails due to Failure due to False acceptance-a Type II error is continued to be under repair of Type II and the other unit failed due to FRTIF resulting from Failure due to False rejection - a Type I error is waiting for repair of Type-II

8($FRTIF_{frtif,urIII}$, $FATIIF_{fatiif, wrII}$)

The one unit fails due to Faulty valve is under multispecialty repair of Type-III and the other unit is failed due to Wrong assessment causes vehicle to crash into the Bay of Bengal is waiting for repair of Type-II.

9($FRTIF_{frtif,urIII}$, $FATIIF_{fatiif, wrI}$)

The one unit fails due to Faulty valve is under multispecialty repair of Type-III and the other unit is failed due to Wrong assessment causes vehicle to crash into the Bay of Bengal is waiting for repair of Type-I

Transition Probabilities

Simple probabilistic considerations yield the following expressions:

$p_{01} = \lambda_1/\lambda_1+\lambda_2$, $p_{02} = \lambda_2/\lambda_1+\lambda_2$, $p_{10} = pG_1^*(\lambda_1)+q\,G_2^*(\lambda_2)$,

$p_{14} = p - pG_1^*(\lambda_1) = p_{11}^{(4)}$,

$p_{15} = q - q\,G_1^*(\lambda_2) = p_{12}^{(5)}$,

$p_{23} = pG_2^*(\lambda_1)+q\,G_2^*(\lambda_2)$,

$p_{26} = p - pG_2^*(\lambda_1) = p_{29}^{(6)}$,

$p_{27} = q - qG_2^*(\lambda_2) = p_{28}^{(7)}$,

$p_{30} = p_{82} = p_{91} = 1$ (1)

We can easily verify that

$p_{01} + p_{02} = 1$,

$p_{10} + p_{14} (=p_{11}^{(4)}) + p_{15} (=p_{12}^{(5)}) = 1$,

$p_{23} + p_{26} (=p_{29}^{(6)}) + p_{27} (=p_{28}^{(7)}) = 1$ (2)

And mean sojourn time is

$\mu_0 = E(T) = \int_0^\infty P[T > t]dt$

Mean Time To System Failure

$\emptyset_0(t) = Q_{01}(t)[s]\, \emptyset_1(t) + Q_{02}(t)[s]\, \emptyset_2(t)$

$\emptyset_1(t) = Q_{10}(t)[s]\, \emptyset_0(t) + Q_{14}(t) + Q_{15}(t)$

$\emptyset_2(t) = Q_{23}(t)[s]\, \emptyset_3(t) + Q_{26}(t) + Q_{27}(t)$

$\emptyset_3(t) = Q_{30}(t)[s]\, \emptyset_0(t)$ (3-6)

We can regard the failed state as absorbing

Taking Laplace-Stiljes transform of eq. (3-6) and solving for

$\emptyset_0^*(s) = N_1(s) / D_1(s)$ (6)

where

$N_1(s) = Q_{01}^*[Q_{14}^*(s) + Q_{15}^*(s)] + Q_{02}^*[Q_{26}^*(s) + Q_{27}^*(s)]$

$D_1(s) = 1 - Q_{01}^* Q_{10}^* - Q_{02}^* Q_{23}^* Q_{30}^*$

Making use of relations (1) & (2) it can be shown that $\emptyset_0^*(0) = 1$, which implies that $\emptyset_0(t)$ is a proper distribution.

$$MTSF = E[T] = \left. \frac{d}{ds} \emptyset_0^*(s) \right|_{s=0}$$

$= (D_1'(0) - N_1'(0)) / D_1(0)$

$= (\mu_0 + p_{01}\mu_1 + p_{02}\mu_2) / (1 - p_{01}p_{10} - p_{02}p_{23})$

where

$\mu_0 = \mu_{01} + \mu_{02}$,

$\mu_1 = \mu_{10} + \mu_{11}^{(4)} + \mu_{12}^{(5)}$,

$\mu_2 = \mu_{23} + \mu_{28}^{(7)} + \mu_{29}^{(6)}$

Availability analysis

Let $M_i(t)$ be the probability of the system having started from state i is up at time t without making any other regenerative state. By probabilistic arguments, we have

$M_0(t) = e^{-\lambda_1 t} e^{-\lambda_2 t}$,

$M_1(t) = p\, \breve{G}_1(t)\, e^{-\lambda_1 t}$

$M_2(t) = q\, G_2(t)$, $M_3(t) = G_3(t)$

The point wise availability $A_i(t)$ have the following recursive relations

$A_0(t) = M_0(t) + q_{01}(t)[c]A_1(t) + q_{02}(t)[c]A_2(t)$

$A_1(t) = M_1(t) + q_{10}(t)[c]A_0(t) + q_{12}^{(5)}(t)[c]A_2(t) + q_{11}^{(4)}(t)[c]A_1(t)$,

$A_2(t) = M_2(t) + q_{23}(t)[c]A_3(t) + q_{28}^{(7)}(t)[c]\, A_8(t) + q_{29}^{(6)}(t)][c]A_9(t)$

$A_3(t) = M_3(t) + q_{30}(t)[c]A_0(t)$

$A_8(t) = q_{82}(t)[c]A_2(t)$

$A_9(t) = q_{91}(t)[c]A_1(t)$ (7-11)

Taking Laplace Transform of eq. (7-11) and solving for $\hat{A}_0(s)$

$\hat{A}_0(s) = N_2(s) / D_2(s)$ (12)

where

$N_2(s) = \tilde{M}_0[\{1 - \hat{q}_{11}^{(4)}\}\{1 - \hat{q}_{28}^{(7}\hat{q}_{82}\} - \hat{q}_{12}^{(5)}\hat{q}_{29}^{(6)}\hat{q}_{91}] + \hat{q}_{01}[\tilde{M}_1\{1 - \hat{q}_{28}^{(7)}\hat{q}_{82}\} + \hat{q}_{12}^{(5)}\hat{q}_{23}\tilde{M}_3] + \hat{q}_{02}[\{\hat{q}_{23}\tilde{M}_3 + \tilde{M}_2\}\{1 - \hat{q}_{11}^{(4)}\} + \hat{q}_{29}^{(6)})\hat{q}_{91}\tilde{M}_1]$

$D_2(s) = \{1 - \hat{q}_{11}^{(4)}\}\{1 - \hat{q}_{28}^{(7}\hat{q}_{82}\} - \hat{q}_{12}^{(5)}\hat{q}_{29}^{(6)}\hat{q}_{91} - \hat{q}_{01}[\hat{q}_{10}\{1 - \hat{q}_{28}^{(7)}\hat{q}_{82}\} + \hat{q}_{12}^{(5)}\hat{q}_{23}] - \hat{q}_{02}[\{\hat{q}_{23}\hat{q}_{30}\{1 - \hat{q}_{11}^{(4)}\} + \hat{q}_{29}^{(6)}\hat{q}_{91}\hat{q}_{10}]$

(Omitting the arguments s for brevity)

The steady state availability

$A_0 = \lim_{t\to\infty}[A_0(t)]$

$= \lim_{s\to 0}[s\,\hat{A}_0(s)] = \lim_{s\to 0} \frac{s\,N_2(s)}{D_2(s)}$

Using L' Hospitals rule, we get

$A_0 = \lim_{s\to 0} \frac{N_2(s) + s\,N_2'(s)}{D_2'(s)} = \frac{N_2(0)}{D_2'(0)}$ (13)

The expected up time of the system in (0,t] is

$\lambda_u(t) = \int_0^\infty A_0(z)dz$

So that $\bar{\lambda}_u(s) = \frac{\hat{A}_0(s)}{s} = \frac{N_2(S)}{SD_2(S)}$ (14)

The expected down time of the system in (0,t] is

$\lambda_d(t) = t - \lambda_u(t)$

So that $\bar{\lambda}_d(s) = \frac{1}{s^2} - \bar{\lambda}_u(s)$ (15)

Similarly, we can find out

1. The expected busy period of the server when there is failure due to False acceptance-a Type II error and failure due to False rejection - a Type I error in (0, t] - R_0

2. The expected number of visits by the repairman Type-I or Type-II for repairing the identical units in (0,t]- H_0

3. The expected number of visits by the multispecialty repairman Type-III for repairing the identical units in (0, t]- W_0

Benefit- Function Analysis

The Benefit-Function analysis of the system considering mean up-time, expected busy period of the system under failure due to Failure due to False acceptance-a Type II error and failure due to False rejection - a Type I error , expected number of visits by the repairman for unit failure.

The expected total cost per unit time in steady state is

$$C = \lim_{t\to\infty}(C(t)/t) \quad = \lim_{s\to 0}(s^2 C(s))$$

$$= K_1A_0 - K_2R_0 - K_3H_0 - K_4W_0$$

where

K_1 - revenue per unit up-time,

K_2 - cost per unit time for which the system is busy under repairing,

K_3 - cost per visit by the repairman type- I or type- II for units repair,

K_4 - cost per visit by the multispecialty repairman Type- III for units repair

CONCLUSION

After studying the system, we have analyzed graphically that when the failure rate failure due to False acceptance-a Type II error and failure due to False rejection - a Type I error increases, the MTSF, steady state availability decreases and the Profit-function decreased as the failure increases.

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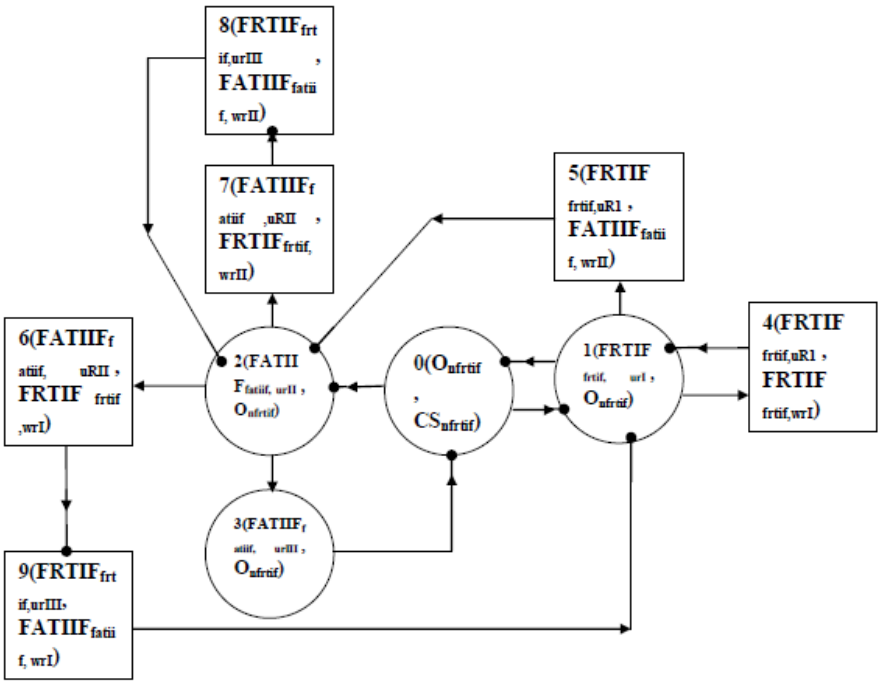


Fig. The State transition Diagram

Up-State Down-State

regeneration point