Failure Risk Exposure based Test Prioritization for Sequential Non-iterative System

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ABSTRACT
To test a system a large number of test cases are required to be generated and applied to the candidate system. In most of the methodologies the testing phase is placed at the end of development life cycle. The time constraint is more in this phase as compared to any other. Hence testing objective is to gain confidence in the product by verifying its reliability. For a reliable system, testing has to be performed more extensively on specific part(s) of the system, which is expected to be used more. In this paper, two additional parameters i.e. risk probability and associated impact expected in each subsystem is considered along with usages pattern. The test case priority is calculated on the basis of effective risk exposure of the even sequence.

Keywords: Usage Pattern, Finite State Machine, Failure State, Risk Impact, Risk Exposure, Reliability.

1. INTRODUCTION
Every system is consisting of various kinds of system elements such as hardware, software. As correctness of a system cannot be proved, efforts are made towards reliability. Same principle applies to component (hardware/software) or subsystem. Effective reliability of a system depends on various parameters, such as reliability of subsystems, interconnections among them. In a system various hardware subsystems interact to transfer control/energy and software elements to communicate dependent information or control signal. Somehow the overall system can be evaluated using its elements and their interconnections. In this work includes additional parameters such as usage pattern, risk and loss due to risk. Usage patterns, depicts how frequently specific part of the systems are used [2].
In this work the system is modeled as finite state machine (FSM). Subsystems are represented by states and transitions among them represent control/information transfer. Usage of a transition path and reliability parameters are included as weight-age of transition. Success and failure states are used as an especial state. Markov chain is used to represent usage and reliability as probability parameter. The success/failures proportionally increase with increase in usage.

2. FINITE STATE MACHINE AND MARKOV CHAIN
Model is an abstract representation of a system. Models are constructed to describe functionality of the system to predict their behavior in various situations. They are simpler than the system they represent. Finite state machine is a commonly used to model various states of a system along with transitions from these state.

Using Markov Chain, state diagram can be represented with probability parameters included as chances of transition among states [1]. A system is described as a tuple < S, P > where S is of set of states, i.e. $S = \{S_1; S_2; : : : ; S_r\}$, and P is set of transition probabilities $P = \{P_{11}, P_{12}, P_{13}, \ldots\}$. Among these states, one is designated as starting state, and according to output of current state, system transits to next state. This process is continued successively from one state to another until it reaches to final state. Each move is called a step. If the chain is currently in state S_i and it moves to state S_j at the next step with a transit probability P_{ij}. This probability does not depend upon previous state visited. If a process remains in the same state, then it occurs with probability P_{ii}. The Markov model is represented as a matrix P, where an element P_{ij} at i^{th} row and j^{th} column denotes probability of transition from state S_i to state S_j. By multiplying the matrix P with itself, transitive sequences can be computed. For example following expression represents the probability of transition from S_1 to S_3 using two events.

$$P_{13}^{(2)} = P_{11}P_{13} + P_{12}P_{23} + P_{13}P_{33} \text{ ---------- } (1)$$

The expression denotes that probability transition from State S_1 to S_3 using exactly two transitions is 'Probability of transition from S_1 to S_1 AND transition from S_1 to S_3 OR Probability of transition from S_1 to S_2 AND transition from S_2 to S_3 OR Probability of transition from S_1 to S_3 AND transition from S_3 to S_3.

Assume that ***'r'*** is number of states in a Markov Chain; following expression represents effective probability of transition from S_i to S_j using exactly two transitions [4]

$$P_{ij}^{(2)} = \sum_{k=1}^{r} P_{ik}P_{kj} \text{ ------------------ } (2)$$

Let ***'u'*** be the probability vector which represents the starting distribution. Then the probability that the chain is in state S_i after ***'n'*** transitions is the i^{th} entry in the vector.

$$u^{(n)} = uP^n \text{ ----------------- } (3)$$

For example u = [1 0 0 0] denotes S_1 is the initial stage of state machine.

3. RELIABILITY AND RISK
Reliability is a statistical measure of the system to represent success rate, for a given period of observation. Depending on this metric a system's success is predicted. However risk is probability of occurrence of an event, which may adversely affect the system. It is usually denoted as negative requirements i.e. situations described with note ***must not happen***. The parameter, risk exposure is product of risk probability and loss

due to that risk. Failure of the system is a type of risk and loss due to failure may vary depending on the cause of failure, i.e. the state in which actually failure occurs.

4. INTEGRATING RISK IN SYSTEM MODEL

The proposed model is represented using Finite State Machine (FSM) model implemented using Markov Chain. The states represent various subsystems (hardware/software components) of the system and transition represent weight included usage and risk/reliability and impact to compute effective risk exposure, which is further used in deciding the priority of the test sequence. In the proposed model two new states are added: (1) ***Failure*** (2) ***Successful Completion***. From every subsystem a transition edge weighted equal to risk of failure of that element is introduced, another weight assigned is loss due to failure. To prioritize the test case, the overall risk exposure is computed, and the decision about which subsystems need to be checked, shall depend on the desired degree of reliability [3].

A system model is composed of many elements represented by states. Each component may have different reliability. Failure Risk of a component shall be combined with probability of usage [5]. For example if ***F*** is failure risk and ***U*** is degree of usage, then effective failure risk shall be ***F*U***. Fig-1 illustrates combined effort of usage profile and reliability.

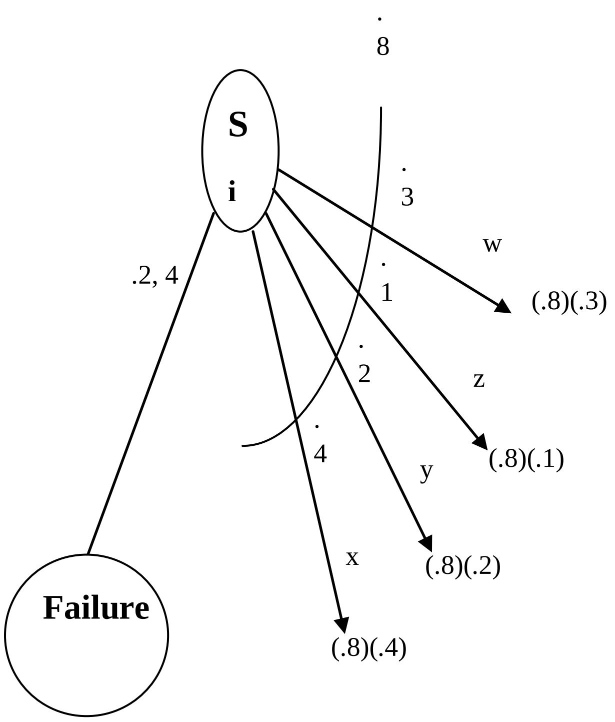

Fig 1: Combining Reliability with Usage

Consider fig-1 refers to a state representing, system component with 80% reliability. Four transitions are possible, while operating successfully. Their usage distribution is 30%, 10%, 20% and 40% respectively. One transition towards ***failure*** state occurs when it is failed, the impact of failure of the component is measured as 4 unit (on the scale of 1 to 10). The weight of transition is calculated on the basis of effective probability of that transaction to happen. Effective probabilities of successful transitions are probability of success and probability of usage i.e. (0.80)*(0.3), (0.80)*(0.1), (0.80)*(.2) and (0.80)*(0.40) respectively.

Similarity weight of transition toward failure is probability of failure, usage and failure impact i.e. 0.20,1 and 4 i.e. (0.20)*(1)*(4), since failure transition is only one, the only choice to transit while failure.

4.1 Example:

For a given system, model shown in fig 2, is represented in Markov chain. Here transition probability is taken from operational profile based on usages of the system.
Failure Risk Exposure due to various components is calculated as below:

Risk Exposure due to failure of S_i = Effective Failure Risk of S_i * Loss Due to S_i failure.

Risk Exposure due to S_2 = (Effective Risk of Failure S_2) *Loss due to Failure of S_2

=(Reliability of S_1 and Failure Risk of S_2)*Loss Due to Failure of S_2

=(Reliability of S_1 * Failure Risk of S_2)*Loss Due to Failure of S_2.

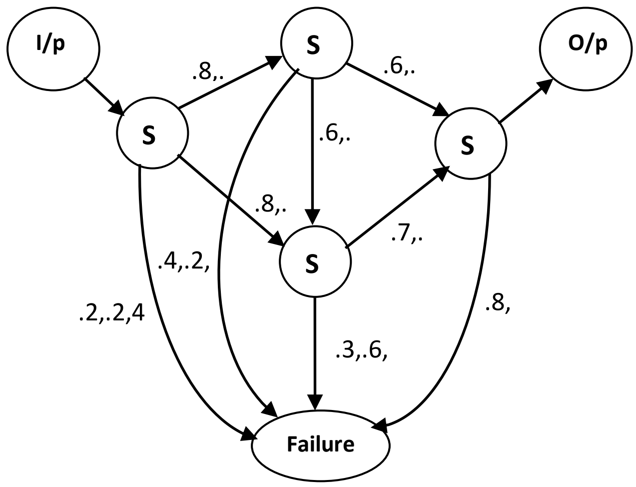

Fig 2: An Example of System Model

For example given in fig-2, failure risk exposure (FRE) of various components are

FRE for S_1 = (0.2)(0.2)(4)=0.16

FRE for S_2 = (0.8)(0.3)(0.4)(0.2)(3)=0.0576

FRE for S_3 = (0.8) (0.5) (0.3) (0.6) (5) + (0.8) (0.3) (0.6) (0.5) (0.3) (0.6) (5) = 0.4248

FRE for S_4

=(0.8)(0.3)(0.6)(0.3)(0.8)(7) + (0.8)(0.5)(0.7)(0.4)(0.8)(7)
+ (0.8)(0.3)(0.6)(0.5)(0.7)(0.4)(0.8)(7)
=0.982016

The criticality of subsystem is in following order

$\mathbf{S_4 > S_3 > S_1 > S_2}$

By normalizing failure risk exposure, contribution of individual component is measured

(60%)>(26%)>(10%)>(4%)

This calculation helps in deciding the effort distribution for testing. Above results depict that improvement in the quality of subsystem S_4 and S_3 contributes 86% in overall quality improvement of the system.

5. CONCLUSION

The proposed work is a fundamental contribution towards prioritization of subsystems for testing to meet the specific requirement of desired reliability goals. The suggested model helps in calculating effective risk exposure due to various subsystems. The results obtained by this method consider impact and usage along with probability of failure for individual component. These results help in deciding the order of testing and number of subsystems to be tested to achieve desired level of reliability.

6. REFERENCE

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