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ANALYSIS OF ROBOT FAILURE AND COMPUTATION OF MTTF USING MARKOV MODEL

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ABSTRACT

The developing applications of robots in some of the industries, nature of their activities will make different challenges in safety. A robot must be safe and reliable, it does not cause to unsafe situations and high maintenance expenses. In this paper, we analyzed failure rate and computation of Mean Time to Failure(MTTF) using Markov Model. MTTF is required to know the lifetime of the robot at subsystems level. Markov Model is a popular Mathematical model used for computation, using Markov Model MTTF of a robot is estimated. To develop the Model faults of the subsystems are identified. The result shows the computation of MTTF of the robot under various real time robot functionalities.

Keyword: *Failure Rate, Markov Model, Mean Time to Failure, Robot, States.*

I. INTRODUCTION

Robots are mostly used in the manufacturing industry. Industrial robots are automated, programmable and capable of movement on two or more axes. These robots have been used to perform a variety of missions, including welding, Painting, material handling and drilling. Using robot takes account of the development of all industries.

production in the administrative cost, saving space in industrial ones, reduction in the investment costs, increase in the production rate and reduction in the demand for workers and difficulty of hiring workers. Over the years many techniques have been developed for implementation of different types of safety analysis and some of them can be used in conducting safety analysis of industrial robots.

In most cases, when robots failed, the failure is due to subsystem failure. In some cases, the subsystem can be replaced. The subsystem in the robot system is inter-connected and it is connected in series. The main issue of the subsystem subsystems is no specified established which assist minimize the robots ownership [1].

This study contains the study of robot failures data and computation of MTTF of a robot using Markov model. Probability theory, a Markov model is a stochastic model used to model randomly changing systems. Markov model is a Mathematical model. They are used to model systems that have a limited memory of their past. In a markov process, if the present state of the process is given, the future state is independent of the past. This modeling technique is very helpful in most of the situations [8].

The Mean Time to Failure is the length of the time a device or a other product is expected last in operation MTTF is often collected by running many units, even many thousands of units, for a specific number of hours. This is a good measure for estimating the average useful working time before the error. The scope of the study is to analyze the failures data and MTTF.

1.1. Basis of the model

As in Figure-1, the robot system consist of five major subsystems which are interconnected with each other, namely the controller, robot arms, end effectors, drive mechanism and sensors[1]. The component failure could then result to robot failures; hence, it is essential to ensure the subsystems of the robot system are in good condition.

The controller is the brain of the robot system. The hardware side of controller is repairable and if it related with software such as microprocessor it is then non-repairable [4].

The robot arm function as manipulator mechanism. This mechanism provides the lifting power of the robot arm function, component is repairable the end effectors provides to serve either handle a part with loading and unloading capability. The component is repairable. the drive mechanism in which is used to drive the robot for function. The component is repairable. The sensors component is a non repairable [4]. Due to many repairable and non-repairable subsystems which are inter-connected in the robotics system. It is vital to analyze the failure rate and Mean Time to Failure (MTTF)

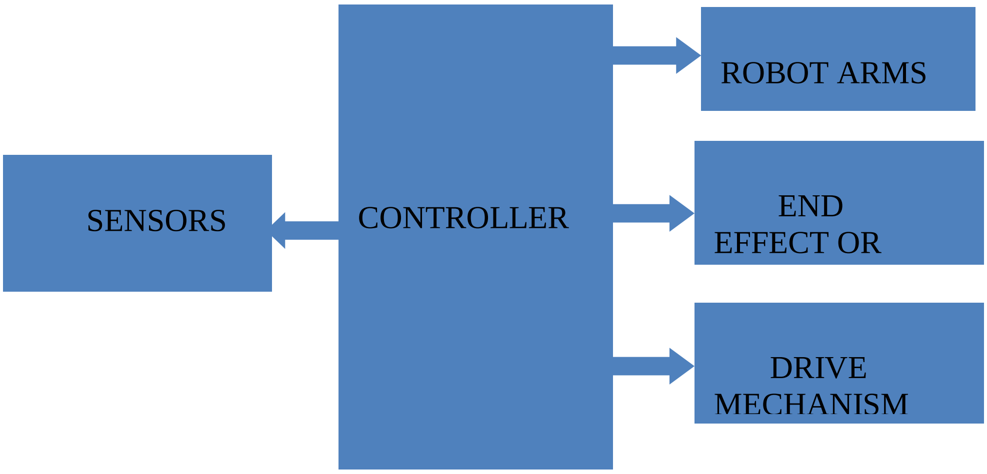

Fig.1 Block diagram of a robot

II. METHODOLOGY

The methodology framework consists of two main steps as per Figure. 2:

Step 1: is the process of identifying and classifying of robot subsystems into repairable and non-repairable

Step 2: is the process to study the MTTF of a robot system that gives the higher probability of failure.

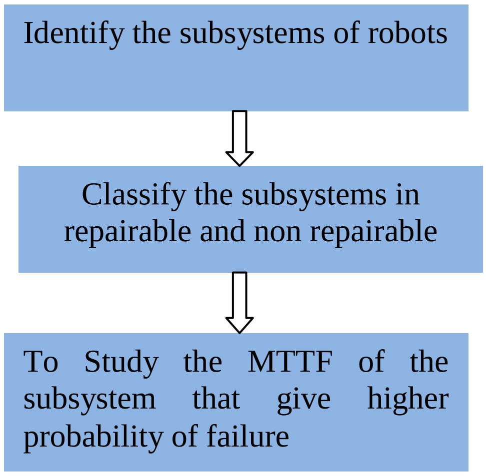

Fig. 2. Research methodology framework

TABLE-1 Probability of failure of subsystems

Subsystems	**Elements**	**Failure rate**
Controller	NR	3
Robot arm	NR	2.5
End effectors	R	1.5
Sensors	NR	1
Drive mechanism	NR	3.5

III. PROPOSED MODEL

The analytical model for the proposed by considering the previous table. The Markov model for MTTF of a Robot system is shown in figure. 3

- S1 = Initial state of the Robot system, with good hardware and software resources
- S2= State of the Robot system, with repairable subsystems such as end effector, driver.
- S3= State of the robot system not functioning (failed state) because of failure of subsystems which is non-repairable subsystems such as robot arms, hose thinner controller, encoder, sensors.
- $2\lambda c$ = Transition rate from S_1 to S_2, indicates the detection of good system to repair system with probability of ‘c’ represents the coverage factor.
- λ = failure rate at which robot move from S2 to S3
- 2λ (1-c) = Transition rate from S1 to S3 with probability of (1-c) represents the coverage factor
- μ = Transition rate from S2 to S1, indicates the repairable state which will come back to initial state

- E[x] = Expected value
- MTTF = Mean Time To Failure of a robot system.

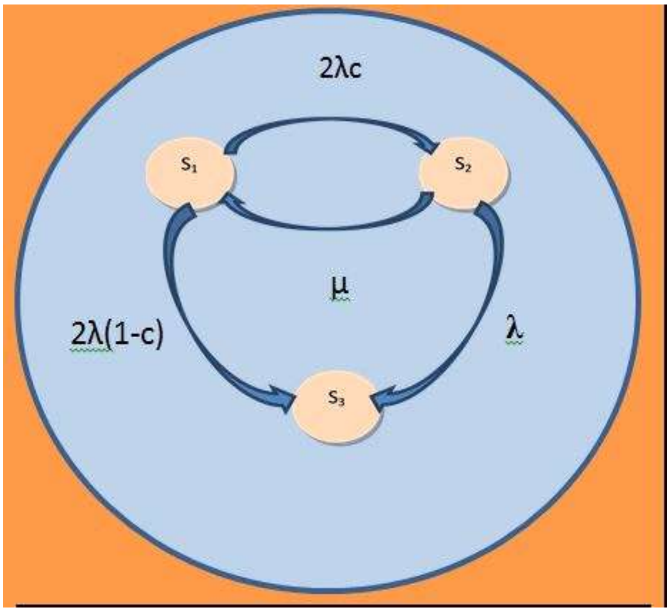

Fig. 3 Markov model of Robot

The Mean Time to Failure (MTTF) of a Robot system which depends on subsystems of the Robot system is computed in this section.

Consider Markov model shown in fig. 3

Assume that the initial state of a Robot system is in state S1.

Hence $\pi_1(0) = 1$,

$\pi_2(0) = \pi_3(0) = 0$.

The system of differential equations becomes

$$\frac{\partial \pi 1(t)}{\partial t} = -\lambda c \pi_1(t) - 2\lambda(1-c)\pi_1(t) + \mu \pi_2(t) \quad (1)$$

$$\frac{\partial \pi 2(t)}{\partial t} = -(\lambda+\mu)\pi_2(t) + 2\lambda c \pi_1(t) \quad (2)$$

$$\frac{\partial \pi 3(t)}{\partial t} = \lambda \pi_1(t) + 2\lambda(1-c)\pi_1(t) \quad (3)$$

Using Laplace transform, we can reduce this system of equations to

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$s\pi_1(s) - 1 = -2\lambda 1\pi_1(s) + \mu\pi_3(s)$ (4)

$s\pi_2(s) = -(\lambda + \mu)\pi_2(s) + 2\lambda c\pi_1(s)$ (5)

$s\pi_3(s) = \lambda\pi_2(s) + 2\lambda(1\text{-}c)\ \pi_1(s)$ (6)

Expected value E[x] using moment generating property of Laplace transform.

$$E[x] = \frac{\lambda(1+2c)+\mu}{2\lambda[\lambda+\mu(1-c)]} \quad (7)$$

IV. SIMULATION AND RESULT

The above graph shows that MTTF for different values of a failure rate at which state of a robot changes from working state to repair state or failure state. When the failure rate increases, the MTTF value is decreasing. The result also shows that probability 'C' that as the probability of the robot moving from working state to repair state increases, (1-C) probability of robot moving from working state decreases, hence MTTF increases.

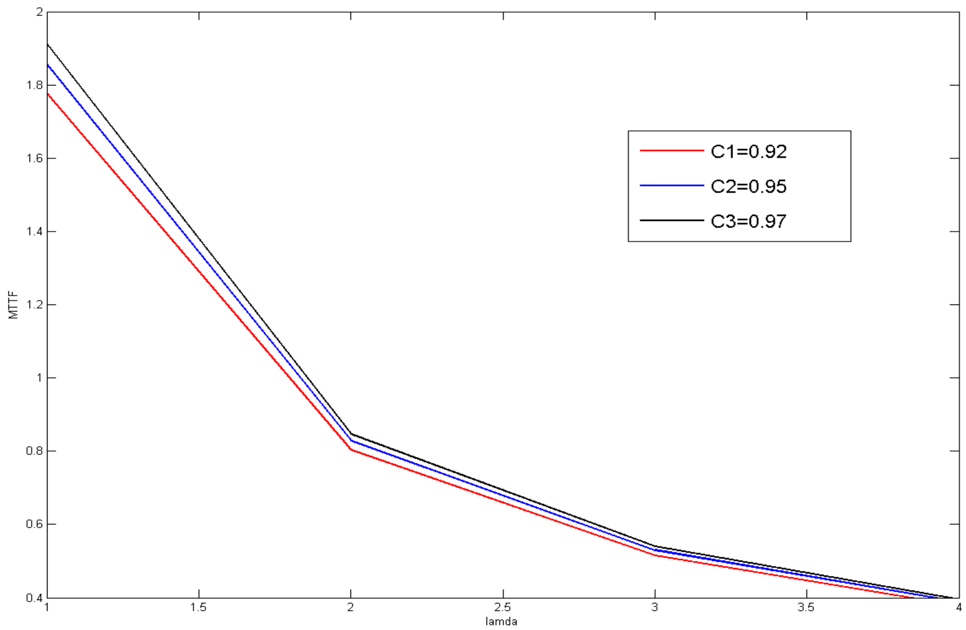

Fig 4 Variation MTTF value with failure rate

V. CONCLUSION

In this paper, robot failures and computation of MTTF using markov model is anlysed. Mean Time To Failure (MTTF) of robot is computed using an Mathematical model. The model is useful for the robot in the industry. The results are essential for the estimation of the MTTF in a robot, when it is used in critical applications. The work carried out plays important role in the design and analysis of robot building used for societal benefits.

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