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Performance Evaluation of Aristo-XT Robot

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Abstract

Today's, robots are being applied in numerous works, which are earlier being performed by humans and hence performance capability of the robot needs to be evaluated. Additionally; the industrial robot concept is gaining a grudging acceptance. Moreover; if the workplace is rationalized, the robot performance requirement is more important and need to be evaluated. Accordingly, experiments and studies were done and correspondingly, in this paper an approach to evaluated new methodologies for assessing the performance of different robots is presented. In this work mathematical model is generated for predetermining the operation time and to evaluate the performance of the robot. In this work, a graphical representation of the relationship between speed and time and the distance and time is shown. Furthermore, a generalized formula of operation time is derived for the movement of the parts of robot. In this study, performance evaluation of the Aristo-XT Robot has been done by considering work analysis as the factor of evaluation.

Keywords: Time- Study; Aristo-XT Robot, RTM.

Introduction

Industries have had a great emphasis on developing the better method of performing the work task. However lot of resistance is usually being offered in introducing new methods. Therefore it is not an economic and feasible proposition that each time an efficient method be discovered and introduced. It would be impractical that every new method could be introduced without assessing its perfection and economic feasibility. Further, manufacturing time is one of the major drivers of evaluation of performance as well as cost of manufacturing and assembly. During the initial stage of planning a manufacturing or assembly system, a quick and reliable method of estimating the time required to complete a given task is mandatory. Literature survey has indicated that an everlasting problem in industries is to enhance productivity and to produce the parts at reduced cost and simultaneously make people safe, healthy, comfortable and efficient at the work place [1]. A number ofmechanized and automated devices were developed for this purpose. However abreakthrough came in this direction with the advent of industrial robot which is programmable, multi-functional manipulator designed to move materials, parts, toolsor specialized devices through variable programmed motions for the performance of avariety of tasks. The use of industrial robots is becoming more widespread. As robotsare being applied in the works which are earlier being performed by humans, performance capability of the robot needs to be evaluated. Numerous techniques have been proposed for evaluation of performance of some of the standard robots.

Review of Literature

In 1979, R.L Paul and Shimon Nof [18] developed a technique for performance evaluation of robot was developed named as Robot Time and Motion (RTM). In this paper, the basic capabilities of robots, their sensors were examined, and the appropriate level of error recovery in order to compare and contrast human and robot task performance. Based on the capabilities of robots an outline was made for a level of task primitives, programming detail, and task performance techniques suitable for robots. In1980, Shimon Y Nof [20], presented a general ergonomics procedure for optimizing industrial robot work, and entailed the analysis and evaluation of whether a human or arobot should be employed for the job. In 1983, H Lechtman et al. [8] together proposed models to estimate performance time of operations in the context ofRTM. In this work, certain capabilities of RTM were reviewed, and a simplified version for point operators was developed and demonstrated with Unimate 4000B in Spotwelding. Mi-Kyung Kim [16] developed a Robot Performance Evaluation System (RPES) with the laser tracker Leica LTD 500 according to the ISO 9283 robot performance criteria. According to ISO 9283, the developed Robot Performance Evaluation System (RPES) covers the following performance criteria: Position accuracy and repeat accuracy, Position Overshoot and stabilization time, Multi direction position accuracy deflection, Distance accuracy, Distance repeat accuracy and Mini pose time. The first predetermined time system used in the study and evaluation of manual work elements was Motion Time Analysis by A. B. Segur and company in 1924. Many systems followed, including Work Factor in 1938 and Methods Time Measurement (MTM), which was released by the Maynard Engineering Council in 1948. Paul et al. Nof (1979) developed a method called Robot Time and Motion (RTM) [18]. This method was based on the concept of Methods-Time Measurement (MTM). In 1980 method called Job and Skill Analysis was developed by Shimon Y., this methodused left and right hand analysis to arrive at the estimated time.

Methodology

Operation time is one of the major issues for evaluation of performance as well as cost of manufacturing and assembly. During the initial stage of planning a manufacturing or assembly system, a quick and reliable method of estimating the time required to complete a given task is mandatory. Manufacturing / assembly cycle time is the period of active time from starting to finishing an operation and the operator (robot / human) is expected to be able to perform the task within the specified cycle time. Evaluation of operation time in advance of actual production is one of the challenging parts of production of products. Present study is therefore purported to develop a robotic predetermined motion time system (RPMTS) so that time as well as cost of processing can be evaluated in advance. The data so obtained will further be utilized for performance evaluation of robot. The problem with RTM method is that the time data chart is different for every individual robot. In this method the operation is divided into various elements like reach, grasp, move etc., thereby, having a limitation of motion for the robot. For every new operation to be performed an elemental time chart is to be prepared and a standard time for the operation needs to be established. Therefore, to overcome this limitation anew motion time system is developed where the elemental time data is not generated rather the time for the joint movement of the robot is analyzed at different speeds to generate a generalized equation of motion for the different joints. Combined time taken for the joint gives the total time for the operation. Major Limitations of RTM:

1. Speed of the operation cannot be altered. The speed of the joints of therobot needs to be constant for the time measurement.
2. Time for any new operation cannot be pre-determined using RTM. Forany new operation that can be performed by the robot, the operation needs to be divided into elemental time chart and then a standard time is to be established for further performance evaluation.

In this work, Aristo-XT robot is used for the evaluation of time. ARISTO is a 6axis articulated robotic arm of industrial design, for training and research and is manufactured to industrial standards. The robot is capable of lifting up to 3 kg of payload. The robot can be used with pneumatic/electrical grippers. As the major task inthis work, is to generate a mathematical model for predetermining the operation time and to evaluate the performance of the robot. In the case studies surveyed through the previous papers, the parameter of speed was assumed to be constant whereas this is a very unusual assumption. In general, the parameters of a process change. Therefore, we need to develop procedures for estimating the time taken for the operation. In this work, a graphical representation of the relationship between speed and time and the distance and time is shown. Furthermore, a generalized formula of operation time is derived for the movement of the parts of robot.

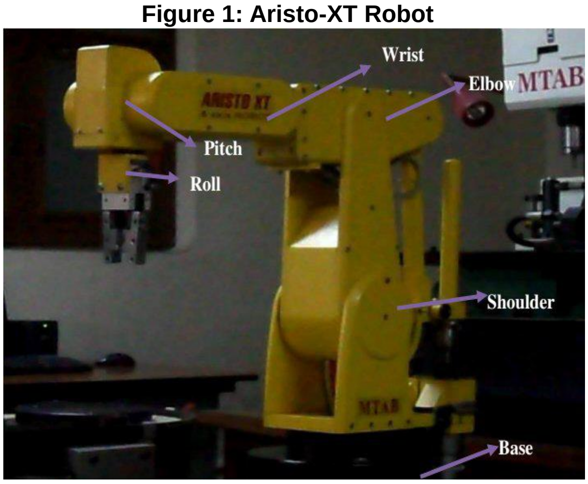
Terminologies Used

T= Total Time for the Operation
Tb= Total Time taken for the base movement
Ts= Total time for the Shoulder movement
Tw= Total time for the Wrist movement
Te= Total time for the Elbow movement
Tp= Total time for the Pitch movement
Tr= Total time for the Roll movement
s= Speed of the Joint
x= Distance moved in deg. (degrees to be calculated from base angle)
a= coefficient of Regression
n= Number of Steps

The branch of Robotics have repeatedly under estimated the complexity of replicating capabilities that humans find particularly easy (Majidi 2013, Yang et al. 2017) and thus solutions pertaining to robotics system are needed to be explore and should also work for long term interactions and relationships (Polygerinos et al. 2017, Kim et al.2013). Robots are programmable-independent movable devices, which are competent in transporting manufacturing and industrial stuffs in a logistic cycle (sahu 2018a). Robot appraisement underneath a variety of dimensions and directions is a decisive matter in real-time manufacturing scenario. The most momentous challenges that is required during robot evaluation is that the building robots can effectually interact socially with people. It is important that modelling pertaining to robotics can entail social dynamics and social learning along with moral ethics (Valero-Cuevas 2017, Ijspeert 2014). There is a need to build and develop advance robotic theory of mind (Bauer et al.2008, Lake et al. 2017). Robots are needed to be deployed in human environments and it is important that they should adapt cultural differences and relationship aspects along with the adaptation of appropriate social and moral norms in their setting (Prorok et al. 2017, Sahu 2018a). Sahu2018a, has proposed a chain of decisive concerns needed to opt for the most reasonable robot under group of criterions, as the aforesaid aspects are constantly considered as a sizzling topic under industrial domain. Performance scores against decisive system is required to be obtained for exploring the significant facts of the system (Sahu 2018b,18c) and thus the performance evaluation of the Aristo-XT Robot has been presented by considering work analysis as the factor of evaluation. The main challenges in todays robotic environment is to provide a logical and inclusive mapping of the key mechanisms of human intelligence under a software system (Ijspeert 2014, Bauer et al.2008). Robots that can model their own components and operations are critical for adaptation and evolution (Yang et al. 2017, Polygerinos et al. 2017). The following highlighted the chief objective of the paper

1. The present study proposed an approach to evaluated new methodologies for assessing the performance of different robots.
2. In the present study the performance evaluation of the Aristo-XT Robot has been presented by considering work analysis as the factor of evaluation.
3. The major task in this work is to generate a mathematical model for predetermining the operation time and to evaluate the performance of the robot.
4. In this work, a graphical representation of the relationship between speed and time and the distance and time is shown. Furthermore, a generalized formula of operation time is derived for the movement of the parts of robot.

Figure 1: Aristo-XT Robot



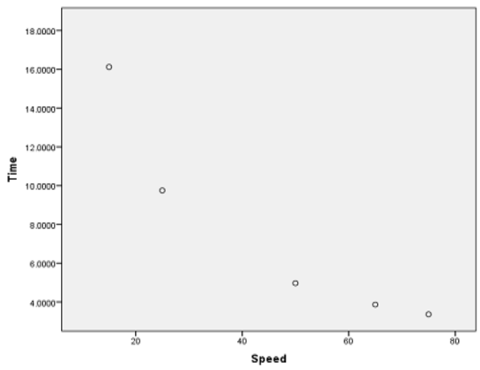
Analysis

Base

Observations are taken for different angles keeping the speed constant; in this work the speed is kept constant at 50rad/msec. Furthermore, a set of observations were made for the time taken to travel up to a certain angle of movement at different speeds. The readings are then fed into SPSS, and the scatter diagram is generated using these readings for Angle-Time and Speed-Time graph. The angle time scatter diagram is used to predict a relationship between the angle of movement and the time of travel. The scatter diagram below shows that a non-linear relationship exists between the two identities. The Speed- time scatter diagram is used to predict a relationship between the speed of movement and the time of travel. The scatter diagram below shows that a nonlinear relationship exists between the two identities. The graph is further used for curve fitting. Using SPSS regression curve estimation is to be done.

Figure 2: Angle-Time Scatter diagram for Base

Figure 3: Speed-Time Graph for Base



These graphs are further used for curve-fitting. Using SPSS regression curve estimation is to be done. In the curve fitting operation 11 types of models were used.

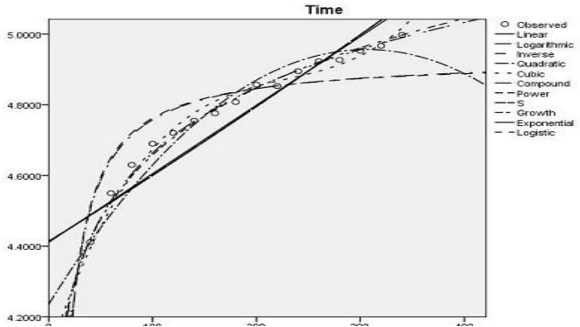


Figure 4: Curve Estimation for Angle- Time graph

From the model above, it can be deduced that the logarithmic curve fits the best for the angle-time Graph, whereas for the speed- time graph fits the best for the power curve with the R2 values to be 0.995 and 1.00 respectively. Therefore, for the further regression analysis logarithmic curve is selected for Angle-Time relationship and power curve is used for the Speed-Time relationship.

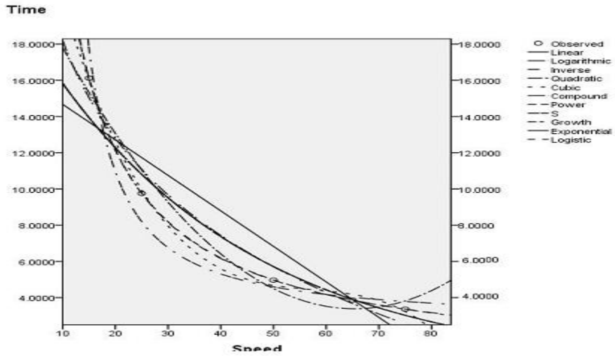


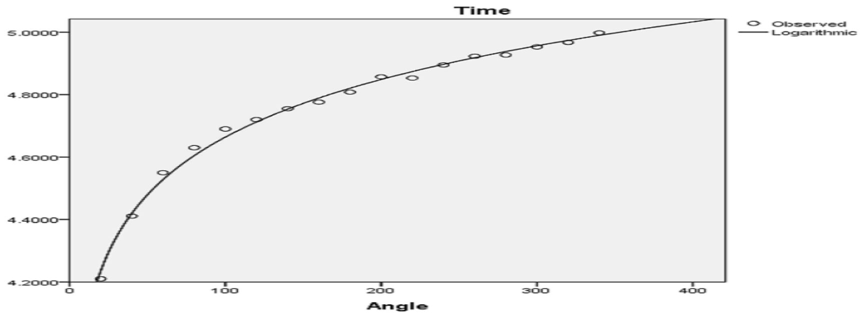
Figure 5: Curve Estimation for Speed-Time graph

Regression Analysis of Base

Angle- Time Curve

It was found that Logarithmic curve fits the best for the Angle- Time graph. Therefore, in this section Logarithmic curve is fitted to the scatter diagram, to obtain an equation of the curve which fits the best. In the figure shown below, shows the logarithmic model summary and the logarithmic curve fit for the graph.

Figure 6: Logarithmic Curve Fit for Angle- Time graph



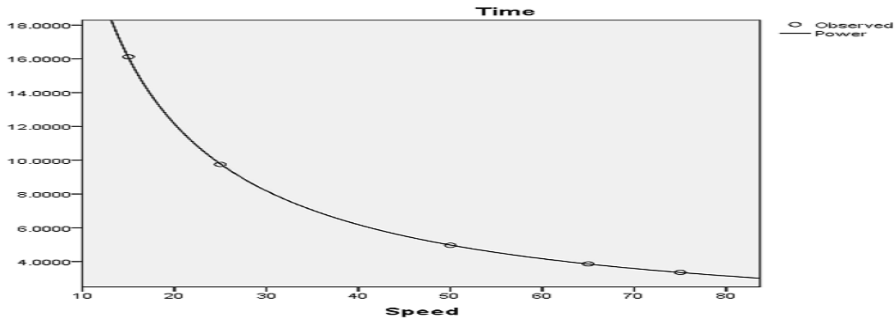
The logarithmic model gives the equation as:

Tb1=3.468 + 0.266 ln(x) …………..(1)

Speed- Time Graph

It was found that Power curve fits the best for the Speed- Time graph. Therefore, in this section power curve is fitted to the scatter diagram, to obtain an equation of the curve which fits the best. In the figure shown below, shows the power model summary and the power curve fit for the graph.

Figure 7: Power Curve Fit for Speed- Time graph



According to Power law, power functions are functions in which the variable is the base of a number with a constant exponent. Therefore, when interpreting the graph, the base changes while the exponent stays the same. Therefore, depending on the exponent, the graph could a various collection of curves. After taking a set of observations for time taken to travel a certain angle at different speeds, it was found that the time taken for the travel is inversely proportional to speed with a power of 0.97.

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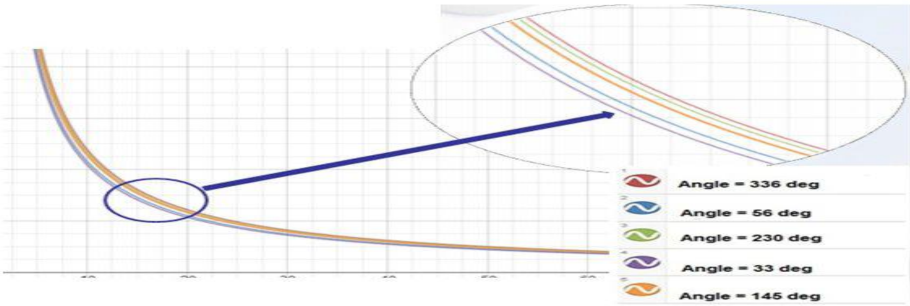
Figure 8: Speed Time Graph for Various Set of Angles



From the above graph it was calculated that;
Tb2 α S-0.97
or, Tb2= aS-0.97
Where, a= coefficient of regression.
Therefore, for the speed time Curve, the generalized equation is:
Tb2= aS-0.97………………………………………. (2)

- Calculating the value of constant:

As the angle time curve for Base movement was recorded keeping speed constant i.e., speed= 50, therefore, when speed is 50 both the equations should give same value for a particular angle,
When Speed = 50,
Tb1=Tb2
Therefore,
3.468 + 0.266 ln(x)= a S-0.97
Where, S=50,
Therefore,
3.468 + 0.266 ln(x) = a(50-0.97)
a= [3.468 + 0.266 ln(x)] 500.97
a= 11.83 [13.04 + ln(x)]

Putting this value of 'a' in the generalized Speed- Time equation for Base movement:

Therefore, total time taken for the base movement for 'x' angle at 'S' speed is,
Tb= aS-0.97
Tb= 11.83[13.04+ln(x)]*S-0.97 …………………… (3)

Similarly equations were derived for the other joints of the robot, the equationsare shown below:

Ts= 34.91 [3.623 + ln(x)] *S-1.006 ……………… (4)
Te= 12.76 [8.102 + ln(x)] *S-0.866 ……………. (5)
Tw= 27.012 [1.456 + ln(x)] *S-0.922 …………. (6)
Tp= 7.534 [19.25 + ln(x)] *S-0.938 ……..…… (7)
Tr= 9.464 [13.07 + ln(x)] *S-0.933 ……….. (8)

Total time for operation

$$T_{to} = \sum_{i=1}^{n} (T_j) + 3.24n$$

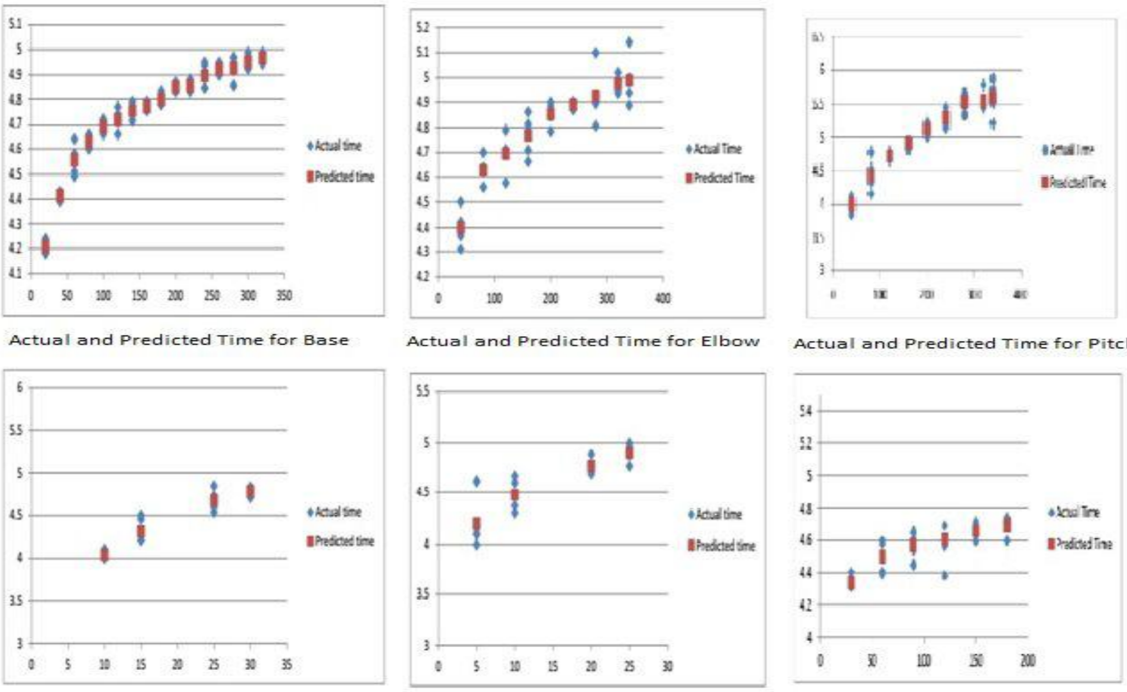
……………………………………………….. (9)

Where, Tj= max(Tb, Ts,Te, Tw ,Tp,Tr)
n= Number of steps involved in the operation.
Where, 3.24 is the time of execution of the command (in secs).

Result and Conclusions

In this work, Aristo-XT robot is used for the evaluation of time. ARISTO is a 6 axis articulated robotic arm designed and manufactured as per industrial needs and industrial standards. In this work, the mathematical model is generated for predetermining the operation Robot Time and Motion (RTM) to evaluate the performance of the robotand based on time data chart, it is found that the problem stated with RTM is different for every individual robot and speed of the operation cannot be altered.The speed of the joints of the robot needs to be constant for the time measurement. Time for any new operation cannot be pre-determined using RTM, which is overcome in this work. It is found that the earlier methodology suggestedto divide the operation into elemental commands as reach, move, grasp, etc.In the present work the movement time of each joint is calculated using angle-time and speed-time analysis, which helps in trajectory planning and hence the time taken for the operation can be pre-determined for the given Robot. Using the null hypothesis test, it is concluded that the predicted values calculated are quite similar to the actual values and any difference in the data can be stated as occurred by chance. The graphs show in figure 9, depicted the differences in the predicted and the actual value of time for a pair of constant speed and variable angles for each joint, where the speed is kept constant at 40rad/msec.

Figure 9: Actual and Predicted Time for Different Joints



Actual and Predicted Time for Base — Actual and Predicted Time for Elbow — Actual and Predicted Time for Pitch

Actual and Predicted Time for Shoulder — Actual and Predicted Time for Wrist — Actual and Predicted Time for Roll

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