FEASIBILITY STUDY ON ROBOT OFF-LINE PROGRAMMING AND SIMULATION USING MATLAB TOOLS; SIMMECHANICS AND SIMULINK PACKAGES

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بسم الله الرحمن الرحيم

In the Name of Allah, the Most Gracious, the Most Merciful

DEDICATION

To my beloved wife, sons and my whole family

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ABSTRACT

Since 19th century, the development of robot in manufacturing industry have been increased rapidly, thus require the need to track down the historical development of robots by robot manufacturers that brings the robot function like todays. Due to demand, robot is said to be replacing human labour because of some factors such as its capability to do work effectively, reducing cost and task that human cannot do. In this research, a feasible study on robot off-line programming and simulation using MATLAB SimMechanics and Simulink packages will be the main objective. This project will be addressing about the development of robot modeling and simulation in the SimMechanics. It is aimed that this approach will be helping the academician and researchers in the related field because MATLAB is widely used in the world in various application.The result of this project shows that it is possible to do programming and 3D simulation using SimMechanics in order to obtain mechanical variables such as joint angle, angular acceleration, reaction force, and torque including draws the respective 3D robot motion that are programmed. SpaceLib program is then used to obtain the desired location and program each robot link to the respective coordinate system in matrix form.

ABSTRAK

Sejak kurun ke 19, pembangunan robot di dalam industri pembuatan telah meningkat secara drastik dan ini memerlukan penjejakan kembali sejarah pembangunan robot oleh pembuat robot bagi melihat bagaimana robot berkembang sehingga ke hari ini. Berdasarkan kepada keperluan, robot dikatakan akan mengambil alih tugas pekerja disebabkan oleh beberapa faktor seperti kebolehannya melakukan kerja dengan efektif, mengurangkan kos dan melakukan tugas yang tidak dapat dilakukan oleh manusia. Objektif kajian ini adalah untuk mendapatkan pembelajaran dan pengetahuan mengenai '*off-line programming*' dan simulasi menggunakan perkakasan MATLAB iaitu lebih spesifik kepada SimMechanics dan Simulink. Adalah diharapkan kajian ini dapat membantu para pengajar dan pengkaji di dalam bidang yang berkaitan terutama robotik kerana MATLAB digunakan secara meluas di dunia di dalam pelbagai bidang. Hasil daripada kajian ini menunjukkan bahawa MATLAB SimMechanics boleh melakukan '*off-line programming*' dan simulasi 3D untuk mendapatkan faktor mekanikal seperti sudut cantum, pecutan sudut, daya reaksi dan kiraan tork di samping memberikan gambaran 3D sebenar pergerakan robot semasa operasi. Manakala SpaceLib kemudian digunakan untuk mendapatkan kedudukan dan program bagi setiap bahagian robot berdasarkan kepada satu sistem koordinat di dalam bentuk matriks.

TABLE OF CONTENTS

CONTENTS

TABLE LIST

FIGURE LIST

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION: ROBOT AND PROGRAMMING

1.1 Research Background

Robots are believed to take the human work task in the future due to the demand and safety they offer. This phenomenon can be predicted if we take a look in our environment especially in manufacturing and industry. Movie industry for an example had launched a new action series, "I, Robot" that showing us the future that we will be living with the help of robot, have going beyond our expectation. Equipped with artificial intelligence that can be easily being mounted into a robot, this is not impossible because numerous researches are rapidly increased on the specified subject.

The term of the robot was first been introduced by a Czech dramatist, Karel Capek in 1921 of "Rossum's Universal Robots" that referring to a perfect and tireless worker performing manual labor jobs for human beings. Since Asimov raised the word robotics in his science fiction stories about robot 1940's, people began to think and design robot. Japanese defined robot as an all-purpose machine equipped with a memory device and a terminal and capable of rotation and replacing human labor by automatic performance and movement. Another good definition was made by the Robot Institute of America, that robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools or specialized device, through variable programmed motions for the performance of a variety of tasks [Antti, 1989][Fu K.S et al, 1987].

That is in short, a robot is a reprogrammable general-purposes manipulator with external sensors that can perform various assembly tasks, possessing intelligence associated with its control and sensing system [Fu K.S et al, 1987].

According to Joseph, there are Three Laws of Robotics remain worthy design standards [Engelberger, 1983]:

1. A robot must not harm a human being, nor through inaction allow one to come to harm.

2. A robot must always obey human beings, unless that is in conflict with the first law.

3. A robot must protect itself from harm, unless that is in conflict with the first and second laws.

Future robots are likely to have a greater number of attributes similar to human such as having greater sensor capabilities, more intelligence, higher level of manual dexterity and also limited degree of mobility. Although today robot does not behave like humans, there is no denying that the technology is moving in a direction to provide those machines with human capabilities.

Industrial robots are now being focused due to its capabilities and advantages especially in the aspect of how factories run. Yet too many robots are become too expensive and too complicated. There is no doubt that the use of robots will be the key to growth in manufacturing in the next decade and more companies using robots will boost their productivity.

It is seems that in the last twenty years, the cost of a universal robot has hardly increased, yet labor cost have quadrupled. In year 1981, Unimation Inc claimed that the hourly cost of a robot was about 30% of labor cost in the US automotive industry whereas in 1966 the costs were similar [Harley, John, 1983].

Why do we use robot in industry? The principle advantage of a robot is its flexibility such as;

1. Able to cope with different products on one line as market demand changes

2. Able to be re-programmed to suit minor modifications or when a completely new model been introduced

This availability offers the high-volume manufacturers in a way of coping with change in volume or type, and for the small manufacturers for the chance of a big jump in productivity while continuing to produce in small batches, such that in some cases, he may be able to compete with much larger companies. Table 1 shows the main advantages of robots.

Table 1.1 Main advantages of robots [Harley John, 1983]

1	Improvement in productivity through the use of robots	94.00%
2	Stabilization of product quality and improved job efficiency	69.70%
3	Improve labor safety	52.80%
4	Changing workers attitudes	51.40%
5	Shortage of laborer and skilled workers	45.00%
6	Increased flexibility of production system	39.70%
7	Progress of engineering and technology of robot	37.30%

Modern industrial arms have increased in capability and performance through controller and language development, improved mechanisms, sensing, and drive systems. In the early to mid 80's the robot industry grew very fast primarily due to

large investments by the automotive industry. The benefits of robots to industry include improved management control and productivity and consistently high quality products.

As manufacturing moves to become more responsive environment with products having shorter life cycles and batch quantities reducing in size, robot programming times become critical, and hence an area to be addressed in order to seek improved productivity. *Off-line programming* is an approach that could reduce the required skill levels of a programmer, reduce the programming times, allow the operator a 'natural' interface with which the operator would conduct the task in the real world, and reduce the boredom factor [Boud, A.C. Steiner, S.J. ,1997][Naylor, A et. al, 1987].

Although that in the beginning *on-line programming* is mainly used but due to *on-line programming* have some deficiencies factors, *off-line programming* become popularly used in the industries and MATLAB is able to provide it. We can find one of the developments using the MATLAB® software in robot technology in the "Simulink-Based Robotic Toolkit for Simulation and Control of the PUMA 560 Robot Manipulator" [Dixon, W.E. et. al, 2001]. The PUMA 560 robot manipulator is developed by using the MATLAB®/Simulink based platform that can be easily executed on the LINUX or Win32-based operating system. The toolkit represents a graphical user-friendly nature that allowing the toolkit can be customizing in real-time simulation without writing any code. It is also give the users to easily incorporate additional functionality and hardware through the simple block diagram interface that Simulink provides thus providing the flexibility for easily modifying component for increased functionality.

There is also some off-line programming software available whether made individually by research or provided by the robot manufacturers. Some of the software developed by the researchers is as mentioned above, SRTK, ROBOSIM, SPACELIB, RRS, WorkSpace, RoboWorks etc. Table 1.2 shows the example of robot manufacturers that provided along the off-line programming software that are compatible only with their robots.

Table 1.2 Robot manufacturers and its off-line programming software

No	Robot Manufacturers	Off-line programming software
1	ABB	RobotStudio
2	Fanuc	RoboGuide
3	Motoman	MotoSim
4	Kawasaki	PC-Roset
5	Adept	Adept DeskTop
6	Staubli	Staubli Studio

1.2 Robot Programming

In the global competition for the manufacturing industries, there are some aspect that has to be concerned such as productivity, cost reduction and also product flexibility. In this subject, there has exist a number of *on-line programming* and *off-line programming* that are spoke to be able to reduce for the mentioned problem.

The number of industrial robots that have been applied in the manufacturing production and other areas in the past decade is significantly smaller than the number predicted at the beginning of the decades. This is due to some of problem such as programming of robot for various tasks in not the least trivial problem and thus bringing the word *"off-line programming"* catches researcher's eye for further investigation and research rather than *"on-line programming"* that is time-consuming process and not very efficient in a flexible manufacturing environment [Leondes C.T and Shirinzadeh B. , 2001]. Furthermore, the *''on-line''* programming technique requires the use of the actual robot which is physically put through the desired sequence of actions.

Programming means the generation of algorithms and data. Hunt have been outlined five objectives of structured programming that are needs to be considered and fulfilled before any of robot programming are done [Hunt, V.D, 1983];

1. Program readability and clarity
2. Increased programmer productivity
3. Reduced testing time
4. Reliability
5. Maintainability

According to Lee et al, there are four main categories in robot programming techniques available [Lee et.al, 1990];

1. Manual on-line programming that physically teaching a robot the desired trajectory through interaction with a teach pendant or other similar devices and also known as 'teach by showing' or 'lead-through' programming.

2. Use of explicit robot programming languages where entire motion cycle of the robot is specified explicitly by a computer program containing specific commands.

3. Task-level programming that needs the robotic arm to be command in order to perform certain task using various artificial intelligence techniques.

4. Off-line programming that combining computer simulations and graphics to produce a desired trajectory plan without need for physical direct access to the manipulator or its movement that also include the calculations and its corresponding differential motions.

On-line programming is a robot program that a robot is being physically moved through the task by an operator [Shirinzadeh, 2001].

Lewis F.L said that computer-integrated manufacturing operations require off-line programming and simulation in order to layout production facilities, model and evaluate design concepts, optimize motion of devices, avoid interference and collisions, minimize process cycle times, maximize productivity, and ensure maximum return on investment [Lewis, F.L. et. al, 1999]. There are some software (e.g., ROBCAD and SILMA) provides support for 3D workable layouts including robots, end effectors, fixtures, conveyors, part positioners, and automatic guided vehicles.

What actually does the off-line programming means? Eberhard explained that off-line or indirect programming means generating a robot program freed from a robot control or a programming device, remote from the industrial robot's workplace, for instance in central programming development [Eberhard R. and Behrens A., 1996]. Almost same definition is made by Lee that has been mentioned above. Off-line programming involves use of a high-level robot programming language. This allows writing and editing programs in a language which is closer to the operator's language than to the machines. Off-line programming can be based on an explicit programming language or on a 'world modeling'; implicit or 'model-based' language.

Illija have been done some good research to do robot off-line programming using a personal computer and robots modeling by AutoCad also simulate using the 3D Studio program packages [Nikolic, I.Z and Maksic, V, 1995]. They've modeled some robot such as PUMA robot, SCARA robots and also educational robots by the AutoCad and then simulating the robot animation by the 3D Studio program packages without the need for specialized robot packages that results in cheaper and reasonable cost than depending on the available and existing software.

Numerous off-line programming have already been developed nowadays. Programming of the robot for various tasks in production can be done in two ways in the real system, either that requiring industrial robot to be mounted in the place of working environment or by animation using off-line programming method. These two methods are requiring significant financial means but the off-line programming system for the robot programming has the main advantages to enables prediction and

avoidance of possible numerous collision situations, before robot introduction to the real system. The needs to buy a special programming packages and the corresponding hardware also required here thus bringing the choices to the customers to think the appropriate or suitable software to meet their needs. Time and costs for robot introduction for education and training on the programming systems for the person who will be conducting the robot are also items to be considered. These factors effect for slower introduction of robot in smaller and medium size companies.

The use of off-line programming and simulation system to program industrial robots enabling the shift of programming creation and optimization away from production thereby offers the possibility to reduce down times in production. Furthermore, by using the off-line programming, a simulation program can be adapted and simulating variety of scenarios and processes of a robot specific task. Thus, this will be optimize the process and do not affect the production cell flow.

Hodges claimed that there are some advantages that off-line programming offers [Hodges, Bernard, 1992];

1. Improved robot and programmer safety;

   (a) Programmer is remote from a potentially hazardous environment.

   (b) The programmer and the robot are not placed at risk by the accidental operation of the wrong controls, as when the robot is very close to the workpiece.

   (c) Operator eyes need not to be close to the tool point to achieve the desired accuracy of positioning. Conventional programming places the operator in a vulnerable position inside the working envelope. High-precision task require this risk period to be long and continuous, particularly if the program consists of several hundred points. Control mistakes, operator fatigue and errors

induced by visual problems such as restricted view and eye strain can easily cause mistakes in the program and poor accuracy.

2. Postprocessors enable a variety of types of robots to be programmed from one workstation.

3. The system permits verification, assisted by the graphical simulation system, of robot programs in terms of positional data and program logic. This may include input/output signals for control of peripheral equipment, the processing of sensory inputs, path control informations and programming structures such as loops, branches and wait instructions, and the inclusion of previously written subroutines.

4. In off-line programming the robot program is developed, partially or completely, without requiring direct use of the robot, which can remain in production while its next task is being programmed. This makes the use or robots economic for small batch production, and increases the economic viability of the robot installation.

5. The use off-line programming enables complete automation system to be planned, built up and modified to suit the desired requirements. This can include the layout of machine tools, materials handling devices such as bowl feeders and conveyors system, as well as the evaluation of different robots and their individual positioning and work envelope considerations.

6. Off-line programming allows data built up in CAD and production control systems to be incorporated into the design of the robot installation.

Engineers always found themselves in problem that when they are trying to synchronize the virtual and the real situation in manufacturing process. Although there are many of offline simulation programming been introduced by many manufacturers especially for robot such as workspace, roboguide, roboworks etc,

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