THE INVESTIGATION OF TRAJECTORY GENERATION OF A CURVED WALL BRICK LAYING USING 5 DOF MOBILE ROBOT

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SUPERVISOR'S ENDORSEMENT

I hereby declare that I have read through this report "THE INVESTIGATION OF TRAJECTORY GENERATION OF A CURVED WALL BRICK LAYING USING 5 DOF MOBILE ROBOT" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Mechatronics)

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A report submitted in partial fulfilment of the requirements for the degree of Mechatronics Engineering with Honor

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STUDENT'S DECLERATION

I (Mohammed Ahmed Salem) declare that this report entitles "THE INVESTIGATION OF TRAJECTORY GENERATION OF A CURVED WALL BRICK LAYING USING 5 DOF MOBILE ROBOT**"** is the result of my research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature:

………………………………………

Name: MOHAMMED AHMED SALEM

Date: 14 JUNE 2017

To my beloved mother" AMAL" and father "AHMED"

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ABSTRACT

The masonry brick layer is related strongly with human health risks such as dermatitis, struck by falling object or musculoskeletal disorders. According to Map of the Construction Industry Amsterdam, Netherlands, 38% of bricklayers reported musculoskeletal disorders. In this project the main problem is on how to enable the user to describe the initial conditions of the desired curved wall brick layering (The coordinate of the first, middle and the last brick). To generate trajectory to obtain the profile of the curved wall brick positioning using 5 degree of freedom manipulator (KUKA youBot). The objectives of this project are, firstly to analyze the problem of curved wall brick laying using a five degree of freedom manipulator (KUKA YouBot), secondly is to design a trajectory profile relative to the curved wall brick laying and lastly to evaluate the accuracy of the brick positioning using KUKA YouBot utilizing parabolic polynomial equation. The parabolic polynomial equation is used, due to its simplicity, smooth motion and high accuracy. To achieve the objectives, trajectory is generated by using the parabolic polynomial equation. In order to validate the curved brick laying process, a simulation using VREP simulator is used to get the Cartesian axis (x, y, z) of the brick positioning. The parabolic equation is written in term of a code in MATLAB software to prove it is ability to produce any type of desired curve. The curves obtained from the parabolic equation are compared in term of the equation used, the arc length of the curve and the estimated bricks number required to complete the brick laying process. The result of the project is the curved wall brick laying obtained from the V-REP simulator with minimum accuracy of 77.53571% and Root Mean Square error (RMSe) of 0.02190791. In conclusion, the trajectory profile relative to the curved wall brick laying is designed with the use of the parabolic polynomial equation. The future work of this project is to increase the curve layers (starting from the second layer) as this project focuses on how to build any desired curve for the first layer. Moreover, this project is done in the V-REP simulator, so testing the experiment in the real (lab or physical) environment is highly recommended, especially to analyze the accuracy of every constructed curved wall.

ABSTRAK

Lapisan batu bata berkait kuat dengan risiko kesihatan manusia seperti dermatitis, dipanah objek atau gangguan otot jatuh. Menurut Peta Pembinaan Industri Amsterdam, Netherlands, 38% daripada penurap bata dilaporkan mengalami gangguan muskuloskeletal. Dalam projek ini masalah utama ialah bagaimana untuk membolehkan pengguna untuk menggambarkan keadaan awal melengkung bata lapisan dinding yang dikehendaki (Koordinat pertama, tengah dan bata yang lalu) dan untuk menjana trajektori untuk mendapatkan profil kedudukan bata dinding melengkung menggunakan 5 darjah kebebasan pemboleh ubaha (KUKA youBot). Objektif projek ini adalah, untuk menganalisis masalah dinding bata melengkung dengan meletakkan dan menggunakan lima darjah kebebasan pemboleh ubah (KUKA YouBot), kedua adalah untuk mereka membina profil trajektori berbanding dengan melengkung bata dinding memasang dan seterusnya, untuk menilai ketepatan kedudukan bata menggunakan KUKA YouBot menggunakan persamaan polinomial parabola. Persamaan polinomial parabolic digunakan, kerana kesederhanaan, gerakan yang lancar dan ketepatan yang tinggi. Bagi mencapai objektif, trajektori yang dihasilkan dengan menggunakan persamaan polinomial parabolic. Dalam usaha untuk mengesahkan proses bata meletakkan melengkung, simulasi menggunakan VREP simulator digunakan untuk mendapatkan paksi Cartesian (x, y, z) bagi kedudukan bata. Persamaan parabola ditulis dalam perisian MATLAB untuk membuktikan ia adalah keupayaan untuk menghasilkan apa-apa jenis lengkungan yang dikehendaki. Hasil daripada projek ini adalah bata dinding yang melengkung diletakkan diperolehi daripada simulator V-REP dengan ketepatan minimum 77,53571% dan kesilapan Root Mean Square (RMSe) daripada ,02190791. Kesimpulannya, profil trajektori berbanding dengan lengkungan bata dindingyang diletakkan ini direka dengan menggunakan persamaan polinomial parabola. Pada masa hadapan projek ini adalah untuk meningkatkan lapisan lengkungan (bermula dari lapisan kedua) sebagaimana projek ini memberi tumpuan kepada bagaimana untuk membina apa-apa keluk dikehendaki untuk lapisan pertama. Selain itu, projek ini dilakukan dalam simulator V-REP, ujian eksperimen dalam keadaan nyata (makmal atau fizikal) Persekitaran amat dititik beratkan, terutamanya untuk menganalisis ketepatan setiap dinding melengkung yang dibina.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Scientific literature suggests that masonry work is often related to human health and diseases. There are several health risks that a bricklayer may face during the brick layering which may include: dermatitis, struck by falling objects, eye injuries or musculoskeletal disorders [1].

In 1999, a study observed that 38% of the bricklayers in the Netherlands reported musculoskeletal disorders [2]. In addition to the health risks, the bricklayers are not expert, fast and precise enough in comparison with a bricklayer robot such as bricklaying robot manufactured by The Australian company FASTBRICK Robotics [3].

The studies show that the average bricklaying rate of one human is 140 bricks/hour [2], while the robot can lay 255 bricks per hour [2]. Moreover, several studies observed a high rate of inefficiency in the masonry industry of different countries. For example, studies reported inefficiencies at approximately 68%, 50%, 40%, 7%, and 2% for firms in Spain, Canada, Portugal, Greece, and China respectively [2].

Automation increases productivity and reduces the risk of work disorders in highly repetitive and physically strenuous tasks. Therefore, this project (the investigation of trajectory generation of a curved wall brick layer robot) is to provide an assistance to the curved wall bricklayers to overcome the risks and increase the efficiency rates. This research will provide as well the use of trajectory kinematics to achieve the time history of position, velocity and acceleration of the curved wall brick layer robot.

1.2 Problem Statement

In this project, the problem of trajectory generation in curved brick laying is on how to enable the user to describe the initial conditions of the desired curved wall brick layering (The coordinate of the first, middle and the last brick). Path planning is the points in which the curved wall brick layer manipulator should follow to reach the desired location.

In order to make the motion of the curved wall brick layer manipulator flexible for the user of the robot system, the user is required to describe the desired motion by non-complicated functions of space and time to specify the trajectory motion.

By creating a trajectory generation that allow the curved wall brick robot to use similar algorithms for curve bricklaying having different degree of curvature and different arc length, by changing the desired parameters such as position of the first and the end bricks, then let curved wall brick laying robot decide the details of the complicated trajectory generation of space and time.

The user might want to specify the desired destination position and orientation of the end-effector for the brick layering process and leave it to the KUKA robot to decide on the exact shape of the path to reach to the desired position, the duration, the velocity profile. We also are concerned with how we can simulate these trajectories and represent them in the computer after they have been planned using V-rep simulation software.

By using KUKA manipulator as a brick layer, the user will have an advantage of not doing the complicated trajectory calculations but the accuracy of the brick positioning may be decrease because of the automatically control of the inverse kinematics by the KUKA robot arm, and the singularities that may happen. This problem may happen due to the performances of KUKA arm's angular velocities of the joints with differences distance between robot and the brick at the desired placing coordinate. Moreover, some desired positions are not reachable by the 5 degree of freedom manipulator due to some geometric problems of the path in Cartesian space or the limitation of the workspace of the manipulator.

Based on this problem described, the project need to address a method on how to achieve any type of desired curve. The proposed method is to use the parabolic polynomial to generate the desired trajectory and observe how it responds.

1.3 Objectives

The objectives of this research focused on the points that are related to the trajectory generation of the curved brick layer process, these points are as follows:

1. To analyze the problem of curved wall brick laying using a five degree of freedom manipulator (KUKA YouBot).

2. To design a trajectory profile relative to the curved wall brick laying using parabolic polynomial equation.

3. To evaluate the accuracy of the brick positioning using KUKA YouBot.

1.4 Scope of the project

The scope of this research focused on several points that are related to the trajectory generation of the curved brick layer process, these points are summarized as follows:

1. Study on the trajectory generation methods in order to choose the smooth and accurate method in generating the position, velocity and acceleration profiles.
2. Use V-REP simulator to generate trajectory planning profiles by using parabolic polynomial equations.
3. The study of the curved brick layering process is developed in a controlled environment with an assumption of no external factors need to be consider such as obstacles.
4. The achievement of any curved wall brick laying of the first layer.
5. Use a five degree of freedom (5 DOF) manipulator (KUKA) to apply the curve brick layering process.
6. To find error and accuracy between desired coordinate (x_d, y_d, z_d) and actual coordinate (x_a, y_a, z_a) by using methods of analysis.
7. The position and orientation of the robot while pick and place the brick using Cartesian space trajectory generation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The standing chapter is intended to summarize and present the prior research works from open literature review which are relevant to the curved wall brick laying. However, the path description and trajectory generation of the curved wall brick laying robot are the most main points taken under considerations in order to identify the most important difference between the path description and trajectory generation. In line with making potential effort to designate the most significant points as general review, the following subtitles such as Analyzing the information related to trajectory generation of the bricklaying robot (path planning and trajectory generation of the curved wall brick layer robot, basic of trajectory generation (Cartesian-Space Scheme, joint-space scheme), Geometric problems with Cartesian paths and the Process of Bricklaying), synthesizing the information gathered (the performance matrix, existing brick layer robot's compression and conclusion on the limitation of the existing design) and evaluating the information by selecting the suitable method in term of curved wall brick laying process.

2.2 Path planning and trajectory generation of the curved wall brick layer robot

Generally, pure geometric description of motion is provided by the path. In conjunction of the obstacle avoidance or brick layering in the curved wall with regards to path is usually planned globally (path planning). Furthermore, trajectory is a path with considering of both velocities and accelerations in each point in the space in which brick laying robot should follow. Table 2.1 summarizes the comparison between the path planning and trajectory generating, while Figure 2.1 shows the General block diagram. as shown below. In Figure 2.1 the relation of the general block diagram with the brick layer robot is explained in more details as follows:

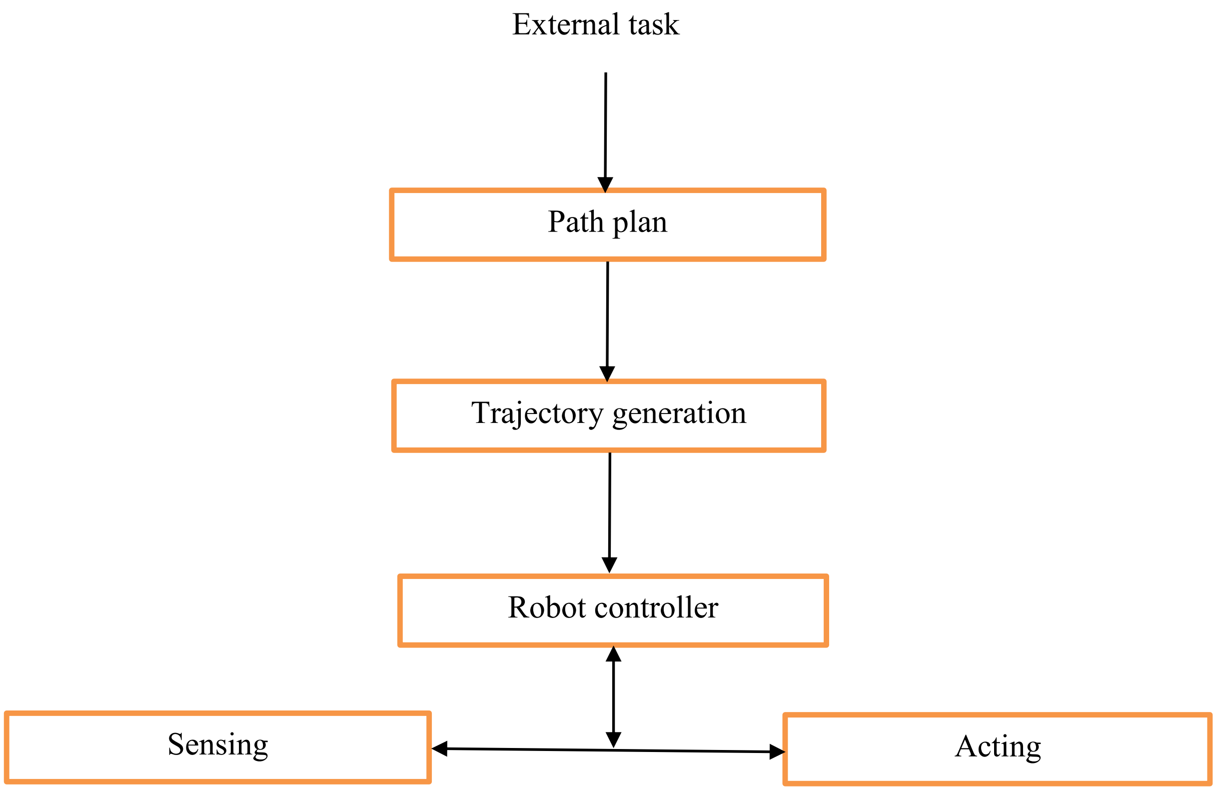

Figure 2.1: General block diagram

Where:

External task stands to lay bricks in the curve wall.

Path plan stands for desired curved path of brick laying process.

Trajectory generation considers of velocities and accelerations in each point in the space in which brick layering robot should follow.

Robot controller stands for using the KUKA robot controller.

Sensing stands for vision sensor.

Acting stands for putting the brick at the desired position by generating a time-based control sequence.

In this project, the consideration is focused on the trajectory generation only.

Table 2.1: Path planning (global) vs trajectory generating (local)[4]

Path planning (global)	Trajectory generating (local)
The (geometric) path is a sequence of Waypoints defining the trajectory coarsely. Issues solved at this level: obstacle avoidance, brick layering in the curved wall.	The path provided by path planning constitutes the input to the trajectory generator. Trajectory generator approximates the desired waypoints by the use of the polynomial functions and generates a time-based controlled sequence moving the end effector of the manipulator from the based point to the desired point.

In order to complete the curved brick laying process, the path planning and trajectory generations are integrated together. The connection between path planning and trajectory generation is shown through the block diagram in. Figure 2.2.

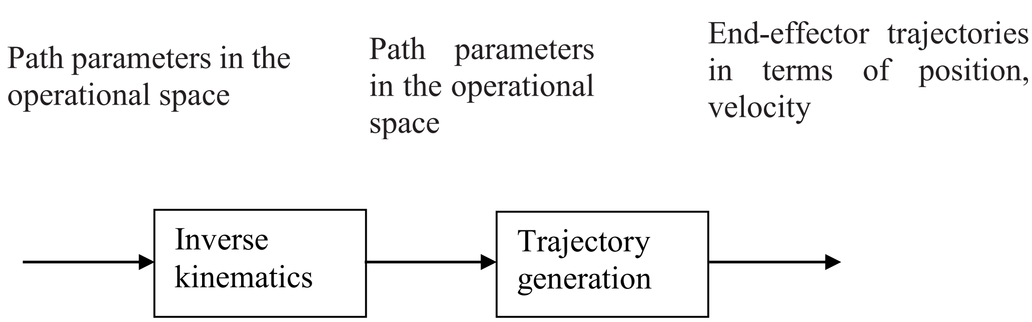

Figure 2.2: Functional block diagram of the brick layer robot[4]

Figure 2.2 illustrates the block diagram that the path parameters in the operational space are the initial and final end-effector location, the inverse kinematics is to calculate the required angles need to be rotated which is the inputs to the trajectory generation to specify the position, velocity and the acceleration of the end effector of the manipulator. In addition, Figure 2.3 shows the process of moving the end effector of the manipulator from an initial position to a desired final position.

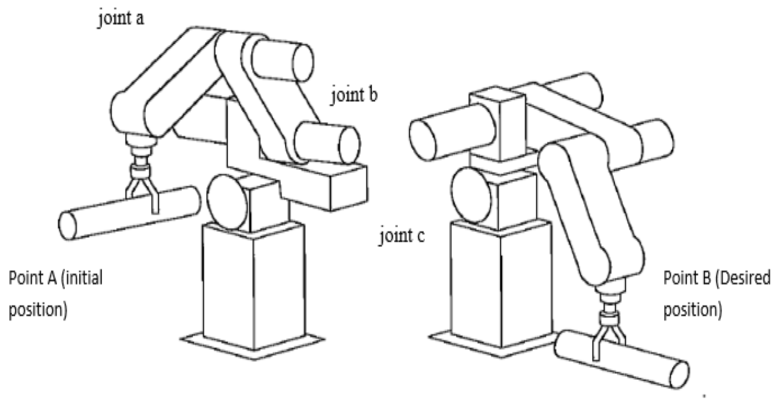

Figure 2.3: Moving the manipulator from an initial position to final position [4]

The most functional processes in Figure 2.3 are explained and elaborated as follows:

The path parameters in the operational space process is the initial and desired locations (Point A and B), while Inverse kinematics process is to calculate the angles rotation required at joint a, b and c, however trajectory parameters in the joint space process is to calculate the angles and trajectory generation process is to obtain the desired end-effector's position (Point B axis (X, Y and Z)), velocity and its acceleration.

2.3 Basic of Trajectory Generation

Trajectory is basically identified with velocity, acceleration and position for each joint (degree of freedom). The trajectory motion incorporates the human-interface in term of determination through space [4].

The most straightforward approach to portray the robot movement for client of a robot system is that the human client ought to be required to compose uncomplicated function (inputs) with a specific end goal to decide the task of the robot.

At the same time the ability of deciding Trajectories with straightforward portrayals must be in thought keeping in mind the end goal to get the desired movement. For example, in some cases the client (user) has to decide the wanted position and orientation of the end effector. In the meantime, the client abandons it to the manipulator to pick the wanted path of the trajectory generated to get alternate points of interest, for example, velocity and the acceleration profile [4].

Furthermore, identification of the trajectories by utilizing PC after the trajectories that have been arranged is the enormous concern, toward the end, obtaining the desired path from the generated trajectory is an issue that is accessible.

Widely recognized case, three parameters must be processed which are velocity, position and acceleration. Therefore, these trajectories are obtained at different sampling time [4]. The application of generating the desired trajectory path will be discussed in chapter four.

2.3.1 Joint-Space Schemes

Techniques for way generation in which the path are depicted as elements of joint angles. Each path point is normally shown as a desired position and orientation of the tool frame, {T}, with respect to the station frame, {S} [4]. By utilizing application in respect to inverse kinematics, every one of these through focuses is "exchanged" into an arrangement of coveted joint angles.

Along these lines, every portion is required a similar time for each joint so all joints can have the capacity to reach through the via point in the meantime, so the alluring Cartesian position of the end effector (tool frame) will accomplish at each via point. In addition, every joint has its own particular sought join point which is independent of alternate joints. Subsequently, join space plans accomplish the desired position and orientation through via points.

Moreover, the trajectory generation is considered to be ease to compute in joint space scheme compared with the Cartesian space because of the simple calculations required in the join space schemes. Furthermore, In the join space schemes there is fundamentally no issue with singularities of the system [4].

2.3.2 Cartesian-Space Schemes

Cartesian space is defined as the movement between the two points that is specified at all times and controllable. Cartesian space is easy method that can help to imagine the trajectory, although Cartesian space is not easy to ensure the singularity. Thus, in the joint space, the paths in order to ensure that via and desired points are achieved, even if these path points were determined by means of Cartesian frames [4].