“I hereby declare that I have read through this report entitled “The Investigation of Circular Path Generation and Hand Motion Tracking Problem Using Vision Based 5DOF Robot” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering with Honours.”

Signature : ..........................................................

Supervisor’s Name : PM Dr. Muhammad Fahmi Bin Miskon

Date : ..............................................................
THE INVESTIGATION OF CIRCULAR PATH GENERATION AND HAND
MOTION TRACKING PROBLEM USING 5DOF VISION BASED ROBOT

FARAH AMIRAH BINTI RASID

A report submitted in partial fulfillment of the requirements for the degree
of Bachelor of Mechatronics Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017
I declare that this report entitle “The Investigation of Circular Path Generation and Hand Motion Tracking Problem Using Vision Based 5DOF Robot” is the result of my own 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 : Farah Amirah Binti Rasid

Date : ........................................
To my beloved mother and father
ACKNOWLEDGEMENT

Grateful to Almighty Allah for His blessings I successfully complete my final year project to complete my study for Bachelor of Mechatronics Engineering with Honours. I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals. I would like to extend my sincere thanks to all of them.

A special gratitude I give to my final year project supervisor, Associate Professor Dr Muhammad Fahmi bin Miskon, whose contribution in suggestions and encouragement, guide me to make my project possible. I really thank him for providing me the conceptual and theoretical clarity in that enabled me to develop an understanding of this project thoroughly.

Furthermore, I would like to appreciate my parents for giving me support, love and encourage me to finish this project successfully. Special thanks go to BEKM members, who help me to assemble the parts and gave suggestion about my project.

Lastly, to University Teknikal Malaysia Melaka (UTeM), I am grateful that this institution really wanted to see its students to be skilful and knowledgeable.
ABSTRACT

Robotic rehabilitation has widely being used especially for upper limb impairment due to neurological disorder or accident. Research has shown that robotic training can also provide repetitive movement without therapist assistant. This project address two main problem in robotic rehabilitation applications which are generating a circular path in Cartesian space and the problem in identifying the positions (x,y,z) of robot’s arm end effector when generating a circular motion that can vary depending on the vision based feedback of patient hand. The aim of this project is to analyse the problem of generating circular path and tracking method using a vision based robot. Secondly to develop circular path algorithm and vision based circular tracking algorithm to match with the patient hand motion and to validate the smoothness of circular path and the accuracy of a vision based robot motion when tracking and following the patient hand motion using statistical method. The idea to generate circular path is by using point to point method in Cartesian space. To get the circular motion, the trigonometry formula combined with formula of circumferences was used to generate the circle. MATLAB is used for the circular generation while the simulation for circular path is done in VREP by using LUA. For the visual part, blob detection, centroid detection (x,y) is used with the imposing of inverse kinematic to track the image. The OpenCV library was used to do blob detection. The robot simulation is done using VREP and the algorithm is developed using LUA. In generating a circular path, the smoothness of circle is important. To measure the smoothness of circle path, the number of point to point is increased. For the tracking part, the accuracy of robot is measured using the statistical method. The youBot have high accuracy in tracking part which is 97% with absolute error 0.03. In conclusion, a vision based robot is reliable for circular hand tracking problem for rehabilitation purposes. A future research can be done to make a precise robot motion by developing a new control method for the robot and add features that enable the robot to save the results of motion for therapist to follow up the patient hand condition.
ABSTRAK

Penggunaan robot semakin luas dipergunakan untuk terapi pemulihan anggota badan bahagian atas yang rosak atau bermasalah disebabkan masalah saraf atau pada masa kemalangan. Kajian terbaru menunjukkan bahawa latihan menggunakan robot juga boleh memberi pergerakan secara berulang tanpa bantuan ahli terapi. Projek ini menggariskan dua masalah utama dalam aplikasi penggunaan robot untuk latihan pemulihan iaitu dalam menjana gerakan bulatan dalam ruang Cartesian dan masalah untuk mengenalpasti kedudukan (x,y,z) robot apabila mengesan pergerakan tangan pesakit yang diterima melalui visual. Tujuan projek ini ialah untuk menganalisis masalah menjana gerakan bulatan dan mengesan pergerakan tangan menggunakan robot yang mempunyai visual. Yang kedua ialah, membina algoritma gerakan bulatan dan algoritma untuk mengesan pergerakan tangan menggunakan robot visual serta mengesahkan kelancaran bentuk bulatan dan ketepatan robot mengesan gerakan tangan pesakit menggunakan kaedah statistic. Idea untuk menjana gerakan bulatan yang tepat ialah dengan menggunakan kaedah titik ke titik. Gerakan bulat, dihasilkan menggunakan persamaan bulatan dalam MATLAB. Simulasi dijalankan menggunakan VREP dan LUA. Untuk bahagian visual, teknik pengesanan tomptom, pengesanan titik tengah (x,y) digunakan dengan mengenakan kinematic songsang untuk mengesan tangan. OpenCV digunakan untuk melakukan pengesanan tomptom. Simulasi robot dilakukan dengan menggunakan VREP dan algoritma dibangunkan menggunakan LUA. Dalam menjana gerakan bulatan, kelancaran bulatan adalah bertambah apabila, nombor titik ke titik bertambah. Untuk bahagian pengesanan, ketepatan robot diukur menggunakan kaedah statistik. KUKA youBot mempunyai ketepatan yang tinggi di bahagian pengesanan iaitu 97% dengan ralat mutlak 0.03. Kesimpulannya, sebuah robot yang mempunyai visual boleh dipercayai untuk menyelesaikan masalah pengesanan tangan untuk tujuan rehabilitasi.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>ACKNOWLEDGEMENT</strong></td>
<td>v</td>
</tr>
<tr>
<td></td>
<td><strong>ABSTRACT</strong></td>
<td>vi</td>
</tr>
<tr>
<td></td>
<td><strong>TABLE OF CONTENTS</strong></td>
<td>viii</td>
</tr>
<tr>
<td></td>
<td><strong>LIST OF TABLES</strong></td>
<td>xi</td>
</tr>
<tr>
<td></td>
<td><strong>LIST OF FIGURES</strong></td>
<td>xii</td>
</tr>
<tr>
<td></td>
<td><strong>LIST OF SYMBOLS</strong></td>
<td>xiv</td>
</tr>
<tr>
<td></td>
<td><strong>LIST OF APPENDICES</strong></td>
<td>xv</td>
</tr>
<tr>
<td>1</td>
<td><strong>INTRODUCTION</strong></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.1 Motivation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.2 Problem Statement</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1.3 Objectives</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1.4 Scope of the project</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td><strong>LITERATURE REVIEW</strong></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2.1 Robotic Rehabilitation</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2.2 Generation of Circular Path</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>2.2.1 Trajectory for Generating Circular Path</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>2.2.2 Problems of Generating Circular Path in</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Cartesian Space</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.2.3 Available Solution for Generation of Circular Path</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>2.2.4 Summary for Available Solution in Generation of Circular Path</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>2.3 Visual based robot for rehabilitation applications</td>
<td>12</td>
</tr>
</tbody>
</table>
2.3.1 Robot Vision for hand tracking using Marker

2.4 Method to Generate Circular Path and Tracking Hand Motion

3 RESEARCH METHODOLOGY

3.1 Theoretical Concept

3.1.1 Flowchart for Circular Path Generation and Tracking Hand Motion

3.2 Generating circular shape motion

3.3 Object Tracking Method

3.4 Calculating Vision Frame Size

3.5 Angle of View from the Camera

3.6 Positioning the End-Effector to Make the Target in the Centre of Vision Frame

3.7 Objective of simulation

3.8 Simulation Equipment

3.9 Simulation Setup

3.9.1 Workspace of the Circular Generation and Tracking Hand Motion

3.9.2 Pseudo code of Point to Point Circular Path Generation for KUKA youBot

3.9.3 Pseudo code for Path

3.9.4 Pseudo code of Vision Sensor

3.9.5 Pseudo Code of Circular Hand Tracking for KUKA Youbot

3.10 Procedure of Simulation in VREP

3.10.1 Problems and Issues in Simulation

3.11 Method of Analysis

3.12 Consideration on the Validity of the Simulation

3.13 Discussion on the reliability of data

4 RESULT AND DISCUSSION
4.1 Circular motion test in MATLAB 45
  4.1.1 Circular Path Generation with Different Radius 45
  4.1.2 Increasing the Number of Points to Points in the Circular Path 47
4.2 Simulation of vision based robot in VREP using LUA 49
  4.2.1 Circular Path Generation 49
  4.2.2 Image centre tracking based on Vision Algorithm using blob detection 50
  4.2.3 Image Tracking Using Vision Based Robot 52
  4.2.4 Image tracking for adjustable radius 57

5 CONCLUSION 62
  5.1 Conclusion 62
  5.2 Recommendation 63

REFERENCES 64
APPENDICES 66
### LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Available solution for trajectory generation</td>
<td>11</td>
</tr>
<tr>
<td>3.1</td>
<td>Position of equipment in VREP simulator</td>
<td>36</td>
</tr>
<tr>
<td>3.2</td>
<td>Initial Position for each KUKA youBout arm joints</td>
<td>36</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Robot path in PTP</td>
<td>6</td>
</tr>
<tr>
<td>2.2</td>
<td>Acceleration and deceleration of link from start and end motion</td>
<td>6</td>
</tr>
<tr>
<td>2.3</td>
<td>Trajectory generation overview</td>
<td>7</td>
</tr>
<tr>
<td>2.4</td>
<td>Cartesian-path problem type</td>
<td>9</td>
</tr>
<tr>
<td>2.5</td>
<td>Cartesian-path problem type 2 in circular path</td>
<td>10</td>
</tr>
<tr>
<td>2.6</td>
<td>Overview of vision based robot for hand rehabilitation</td>
<td>13</td>
</tr>
<tr>
<td>2.7</td>
<td>Subset of vision-based robot system for visual part</td>
<td>13</td>
</tr>
<tr>
<td>2.8</td>
<td>Block diagram of general simple machine vision system</td>
<td>15</td>
</tr>
<tr>
<td>2.9</td>
<td>Image colour detection</td>
<td>16</td>
</tr>
<tr>
<td>2.10</td>
<td>Edge detection of a car</td>
<td>16</td>
</tr>
<tr>
<td>2.11</td>
<td>Shape detection</td>
<td>17</td>
</tr>
<tr>
<td>2.12</td>
<td>Blob detection with centre of mass of the red object</td>
<td>17</td>
</tr>
<tr>
<td>3.1</td>
<td>Scenario of vision based robot for hand rehabilitation</td>
<td>20</td>
</tr>
<tr>
<td>3.2</td>
<td>Circular motion with point to point</td>
<td>21</td>
</tr>
<tr>
<td>3.3</td>
<td>Method to generate tracking and following circular</td>
<td>21</td>
</tr>
<tr>
<td>3.4</td>
<td>Flowchart of project concept</td>
<td>22</td>
</tr>
<tr>
<td>3.5</td>
<td>Flowchart for generate tracking and following circular hand Motion</td>
<td>24</td>
</tr>
<tr>
<td>3.6</td>
<td>Desire and actual circular shape</td>
<td>25</td>
</tr>
<tr>
<td>3.7</td>
<td>Image trajectory of the objet during robot arm control</td>
<td>27</td>
</tr>
<tr>
<td>3.8</td>
<td>Resolution</td>
<td>28</td>
</tr>
<tr>
<td>3.9</td>
<td>View from vision sensor</td>
<td>28</td>
</tr>
<tr>
<td>3.10</td>
<td>Top view</td>
<td>30</td>
</tr>
<tr>
<td>3.11</td>
<td>World coordinates systems</td>
<td>31</td>
</tr>
<tr>
<td>3.12</td>
<td>World coordinates is VREP</td>
<td>31</td>
</tr>
<tr>
<td>3.13</td>
<td>4x4 matrix</td>
<td>32</td>
</tr>
</tbody>
</table>
3.14 Transformation matrix from original to final position 32
3.15 Transformation matrix in VREP 33
3.16 LUA display value 33
3.17 Before calculation 34
3.18 After calculation 34
3.19 Experimental set up in VREP simulation 37
3.20 Workspace for circular path tracking using vision based robot 38
3.21 Kuka youbot vision 38
3.22 Calculation of error percentage 42
4.1 Adjustable circular radius from MATLAB simulation 46
4.2 Actual and desired circular motion of robot arm 46
4.3 Error area 47
4.4 Increase number of points 48
4.5 Error versus no of point to points 48
4.6 Generation of Circular Path using Point to Point 49
4.7 Generation of Circular Path by Increasing Number of Point to Point 50
4.8 Image centre read by vision sensor for circular motion 51
4.9 Image centre read by vision sensor for adjustable circular motion 52
4.10 KUKA motion versus hand motion 53
4.11 Motion of KUKA youbot in circular path with varying velocity of target 54
4.12 Maximum error region for circular path 55
4.13 Joint position for circular path 55
4.14 Joint velocity for circular path 56
4.15 Joint acceleration for circular path 57
4.16 Motion of KUKA in swirling circular path 59
4.17 Maximum error region in swirling circle shape 59
4.18 Joint position for swirling circular path 60
4.19 Joint velocity for swirling circular shape 61
4.20 Joint acceleration for swirling circular shape 61
LIST OF SYMBOLS

x  -  Horizontal displacement
y  -  Vertical displacement
t  -  Time taken
C  -  Circumference
P  -  Position
R  -  Radius
m  -  Gradient
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Pseudocode for point to point circular generation using youBot</td>
<td>66</td>
</tr>
<tr>
<td>B</td>
<td>Pseudocode for circular hand tracking using youBot</td>
<td>68</td>
</tr>
<tr>
<td>C</td>
<td>Image tracking values for circular motion</td>
<td>71</td>
</tr>
<tr>
<td>D</td>
<td>Image tracking values for adjustable circular motion (swirling)</td>
<td>75</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Motivation

There are many causes that lead to upper limb pain which make the patient unable to move their hand normally such as stroke diseases, sports injury and accident. Statistics has shown that 26.7% Malaysian suffer upper limb pain which causes by sports injuries, overuse of muscle arm, stroke disease and accidents [1]. Patient who suffer this kind of impairment in motor and low muscle strength will typically receive intensive, hands-on physical and occupational therapy to encourage motor recovery and strengthen the muscle. The intensive therapy that will give motivation to the patient in order to help fast recovery after stroke or injury is called rehabilitation program. However, it is impossible for the patient to receive full therapy since the number of therapist in rehab centre and rehabilitation hospital is currently not enough to help the patient since there is a statistic shown that 70 number of patient receiving treatment at one time in a rehabilitation hospital [2]. Not only that, statistic also shown that in Malaysia, the ratio of occupational therapist is 1:20000 [2]. Therefore, due to lack of resources, patients are receiving less therapy and discharged from rehabilitation hospital sooner [3].

In order to solve the problem, recent research have shown that robotic training is a considerably new technology that shows great potential for application in the field of neuro-rehabilitation as it has several advantages such as motivation, adaptability, data collection, and the ability to provide intensive individualized repetitive practice [4]
Therefore, this research is about to provide a new technology to help therapy process by using an assistive vision based robot that able to help patient do the hand exercise without the help of expert occupational therapy practitioner. The new technology using vision based robotic assistance has the ability to provide intensive repetitive practice for each patient individually. The application of computer vision on the robot is to track human hand move in correct line. This project also will analyse the potential of robot to provide accuracy of the joint to reach the target distance and can follow the human hand.

1.2 Problem Statement

The problem in hand rehabilitation exercise is that the patient is not consistent in doing their exercise due to lack of guidance especially a when doing a complicated motion such as circular. An assistive robot is needed in order to guide, track and follow the patient hand accurately to avoid demotivation from stop doing the exercise. In order to track the circular motion accurately, a vision sensor is added to the robot to improve the reliability to assist the patient to ensure that the robot can guide the hand even though the speed and radius of circle is decreasing.

This project address two main problem in robotic rehabilitation applications which are generating a circular path in Cartesian space and the problem in identifying the position (x,y,z) and orientation of robot’s arm end effector when generating a circular motion that can vary depending on the vision based feedback of patient hand.

Firstly, the problem of generating a point to point circular motion in Cartesian space (x,y,z) which involved the trajectory of robot to move from initial position to final position and in multidimensional space. In this problem, there is computational burden where if the number of point to point increases, the calculation will be more. However, by increasing the number of point, it will improve the smoothness of circular path. In this project, to generate the circular path, it requires the combination of trigonometry formula with circumference formula.
Next is the problem in identifying the positions (x,y,z) and orientation of robot’s arm end effector when generating a circular motion that can vary depending on the vision based feedback of patient hand. The problem involved in describing the transformation of points and coordinates systems and describing the position and orientation of one coordinate system relative to another. The present of vision sensor make the robot have to follow the input from the vision feedback. The accuracy of tracking will decreases when the speed is increases. In this project, by combining the equation of straight line and applying some image processing technique such as blob detection, centroid detection and using inverse kinematic it can tracking the image accurately.

1.3 Objective

The objectives of this projects are:

1. To analyse the problem of generating circular path and tracking method using a vision based robot.
2. To develop circular path algorithm and vision based circular tracking algorithm to match with the patient hand motion.
3. To validate the smoothness of circular path and the accuracy of a vision based KUKA youBot motion when tracking and following the patient hand motion using statistical method.

1.4 Scopes of the Project

The scopes of this project are:

- The research is focused on positioning of 5DOF KUKA youBot in circular motion.
- The generation of circular motion is validates by the equation of circle by using MATLAB.
• The generation of circle path is by using LUA and simulated in VREP.
• The generation of tracking algorithm is by using transformation matrix in LUA and simulated in VREP.
• The performance of KUKA youBot is measure in terms of error and accuracy.
CHAPTER 2

LITERATURE REVIEW

2.1 Robotic Rehabilitation

In this era, the research on robotic rehabilitation technology has widely used in biomedical engineering. The used of robotic technology for rehabilitation purpose has help to give motivation to patient with upper limb problem. Generally, in the rehabilitation therapy patient was taught with repetitive motion to improve the smoothness with the help of therapist [5]. Same goes with robotic training, the patient also will receive repetitive movement in order to motivate themselves for recovery. The technique applied in the rehabilitation able to determine the adaptability level of the patient [6].

There are several training programs for enhancing the smoothness of hand motion such diagnosis, teaching with active-assistance robot, training with passive assistance and training with no assistant [7]. Some training enables the patient to move their patient in the pathway without any force pushing it. There are also a training that require an active movement with opposing force which when the patient try to move outside the set path there force that will prevent the hand movement [6].

The research on robotic training has been gradually improved with the applications of many types of sensor and controller such as using virtual curling task, game-based training and visual servoing feedback. In this project, the robot will be the assistant to give motivation to patient by getting the feedback from patient movement via camera. Therefore, the study of visual based robot for hand rehabilitation will help me to get information and knowledge.
2.2 Generation of Circular Path

In order to generate a circular path, there are two types of space which is joint space and Cartesian space. For this project it involves Cartesian space to generate the initial and final point to move the end effector. There are more than two points needed to generate a circular path. Since this project is about rehabilitation of hand, the motion of path is free circular shape and no need a precise controlled path. Therefore PTP is suitable to describe the robot motion. In PTP the movement from point A to point B is not necessary to be in straight line as shown in Figure 2.1. There is acceleration at the starting point and deceleration at the end point as describe in the Figure 2.2 below:

![Figure 2.1: Robot path in PTP](image)

Figure 2.1: Robot path in PTP [13]

![Figure 2.2: Acceleration and deceleration of link from start and end motion](image)

Figure 2.2: Acceleration and deceleration of link from start and end motion [13]
To reduce the acceleration and deceleration, the number of point to point can be increases and the time taken from one point to other will become short thus make the trajectory smooth.

2.2.1 Trajectory for Generating Circular Path

In this project the trajectory is to move the end effector from initial position to the desired position and to determine the smoothness of robot joint position in circular motion. Trajectory generation is related to the computation of desired motion of a manipulator to be smooth in multidimensional space. Trajectory also refers to a time history of position, velocity, and acceleration for each degree of freedom. The term trajectory generation is not only generating a path for a tool frame to be located within a tool frame, but also includes the human interface issue with the robot’ path specification [11]. Trajectories are important because they enable the system to ensure feasibility where the motion can be verified to respect the dynamic constraints of lower level controllers [12]. The block diagram below shows the overview of trajectory system:

![Figure 2.3: Trajectory generation overview [11]](image-url)
The goal of trajectory generation is to describe the required motion of the manipulator as time sequence of joint/link/end-effector locations and derivatives of locations that is generated by interpolating or approximating desired path by a polynomial function.

Trajectory planning produced time history serve as reference input to the manipulator control system and the control system ensure that manipulator executes the planned trajectories [13].

For rehabilitation purposes, the required motion is the motion that generate by the patient with muscle problem. Therefore, the motion of joint is limited and it is generated by imposing the inverse kinematic that drives the manipulator to the desired position. The available inverse kinematic also will determine the accuracy and precision of the robot arm joint motion.

2.2.2 Problems of Generating Circular Path in Cartesian Space

In this project, the simulation is in Cartesian space since in reality the motion of patient hand is in terms of (y,z) coordinates. In Cartesian space, the velocity, position and acceleration is determine in terms of Cartesian coordinate (x,y,z) and the joint actuators are served in joint coordinates to the specific trajectory. To use this technique, user need to specify the desired end-effector path, the travelling time, and the tool orientations along the path [13]. Cartesian technique is quite complex to use compared to joint space. However, it is easy to use this technique if we wish to do straight line path or circular path because it is more accurate. Not only that, if around our workspace have obstacles, it is more suitable to use Cartesian coordinates. The limitation of this technique is singularities may occur at the manipulator. There are some challenges that related with Cartesian path such as intermediate points unreachable, high joint rates near singularity and start and goal reachable in different solutions.
However for rehabilitation purpose, the challenges that might be face in doing the trajectory in circular motion is that the problems of high joint rates near singularities start and goal reachable in different solutions. It is important to discuss this problem because the circular hand motion that is generated by patient might be too big or too small depends on their muscle strength. Therefore, there are possibility that robot might face these problems.

A. Type 1: Problem of high joint rates near singularities

In this problem, by referring to Figure 2.3.1(a) below, it shows that the planar wants to move along path point A to point B. The desired velocity is needed to be constant when moving along the straight line path. However, as it goes to the middle point the velocity of joint one is very high [11].

In the hand rehab point of view, the singularities also might happen when doing circular motion. If the velocity of the joint is high, it will make the joint unable to track human hand properly due to the sudden velocity change.

B. Type 2: Problem of start and goal reachable in different solutions

In this problem, the planar has two-link with equal lengths. This makes the joints limits restrict the number of solutions where it can reach a given point in space. The problem is that the robot might not have same physical solution as the start point to reach goal point. In the it hand rehab view, this problem will happen if the two equal length links with a