

Method of Trajectory Generation of a Generic Robot using Bresenham's Circle Algorithm

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Abstract

Objectives: This paper characteristic the proposed method of trajectory generator of designing the mechanical type manipulator configuration as called the robot model after validating the kinematic analysis and software simulation of the mechanism. **Methods/Statistical Analysis:** The robot manipulator has utilized in this paper used for welding operation. In the mechanical configuration the successful utilization of newly designed universal joints and also the use of screw jack mechanisms at the robot manipulator base give the higher flexibility and degrees of freedom (dof) in the arms of the robot. This paper also describes the path planning of the robot based on the computer graphics concept of Bresenham's line and circle algorithm for trajectory generation. This paper also describes the path planning of the robot based on the Bresenham's line and circle algorithm concepts. **Findings:** This type of algorithm proved to generate the trajectory is very much effective, accurate and fast manner. From the trajectory points the new way of finding the joint angles was found using the inverse kinematics relationship were explained in this paper. **Application/Improvements:** This work is an essential parameter for robot trajectory formation with the given diameter of the cylinder to be going to be welded.

Keywords: Bresenhams Circle Algorithms, Robot Manipulator, Trajectory Generation, Welding Robot

Introduction to Robotic Welding Technology

In the current world the development of Industry depends upon the effective utilization of modern Mechatronics equipment specially robots in the late decades particularly in the welding process. Because of increasingly difficult to employ manual welders now a day for easily^{1,2}. There has a tendency to be a high definite amount work of supervised turnover and this type of course causes the cost for recruitment and need a highly proper method of training skills. The current robotic welding process has lot of advantages as listed in Figure 1.

When labour is a major issue in industries regularly find they working beyond the regular hours called over-time or taking to utilize extra contract labour to meet these kinds of demands and this can surely have a major



Figure 1. Advantages of welding robots in industries.

and serious impact on working company and increases the production costs³. If products cannot be provided to the regular and end customer, these types of losses must be acquired or future important business activities may be at risk without using the automation. While there must

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always be a necessity for labour power in manual welding, companies must that invest and implement the concept of robotic automation are more effective than the manual welding.

2. Related Studies on Arc Welding Robot Trajectory Generation

Industrial robots must have high degrees of flexibility to execute different welding operations and work together with human assistance⁴. Compared with human flexibility, a robot has a multitude of problems to understand even a high accurate movement and motions in a definite working space⁵.

The path planning procedure of the robot arm is the planning of the whole way of motion of the end effectors or gripper of the robot manipulator in a three dimensional space with determined coordinates. This path includes numerous continuous motion trajectories that need the proper trajectory planning for achieving good welding tasks^{6,7}. This type of algorithms were-discussed with a extensive literature review on methods of optimal motion planning of robots also the author described the methods of target point generation in X,Y,Z axis of a robot trajectory from the start coordinates to final coordinate or goal coordinate that fulfils the defined objectives of this paper , such as optimising or minimizing the path achieved by the travelling path distance or in terms of time interval with lowest energy which needed to be consumed in the minimum level or any obstacle in the path that must be eliminated by avoidance methods and satisfying with the help of the robot manipulator kinematics study and dynamics study of the elements presented^{8,9}. The discussion of the trajectory generation and investigation of the robot manipulator on optimization techniques causes to find the optimal method of trajectory planning either in 2D or 3D Cartesian working space or a robot joint space are studied, presented and investigated by using algorithmic approach properly in this paper¹⁰.

Optimal trajectory method of a robot path planning selection and design approaches such as kinematics study and dynamics study techniques with various motion constraints are presented and explained. Although the kinematics approach is simple method and forward kinematics, it would experience and causes many problems and difficulties in implementation because of lack of Inertia and torque constraints in actuators side.

The authors finally concluded that the application of a new approach of Genetic Algorithms to meet and use to find the optimal path planning and trajectory of the robot manipulators especially in the obstacle avoidance is also emphasized. Combining the Genetic Algorithms and investigated on obstacle avoidance trajectory planning. This work also involves the development and use of the hybrid approach for trajectory generation and tracking of a 5-dof robotic arm¹¹. The inverse kinematics model and method of controlling the path and a type of a resolve motion rate control method are physically experimented to calculate and evaluate the performances and measures in terms of accuracy and time response in trajectory tracking. According to this approach trajectory for the taken robot arm to follow in the two dimensional Cartesian space or work space are obtained by the image processing method. This suggests having a transformation from the visual information of the external model to the implementation information of the P2Arm¹².

The transformation process provides the position/orientation of a specific point and the treating of sequential images produces a system of goal points. The effective method of a methodology developed for performance or execution time trajectory generation for the robots used in SMAW application¹³. In this methodology, while the weld electrode is melting the robot makes the diving movement, keeping the parameter of electric arc length to be a constant. The trajectory is generated during the weld execution time as a function of melting rate of the base metal and this method is independent of the welding speed. The proposed methodology practices a variable Tool Centre Point (TCP) model where the shielded weld electrode is considered to be a prismatic joint of a robot, whose displacement is a mathematical function of meting rate of metal^{14,15}. In this work the authors used a KUKA welding robot for investigation.

Another research work which used a concept of machine vision with robot path planning with a purpose of programming-free robotic tasks and applications¹⁶. Particularly as a proof of concept, a programming-free robotic sketching prototype is developed as a research work. Within the framework, they discussed three important parameters in the first study covers the handling of a facial image taken by a webcam to recognise the contours that represent the image; the second study converts these contours to tracks for an industrial robot to follow; and the third study controls the robot adaptively for sketching including automatic -generation of control codes and

achieved a self-calibration. The developed model is a type of closed-loop control system through networked camera and robot system. Intelligent computation was used to identify the contours of the image with minimum number of points and with the correct sequence of points for each path; the sequence of the output robot paths represents the near suitable sequence to reserve the minimum travelling time for the robot.

The robot control module can also retrieve the tool centre point of the robot for off-site monitoring. In particular, they introduced a web-based system that offers the ability for remote operators to monitor and control an industrial robot. Other work is presented¹⁷ an implementation of an effective machine learning system for trajectory reproduction of a robot also described the use of an optical measuring scheme to a trajectory tracking problem through the aim of training a welding robot in a combined system of man-machine welding station. The optical system permits a fast and reliable training of the welding tasks communicated by the human co-worker¹⁸.

An algorithm was established for this application filters inaccurate and noisy data, re-orders points and divides a trajectory suitable for a welding robot. This can reduce the time required for programming a robot. The industrial significance of this application was essential for it increases the safety of human workers by using the robot to perform the risky tasks, namely the robot welding, on the other side it assures higher repeatability than manual execution methods.

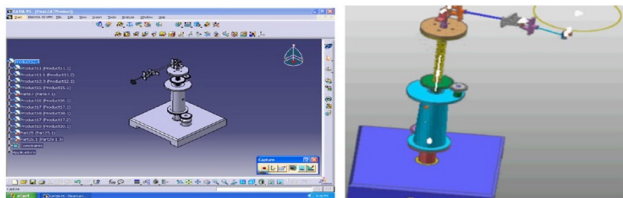


Figure 2. Modelling of robot arm.

3. Designed Mechanical Configuration of a New Robot Arm

The robot manipulator considered this work as a whole mechatronics system which is fabricated with several internal mechanical components. The robot mainly consists of two parts viz. Base part and the arm of the robot. The base of the robot comprises of lifting mechanisms. The arms are stable, which carries the welding gun. The important and essential components of the proposed

robot are listed below and also modelled by using the CAD modelling software as shown in Figure 2.

1. Base: - Mechanical stability
2. Screw jack mechanism: - Rise or lower the manipulator.
3. Universal Coupling at arm joints: - To Provide more flexibility in link movement.
4. End Effector: - to hold the welding gun.

The total degree of freedom of the robot = 1 d.o.f (base rotation) + 1d.o.f (up & down motion) +2d.o.f (universal joint motion at first arm) +2d.o.f (2nd universal joint motion at second arm+ 1d.o.f (end knuckle motion) = 7 d.o.f.

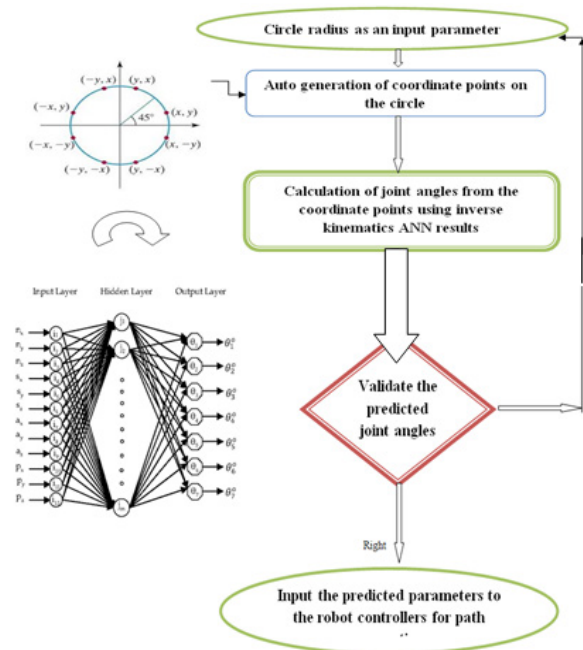


Figure 3. Algorithm for Robot circular weld trajectory.

4. Procedures for Robot Circular Weld Trajectory using Bresenham's Circle Algorithm

The circular path welding trajectories were generated by using the Bresenham's algorithm^{19,20} was proposed in this work. From this algorithmic approach the Cartesian coordinates of the point which is on the weld path were automatically calculated for the given radius of the circle. These points were further utilized for calculating the different joint angles present in the robot manipulator using the inverse kinematics results in the previous work. These types of developed algorithms are based on the indica-

tion of defining the subsequent trajectory dimensioning points required to draw the circle which is shown in Figure 3. According to the procedures of Bresenham's circle algorithm shown in Figure 4.

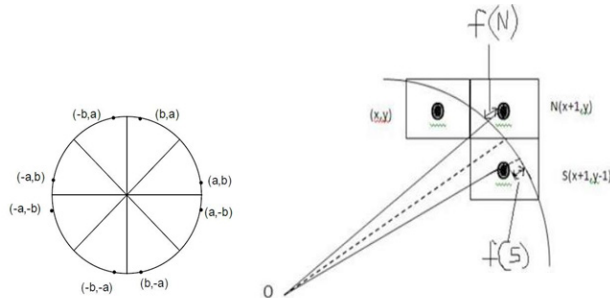


Figure 4. Bresenham's circle algorithm.

The equation of a circle is $X^2+Y^2=r^2$, where r is radius.

Algorithm steps

- Step 1 – Get the X,Y coordinates in the centre of the welding circle and radius. (Store them in Px, Py, and R (Radius). Set P=0 and Q value = R (radius).)
- Step 2 – Let the decision constant parameter $D = 3 - 2R$.

- Step 3 – Repeat the procedure defined step-8 while $PX < PY$.
- Step 4 – Call the Drawing specified Circle (PX, PY, P, and Q).
- Step 5 – Increment the obtained value of P.
- Step 6 – If the value of $D < 0$ then assign $D = D + 4Px + 6$.
- Step 7 – Else Set the value of $Y = Y + 1$, and the value of $D = D + 4(PX-PY) + 10$.
- Step 8 – Call Drawing specified Circle (PX, PY, P, and Q).
- Step 9 – Print the coordinate point on the circumference of the circle.

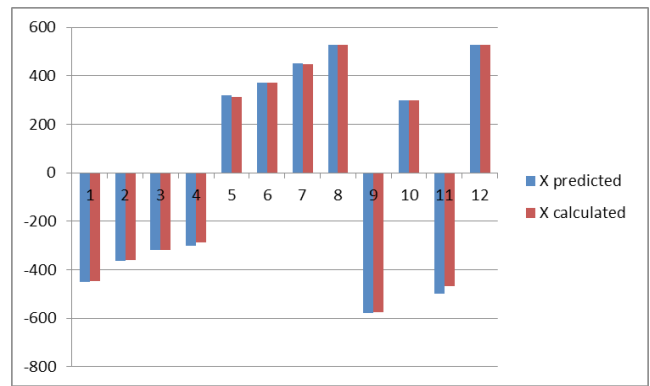


Figure 5. Comparison graph of X coordinate values.

Table 1. Predicted coordinate points Vs. Calculated Coordinate points on weld trajectory

SL no.	Point description	Predicted coordinate point on the circular weld trajectory using algorithms	Calculated Coordinate points on the robot trajectory using Computer aided plotting framework	% of error in X coordinates	% of error in Y coordinates
1	P1= (X1,Y1,Z1)	(-450,-150,900)	(-448.23,-152.27,900)	0.39	1.51
2	P2= (X2,Y2,Z2)	(-365,-130,900)	(-360.34,-129.98,900)	1.27	0.01
3	P3= (X3,Y3,Z3)	(-320,-75,900)	(-317.89,-75.34,900)	0.65	0.45
4	P4= (X3,Y3,Z3)	(-300,0,900)	(-288.67,0,900)	3.77	0
5	P5= (X5,Y5,Z5)	(319,71,900)	(312.67,73.34,900)	1.97	3.29
6	P6= (X6,Y6,Z6)	(370,122,900)	(371.23,119.23,900)	0.33	2.27
7	P7= (X7,Y7,Z7)	(450,150,900)	(448.97,152.9,900)	0.22	1.93
8	P8= (X8,Y8,Z8)	(-529,126.3,900)	(-527.99,124.987,900)	0.19	1.03
9	P9= (X9,Y9,Z9)	(-579,75,900)	(-576.45,74.87,900)	0.44	0.17
10	P10= (X10,Y10,Z10)	(300,0,900)	(299.96,0,900)	0.01	0
11	P4= (X11,Y11,Z11)	(-500,-75,900)	(-469.234,-73.45,900)	6.15	2.06
12	P4= (X12,Y12,Z12)	(529,-130,900)	(527.989,-128.56,900)	0.19	1.10

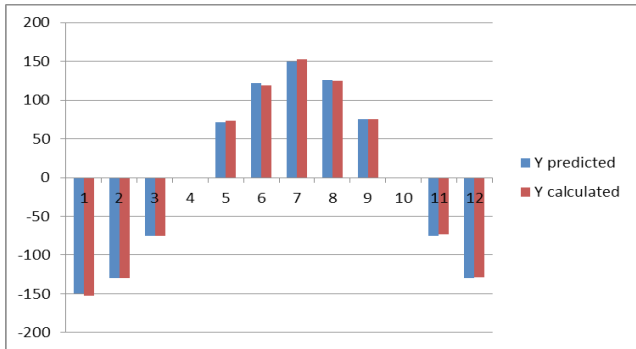


Figure 6. Comparison graph of Y coordinate values.

The following Table 1 indicates the variation in x, y coordinates of the robot Cartesian parameters calculated using the proposed algorithms. Here the reference values are taken from the computer aided plotted results using CAD software^{21,22}. The weld trajectory for the required circular path first can be modelled in the drawing software and the coordinate points were taken from the centre of the robot axis and the circumference points of the weld path. The comparison of predicted vs the calculated values were shown in graphical manner in Figures 5 and 6.

5. Conclusions

From this paper the accurate path planning of the required welding motion has been calculated from the radius of the circular path only. The single data is only the parameter to identify the robot joint parameters using the kinematics equation of the robot. The percentage of error is to be reduced for choosing of the correct coordinate values of the circumference points. The Bresenham's algorithms are used to predict the points using the software. The final step these points were sent to the controller of the robot for achieving the trajectory. Usually more error was observed in the X coordinate points because of the dramatic changes or increments in the values.

6. References

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