Maestría en Ingeniería en Automatización de Procesos Industriales

Title

Automation of a polishing system

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1. Introduction

Today, most of the work surface polishing is done manually by operators, however, the manual polishing is expensive, slow, laborious, error-prone, as well as the needs and overall requirements polishing are changing rapidly with the growing demand for surface quality, therefore, manual methods and old machines conventional polishing are slowly becoming obsolete, the need to improve part quality, efficiency and methods profitable manufacturing encouraged new approaches machining and polishing automation polishing process.

Despite its similarity to the CNC machining methods, the robotic machining has advantages over conventional CNC machining as high flexibility, relatively low investment, long working hours.

Polishing is a type of finishing process done after machining, has its specialty compared to other machining processes, the purpose of polished is to reduce surface roughness and improve quality without changing the geometric shape of the surface. Polishing does not require a high positioning accuracy, it is for this reason that articulated robots are potentially more suitable for automation of polishing a surface.

The development of automation system polished, no doubt can help, significantly, the industrial sector dedicated to machining processes, surgical, automotive, among others, offering alternatives for improving their production processes.

2. Objectives

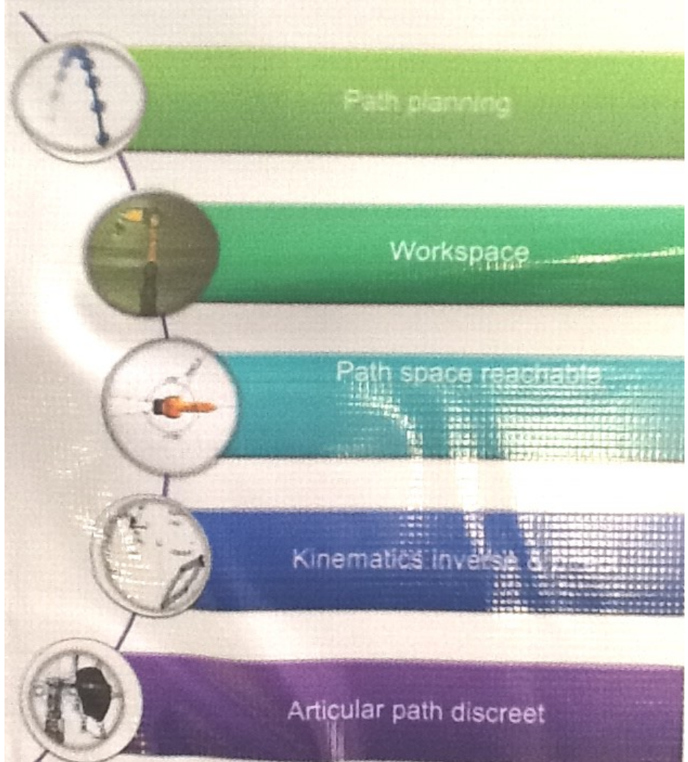
2.1. General objective

Automate the polishing system simple geometries by programming paths in PLM and MATLAB software to select the most appropriate.

2.2. Specific objectives

- To model direct and inverse kinematics for an anthropomorphic industrial robot with six degrees of freedom.
- To perform the simulation and programming simple polished paths.
- To analyze the results to select the most appropriate paths for polishing system.

3. Method



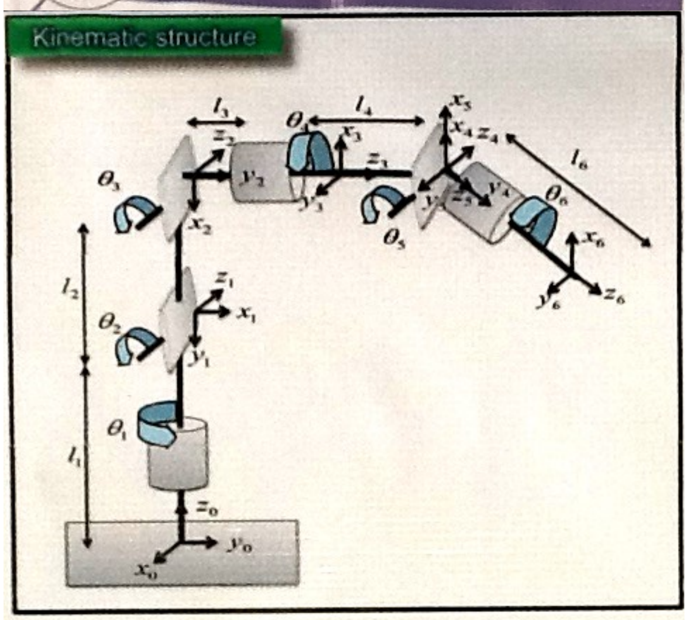


Figure 2. Kuka KR6 R900 robot kinematics structure

Denavit Hartenberg geometric parameters

Articulación	θ	D	A	α
1	$\theta_1+\pi/2$	l_1	0	$-\pi/2$
2	$\theta_2+\pi/2$ [illegible]	[illegible]	[illegible]	[illegible]
3	$\theta_3+\pi/2$	0	0	$\pi/2$
4	θ_4	l_4	0	$-\pi/2$
5	θ_5	0	0	$\pi/2$
6	θ_6	[illegible]	0	0

From this table you can be found direct geometric model to calculate the position and orientation of the robot end effector in cartesian space:

$$ {}^0_6H = {}^0_1H\,{}^1_2H\,{}^2_3H\,{}^3_4H\,{}^4_5H\,{}^5_6H $$

4. Results

The result of the direct kinematics of KUKA KR6R900 robot using homogeneous transformations, which represent the orientation and translation of the working tool with respect to the fixed reference system located at the base of the robot:

$$ {}^0_1H=\begin{bmatrix}\cos\theta_1 & -\cos\alpha_1\sin\theta_1 & \sin\alpha_1\sin\theta_1 & 0\\ \sin\theta_1 & \cos\alpha_1\cos\theta_1 & -\sin\alpha_1\cos\theta_1 & 0\\ 0 & \sin\alpha_1 & \cos\alpha_1 & l_1\\ 0 & 0 & 0 & 1\end{bmatrix} $$

$$ {}^1_2H=\begin{bmatrix}\cos\theta_2 & -\cos\alpha_2\sin\theta_2 & \sin\alpha_2\sin\theta_2 & a_2\cos\theta_2\\ \sin\theta_2 & \cos\alpha_2\cos\theta_2 & -\sin\alpha_2\cos\theta_2 & a_2\sin\theta_2\\ 0 & \sin\alpha_2 & \cos\alpha_2 & 0\\ 0 & 0 & 0 & 1\end{bmatrix} $$

$$ {}^2_3H=\begin{bmatrix}\cos\theta_3 & -\cos\alpha_3\sin\theta_3 & \sin\alpha_3\sin\theta_3 & 0\\ \sin\theta_3 & \cos\alpha_3\cos\theta_3 & -\sin\alpha_3\cos\theta_3 & 0\\ 0 & \sin\alpha_3 & \cos\alpha_3 & 0\\ 0 & 0 & 0 & 1\end{bmatrix} $$

$$ {}^3_4H=\begin{bmatrix}\cos\theta_4 & -\cos\alpha_4\sin\theta_4 & \sin\alpha_4\sin\theta_4 & 0\\ \sin\theta_4 & \cos\alpha_4\cos\theta_4 & -\sin\alpha_4\cos\theta_4 & 0\\ 0 & \sin\alpha_4 & \cos\alpha_4 & l_4\\ 0 & 0 & 0 & 1\end{bmatrix} $$

$$ {}^4_5H=\begin{bmatrix}\cos\theta_5 & -\cos\alpha_5\sin\theta_5 & \sin\alpha_5\sin\theta_5 & 0\\ \sin\theta_5 & \cos\alpha_5\cos\theta_5 & -\sin\alpha\cos\theta_5 & 0\\ 0 & \sin\alpha_5 & \cos\alpha_5 & 0\\ 0 & 0 & 0 & 1\end{bmatrix} $$

$$ {}^5_6H=\begin{bmatrix}\cos\theta_6 & -\cos\alpha_6\sin\theta_6 & \sin\alpha_6\sin\theta_6 & 0\\ \sin\theta_6 & \cos\alpha_6\cos\theta_6 & -\sin\alpha_6\cos\theta_6 & 0\\ 0 & \sin\alpha_6 & \cos\alpha_6 & l_6\\ 0 & 0 & 0 & 1\end{bmatrix} $$

Figure 4. Homogeneous matrix generated from the table Denavit Hartenberg

below the coordinates of the trajectory shown in the drawing surface of the workpiece

4. Results

Position working tool	Angle of joints
$P_i=[x\ y\ z]=[776.962\ 156.934\ 361.607]$ $P_f=[x\ y\ z]=[776.962\ 156.934\ 526]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.962\ 156.934\ 526]$ $P_f=[x\ y\ z]=[776.962\ 131.924\ 526]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.962\ 131.934\ 526]$ $P_f=[x\ y\ z]=[776.962\ 131.924\ 362.999]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.962\ 131.924\ 362.999]$ $P_f=[x\ y\ z]=[776.962\ 106.924\ 362.999]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.962\ 106.924\ 362.999]$ $P_f=[x\ y\ z]=[776.962\ 106.924\ 526]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.962\ 106.924\ 526]$ $P_f=[x\ y\ z]=[776.962\ 81.924\ 526]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.962\ 81.924\ 526]$ $P_f=[x\ y\ z]=[776.962\ 81.924\ 362.999]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.962\ 81.924\ 362.999]$ $P_f=[x\ y\ z]=[776.962\ 56.914\ 362.999]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.962\ 56.914\ 362.999]$ $P_f=[x\ y\ z]=[776.962\ 56.914\ 526]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.962\ 56.914\ 526]$ $P_f=[x\ y\ z]=[776.963\ 31.905\ 526]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.961\ 31.905\ 526]$ $P_f=[x\ y\ z]=[776.961\ 31.905\ 362.999]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.961\ 31.905\ 362.999]$ $P_f=[x\ y\ z]=[776.961\ 6.904\ 362.999]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.961\ 6.904\ 362.999]$ $P_f=[x\ y\ z]=[776.961\ 6.904\ 526]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.961\ 6.904\ 526]$ $P_f=[x\ y\ z]=[776.961\ -18.095\ 526]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]
$P_i=[x\ y\ z]=[776.961\ -18.095\ 526]$ $P_f=[x\ y\ z]=[776.961\ -18.095\ 362.999]$	$\theta=[\theta_1\ \theta_2\ \theta_3\ \theta_4\ \theta_5\ \theta_6]=$ [illegible]

Figure 5. Coordinates and angles of the joints of the path trace

Through reverse kinematic algorithm design, a spatial path defined in MATLAB software on one the faces of the cube with dimensions 20 cm x 20 cm.

Three degrees of rotational freedom which correspond to the shoulder, elbow and extreme end are observed, because there are degrees of freedom rotating on its axis we can not notice them in wiring these correspond to waist, forearm and wrist.

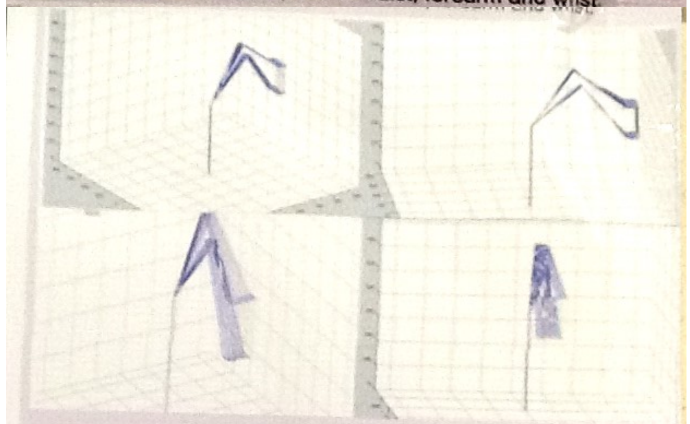


Figure 6. Polished path through the surface of a cube

Then the path previously designed in MATLAB, now the polished path is presented in CATIA-DELMIA.

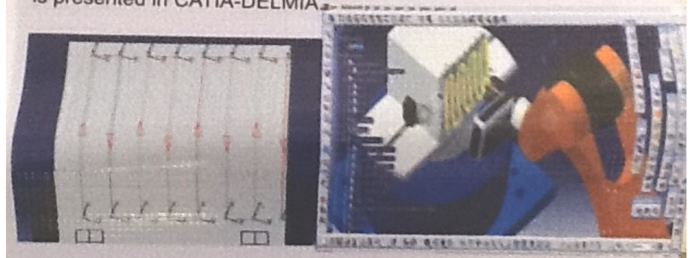


Figure 7. Polished path in software CATIA-DELMIA

5. Conclusion

The Denavit-Hartenberg method allows direct kinematics through a matrix method that systematically establishes a coordinate system linked to each link of the link chain, thus determined the kinematic equations of the entire chain. Obtaining inverse kinematics through the geometric method allows to develop paths to locate the far end through a cartesian plane, simulations in MATLAB and CATIA-DELMIA allow us to observe the movements of the links of the robot KUKA KR6 R900 and the evaluation of different paths. It should be noted that they are currently developing different paths polished for this and other geometries in order to determine the best option.

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