INVERSE KINEMATICS IN A ROBOTIC ARM AND METHODS TO AVOID SINGULARITIES

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AVINASH KUMAR , Roll No.- 10105017

Solid Mechanics & Design , IIT Kanpur

Abstract

Today robots are used in every walk of human life. All over the world, robots are on the move. In order to co-operate with a human, a robot should have a human-like behavior when moving. To achieve this, it is necessary to give the robot humanlike configuration and human like kinematics. Such configurations can be built out of elementary joints linked to each other in such a manner that they form circular joints. In this paper we describe a method to avoid these singularities in the wrist and elbow for a redundant robotic arm.

Keywords : Robot, Kinematics, Inverse kinematics, Singularity, redundancy

INTRODUCTION

The robot system consists of various building blocks like 1) Actuators 2) Sensors :- to enable a co-operation by physical means and enables the robot to react to forces applied to the robot by the human partner and also to register forced applied by the robot to the human. 3) Kinematics :- to understand the concept to analyze the complex movements of a robot and the operations it can perform. 4) Dynamics To solve the inverse kinematics of the robot we use the closed solution that provides joint angles for the position of the elbow when positioning the robot's hand. Therefore, it is very important to avoid singularities in the kinematics of the robotic arm because of the high speed of some parts of the robot while passing these singularities is dangerous to the human partner while human and the robot are in physical contact with each other. Kinematics can be further classified into two broad categories: 1. Forward Kinematics 2. Inverse Kinematics.

WHAT IS INVERSE KINEMATICS ???

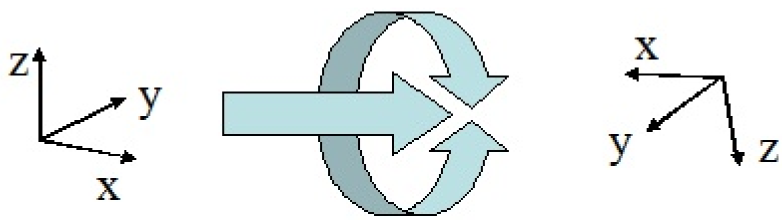
In a two joint robotic arm, given the angles of the joints, the kinematics equations gives the location of the tip of the arm. Inverse kinematics refers to the reverse process. Given a desired location for the tip of the robotic arm, what should be the angles of the joints be so as to locate the tip of the arm at the desired location. There is usually more then one solution and can at times be a difficult problem to solve. In a 2-dimensional input space, with a two joint robotic arm and given the desired co-ordinates, the problem reduces to finding the two angles involved.

• For a robot system the inverse kinematics problem is one of the most difficult to solve.

• The robot controller must solve a set of non-linear simultaneous equations.

• The problems can be summarised as:

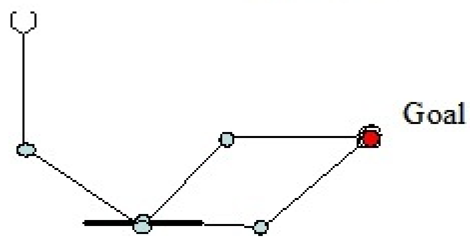
1. The existence of multiple solutions.
2. The possible non-existence of a solution.
3. Singularities.



• This relationship is mathematically represented by a 4 ´ 4 Homogeneous Transformation Matrix, as show

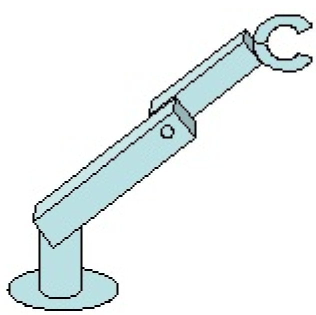
$$
\begin{array}{c}
3 \times 3 \text{ Rotation} \\
\\
1 \times 3 \text{ Perspective}
\end{array}
\left[\begin{array}{ccc|c}
r11 & r12 & r13 & x \\
r21 & r22 & r23 & y \\
r31 & r32 & r33 & z \\
\hdashline
0 & 0 & 0 & 1
\end{array}\right]
$$

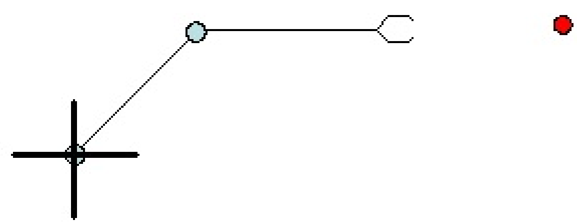
Multiple Solutions



- This two link planar manipulator has two possible solutions.
- This problem gets worse with more ‘Degrees of Freedom’.
- Redundancy of movement.

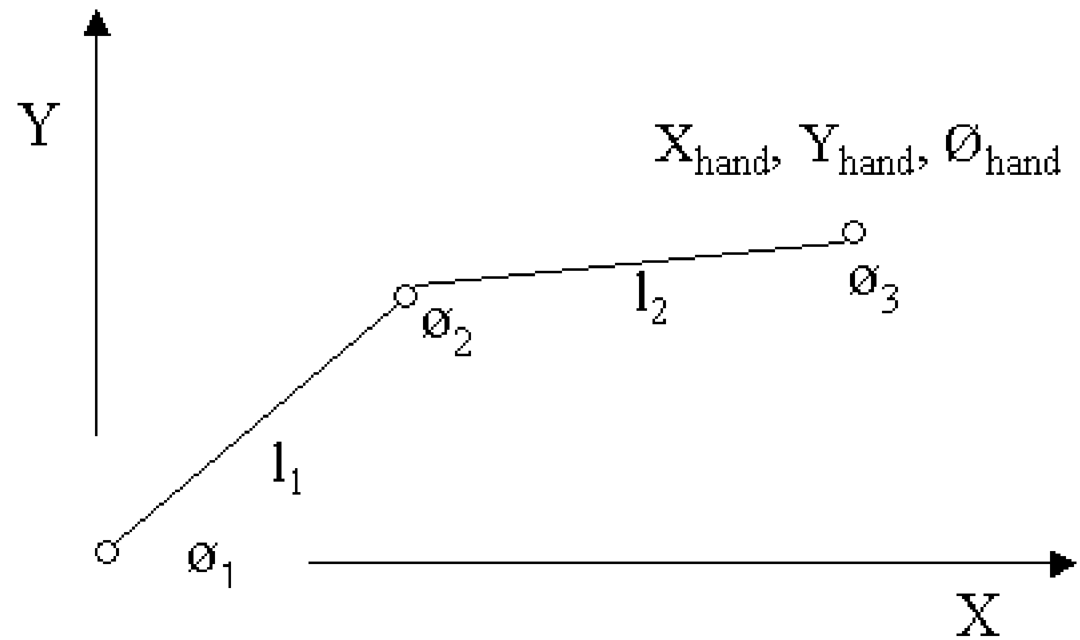
Non Existence of Solutions





- A goal outside the workspace of the robot has no solution.
- An unreachable point can also be within the workspace of the manipulator - physical constraints.
- A singularity is a place of infinite acceleration

At the position level, the problem is stated as, "Given the desired position of the robot’s hand, what must be the angles at all of the robots joints?" Below we will look at how most robots have to solve the problem.



The above schematic diagram represents the planar part of a “six degree of freedom” industrial robot. Here is the statement of the inverse kinematics problem at the position level for this robot

Given: Xhand, Yhand, Øhand

Find: Ø1, Ø2 and Ø3

To aid in solving this problem, we are going to define an imaginary straight line that extends from the robot’s first joint to its last joint as follows:

B: length of imaginary line

q1: angle between X-axis and imaginary line

q2: interior angle between imaginary line and link l1

Then we have:

B2 = Xhand2 + Yhand2 (by the Pythagorean theorem)

q1 = ATan2(Yhand/Xhand)

q2 = acos[(l12 - l22 + B2)/2l1B] (by the law of cosines)

Ø1 = q1 + q2

Ø2 = acos[(l12 + l22 - B2)/2l1l2] (by the law of cosines)

Ø3 = Øhand - Ø1 - Ø2

That completes the solution for Ø1, Ø2 and Ø3 given Xhand, Yhand, Øhand. Most inverse kinematics solutions at the position level proceed in a similar fashion. It can be difficult, and there are usually many or infinitely many solutions. This process can be extremely useful in robotics

AVOIDING SINGULARITIES

Basic problem:

The wrist is realized as a roll-pitch-roll configuration. There are three points in such a configuration in which singularities can occur. One is the shoulder, one is the elbow and one is in the wrist.

The solution for inverse kinematics is got by using the equation:

roll =a tan2 (y,x) , pitch=a tan2 (z, √(x2+y2))

Avoiding singularities in the wrist:

The singularities in the wrist can simply be avoided by used configurations. Although singularities always occur when trying to build a spherical joint by using elementary joints, in this case, the singularities would occur behind the joint limits given by the human anatomy

Avoiding singularities in the elbow:

In the elbow the singularity occurs when the elbow is fully stretched out, because then, the last axis of the upper arm and the first axis of the lower arm are in line. in such a case there are multiple solutions for the orientation of the elbow. This problem is solved by just not stretching out the elbow fully. In order to do this, the arm has to be increased in length to enable the robot to reach the same position the arm could reach as if it were completely stretched out.

CONCLUSION:

In this paper we have analyzed what is meant by inverse kinematics in the robotic arm, the various features and the equations involved in contemplating inverse kinematics for a redundant robotic arm. A solution has been introduced to avoid singularities in the kinematics of a human like robot arm, in the wrist and in the elbow. Using this method safety in robot human co-operation can be greatly increased. This was achieved by evading singularities using a combination of joint angle restrictions and elongation of the arm segments in order to compensate the resulting loss in workspace.

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