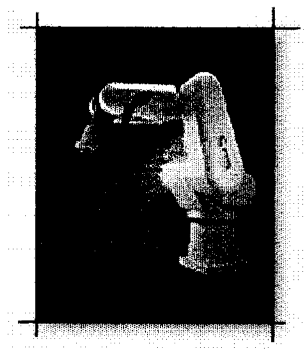
Robotics, CpE 360



Assignment # 1

Good Job!

Submitted to: Prof. Sobh

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Intro to Robotics, CpE 360
Assignment # 1

Problems and solutions:

1.1 What are the key features that distinguish robots from other forms of "automation," such as CNC milling machines?

Sol: Devices that can be programmed to execute a wide variety of motions, without human intervention termed as robots are simply a combination of CNCs and teleoperators.

1.2 Briefly define each of the following terms: forward kinematics, inverse kinematics, trajectory planning, workspace, accuracy, repeatability, resolution, joint variable, spherical wrist, end effector.

Sol: The terms are defined as:

Forward kinematics or the direct kinematics is the position and orientation of the end-effector of the manipulator with respect to a reference coordinate system.

Inverse kinematics is a desired position and orientation of the end-effector of the manipulator and the geometric link parameters with respect to a reference coordinate system.

Trajectory planning approximates the desired path (the space curve that the manipulator hand moves along from the initial location to the final location) by a class of polynomial functions and generates a sequence of time based control points for the control of the manipulator from the initial location to its destination.

Workspace is the area that the end of the manipulator can reach with a particular orientation. Moreover, the workspace of a manipulator must be adequate for a task.

Accuracy is a measurement for the manipulator showing how close it can come in its workspace to a given point.

Repeatability is a measurement for the manipulator showing how close it can return to the desired previous point.

Resolution is the smallest increment of motion that the controller can sense.

Joint Variables refers to the varying quantity and represent the relative displacement between adjacent links. Simply, it can be denoted as θ_i or *di* for a revolute joint and a prismatic joint respectively.

Spherical wrist is a wrist that's joint axes intersect at a common point.

End Effector made of the arm and wrist is the end tool that actually does the work and is used primarily for positioning.

1.3 What are the main ways to classify robots?

Sol: A robot is a reprogrammable multi-functional manipulator designed to move materials, parts, tools, or serialized devices, through variable programmed motions for the performance of a variety of tasks. Robot manipulators can be classified by several criteria as geometry, kinematics structure, design and so on. Basically, they are classified as

- RRR - Articulated

- RRP - Spherical
- RRP - SCARA configuration
- RRP - Cylindrical
- PPP – Cartesian.

1.6 List several applications for non-servo robots for point-to-point robots, for continuous path robots.

Sol: The earliest robots, **non-servo robots**, use open loop computer control devices and their movement is limited to predetermined mechanical stops. They are useful in materials handling, and for special purpose services.

Point-to-point robots are usually programmed to follow a set of points but the path of the end effector is no under control. They are useful in materials handling, welding and so on.

Continuous path robots have the entire path of the end effector under controlled and the velocity and/or acceleration of the end effector can be controlled. They are useful in various fields as welding, grinding, painting, transferring and so on.

1.7 List five applications that a continuous path robot could do that a point-to-point robot could not do.

Sol: In practice continuous path robots could do more than a point-to-point robot could not do because they can be highly controlled. As painting, welding, grinding, debarring, polishing can be efficiently done by the continuous path robots while point-to-point robot fails to conduct.

1.8 List five applications where computer vision would be useful in robotics.

Sol: As in humans, vision capabilities endow a robot with a sophisticated sensing mechanism that allows the machine to respond to its environment in an intelligent and flexible manner. Due to the use of vision and other sensing schemes is motivated by the continuing need to increase the flexibility and the scope of applications of robotic systems. Different applications where vision would be useful can be listed as:

- Defects inspection
- Monitoring
- Sorting
- Programmed pick-ups
- Identifying, and many more.

1.13 Discuss possible applications where redundant manipulators would be useful.

Sol: According to the structure of the redundant manipulators they have been useful for reaching around obstacles, defusing and/or inspection of explosives and hazardous materials, medical use like human arms/limbs and many more.

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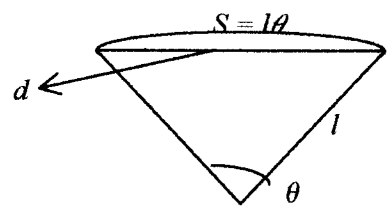
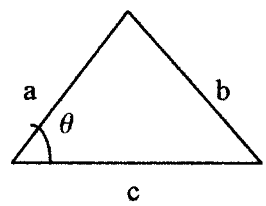
1.14 Referring to the fig. Suppose that the tip of a single link travels a distance *d* between two points. A linear axis would travel the distance *d* while a rotational link would travel through an arc length $l\theta$ as shown. Using the law of cosines show that the distance d is given as $d = l\sqrt{(2(1-\cos(\theta))}$
which is of course less than $l\theta$. With 10 – bit accuracy and l = 1m, θ=90, what is the resolution of the linear link? of the rotational link.



Sol: In the given fig. above, we get



c^2 = a^2 + b^2 – 2abCosθ
then,
l = a = b and c = d

This yields,
d^2 = l^2 + l^2 – 2* l* l* Cosθ = 2 l^2 - 2 l^2 Cosθ

d^2 = 2 l^2 (1 - Cosθ)
i.e. $d = l\sqrt{(2(1-\cos\theta))}$

But we know, $S = l\theta = \pi/2$ =1.57 m

This gives resolution as,
Resolution = total distance / 2^n
where, n = no of bits in encoder = 10 (in this case)

Linear resolution = tot. dist. / 2^10 → as given
= 1.38 *10^-3 m.
Rotational resolution = π / 2*2^10 = 1.53*10^-3m.

Hence the required measurements and verifications were made accordingly.

1.15 A single-link revolute arm is shown in the above fig. If the length of the link is 50 cm and the arm travels 180° what is the control resolution obtained with an 8-bit encoder?

Sol: As in the above-discussed fig.,
Given, length of the link = 50 cm
degree of travels = 180°
Find, control resolution with an 8-bit encoder = ?

We know, resolution = total distance / 2^n
Where, n = no of bits in encoder = 8 (in this case)
Thus, resolution = $l\theta$/2^8 =0.621 m.

1.16 Repeat # 1.15 assuming the 8-bit encoder is located on the motor shaft is connected to the link through a 50:1 gear reduction. Assume perfect gears.

Sol: As in the above-discussed fig.,

Given, the ratio of the connection of the encoder = 50:1

Find, control resolution with an 8-bit encoder = ? (with the assumption)

We know that, l =0.5 m

$\theta = \pi$

Then this gives us,

resolution = total distance / 2^n =1.23 * 10^-2 m.

1.17 Why is accuracy generally less than repeatability?

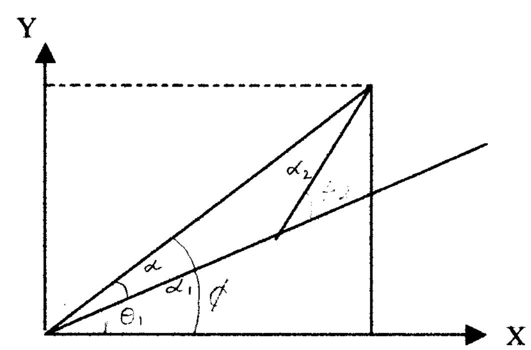
Sol: Accuracy is a measurement for the manipulator showing how close it can come in its workspace to a given point and is affected by computational errors where as repeatability is a measurement for the manipulator showing how close it can return to the desired previous point and comes out to be greater than accuracy since the measurement is computed from the encoder measuring the joints.

1.18 How could manipulator accuracy be improved using direct end-point sensing introduce into the control problem?

Sol: Use of the direct end-point sensing into the control problem will create a less uncertainty while measuring the position of the end-effector. This will eventually result into various difficulties in the process and may cause the system itself to be unstable.

1.19 Derive Equation 1.5.9

Sol:



As shown in the fig. above,

$\theta = \phi - \alpha$

where $\phi = \tan\text{-}(\, y / x\,)$ and $\alpha = \tan\text{-}(\, \alpha_2 \, \text{Sin}\theta_2 / (\, \alpha_1 + \alpha_2 \text{Cos}\theta))$

Where as Equation 1.5.9 states,

$\theta_1 = \tan\text{-}(\, y / x\,) - \tan\text{-}(\, \alpha_2 \, \text{Sin}\theta_2 / (\, \alpha_1 + \alpha_2 \text{Cos}\theta))$

Here, angle θ_1 depends on θ_2 .

1.20 For the two link manipulator of fig 1.25, suppose $a_1 = a_2 = 1$. Find the coordinates of the tool when $\theta_1 = \pi / 6$ and $\theta_2 = \pi / 2$.

Sol: Given,

$\theta_1 = \pi / 6$
$\theta_2 = \pi / 2.$
$a_1 = a_2 = 1$

Find coordinates of the used tool.

Now,

$x = \alpha_1 \text{Cos}\theta_1 + \alpha_2 \text{Cos}(\theta_1 + \theta_2) = \text{Cos}(\pi / 6) + \text{Cos}(2\pi / 3) = 0.366$
$y = \alpha_1 \text{Sin}\theta_1 + \alpha_2 \text{Sin}(\theta_1 + \theta_2) = \text{Sin}(\pi / 6) + \text{Sin}(2\pi / 3) = 1.366$

Hence the coordinates can be expressed as (0.366, 1.366).

1.21 Find the joint angles θ_1, θ_2 when the tool is located at coordinates (1/2, 1/2).

Sol: Given,

$x = ½$
$y = ½$

Find the joint angles θ_1, θ_2.

Now,

$\text{Cos}\theta_2 = (x\text{^}2 + y\text{^}2 - \alpha_1\text{^}2 - \alpha_2\text{^}2)/2\alpha_1\alpha_2$
Substituting the above values→ $\text{Cos}\theta_2 = -0.75$

That means $\theta_2 = \tan^{-}(\pm\sqrt{((1-(-0.75)\text{^}2)/(-0.75))} \Rightarrow \pm 41.419°$

And $\theta_1 = \tan^{-}(y / x) - \tan^{-}(\alpha_2 \text{Sin}\theta_2 /(\alpha_1 - \alpha_2\text{Cos}\theta)) = 23.96°$
$= 65°$

Hence, the required unknown has be found as 23.96° , 65° and ± 41.419° for the θ_1 and θ_2 respectively.

1.22 If the joint velocities are constant at $\theta_1 = 1$, $\theta_2 = 2\theta_2$, what is the velocity of the robot? What is the instantaneous tool velocity when $\theta_1 = \theta_2 = \pi /4$.

Sol: Given,

Firstly→ $\theta_1 = 1,$
$\theta_2 = 2\theta_2$
Secondly → $\theta_1 = \theta_2 = \pi /4$

Find the velocity of the robot.

Now,

$x = - \text{Sin}\theta_1 - 3\text{Sin}(\theta_1 + \theta_2)$
and
$x = - (\text{Sin}\pi /4 + 3\text{Sin}\pi /4) = - 3.70$

Similarly,
$y = \text{Cos}\theta_1 + 3\text{Cos}(\theta_1 + \theta_2)$
and
$y = = \text{Cos}\pi /4 + 3\text{Cos}\pi /2 = 0.707$

Hence, the required observation was made efficiently.

1.25 For the two-link planar manipulator of fig. 1.25 is it possible for there to be an infinite number of solutions to the inverse kinematics equations? If so, explain how this can occur.

Sol: For the two-link planar manipulator of fig. 1.25 it possible for there to be an infinite number of solutions to the inverse kinematics equations. This may occur when, $x = y = 0$ and 180° should be the θ_2.

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