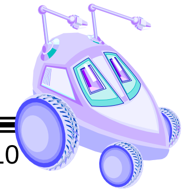

Lecture 5-1: Mobile Robot Kinematics

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Objectives:

- Find the number of DOF for a differential drive mobile robot
- Define the terms: holonomic, redundant, mobile robot kinematics
- Describe the difference between forward and inverse kinematics
- Describe the forward kinematic model and how to use the ICR for pose estimation

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A degree of freedom is the minimum number of coordinates to completely specify the motion of a mechanical system.

In 3D space, there were six degrees of freedom,

- ___________________________________ (x,y,z)
- ___________________________________ (roll, pitch, yaw)

A differential drive mobile robot that operates in 2D space has

____________________________ degrees of freedom

___________________________ controllable degrees of freedom

The Traxster robot is __________________________ because the controllable DOF is less than the total DOF.

What are the two concerns in locomotion?

1. ____

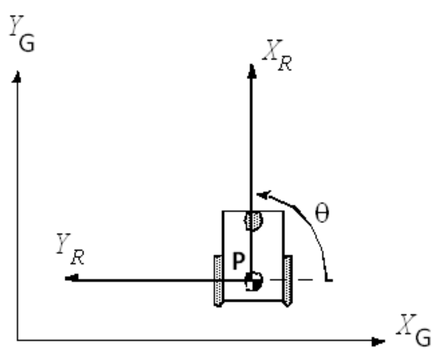
2. ____

What is the difference between forward and inverse kinematics?

Name one disadvantage to using relative position to determine the robot's motion and/or pose.

Example 1:

If the following robot is at point (2,3) and $\theta = \pi/2$ and the robot's velocity with respect to the global reference frame is (0.5 m/s, 0.2 m/s, 0), find the robot's motion with respect to the local reference frame.



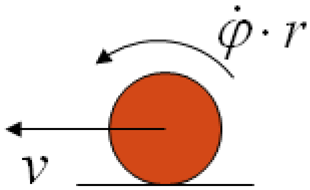
$$\dot{P}_R = R\left(\frac{\pi}{2}\right) {}^G\dot{P}_R = \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} =$$

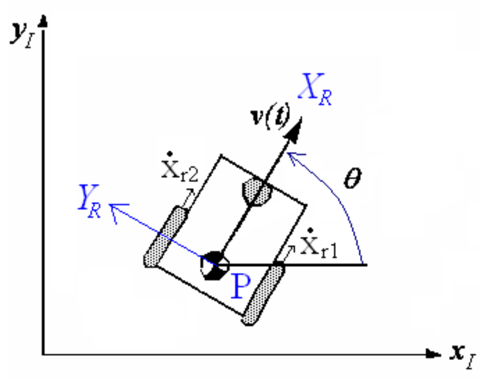
Example 2:

If the above robot is at point (2,3) and $\theta = \pi/2$ and the robot's velocity with respect to the local reference frame is (0.5 m/s, 0.2 m/s, 0), find the robot's motion with respect to the global reference frame.

$${}^G\dot{P}_R = R\left(\frac{\pi}{2}\right)^{-1} V_R = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} =$$

To find the ______________________________ in the direction of $+X_R$ each wheel contributes one half of the total speed.





v(t) = _______________

The ____________________________ about θ is calculated by finding the contribution to each wheel working alone and then summing them.

ω = ____________________________________

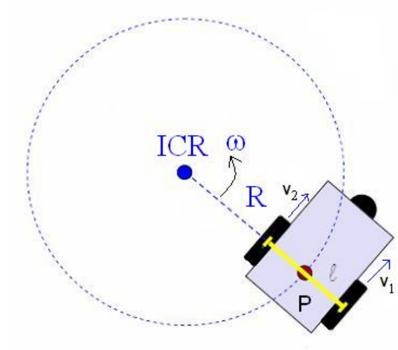
The ____ is a zero motion line drawn through the horizontal axis perpendicular to the wheel plane. The wheel moves long a radius, R, with center on the zero motion line, the center of the circle is the **ICR**. ICR is the point around which each wheel of the robot makes a circular course. The **ICR** changes over time as a function of the individual wheel velocities.

When R is infinity, the wheel velocities are _____________________________ and the robot moves in a straight line.

When R is zero, the wheel velocities are ____________________________ of each other and the robot spins in place.

When R is finite and non-zero and the robot follows a curved trajectory about a point which is a distance R from the robot's center.

Forward kinematics can be used to determine the angular and linear velocity for the robot to reach a certain pose.



$$V =$$

$$\omega = \frac{(v_1 - v_2)}{2l}$$

$$R = \frac{V}{\omega} = \frac{l(v_1 + v_2)}{(v_1 - v_2)}$$

Position can be determined recursively as a function of velocity and position.

The ***kinematic controller*** is used to have the robot follow a given trajectory described by its position and/or velocity profiles as a function of time. A trajectory is like a path but has the additional dimension of time. This is not straight forward because mobile robots are non-holonomic systems and may require the derivative of the position variable.

___________________________________ is determining the wheel velocities that will make the robot move to a new pose from its current pose. This is a very difficult problem because there are too many unknowns, not enough equations and multiple solutions. The easy solution is to spin the robot to the desired angle and move forward to the desired location or vice versa.