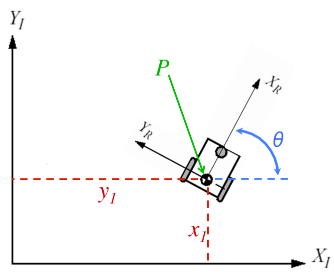
Kinematics

Overview



Class Today

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- Overview of second half of semester
- Schedule updates
- Project updates
- Review of concepts
- Midterm
  - Will be returned Thursday.
  - Overview of topics Thursday.
- Kinematics I

Class From Here

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- First half is *hardware and terminology*.
  - What's a robot made of?
  - What determines what it can do?
  - How do we talk about the different needs and goals?
  - High-level overview of many topics
  - Lots of manipulation
- Second half is *software, problem solving, and control*.
  - More technical, more in-depth, more math
  - Big problems: kinematics; localization; cognition
  - Homeworks and exams will be different
  - Mostly mobile robotics

Schedule From Here

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- HW 3 canceled (as I'm sure you noticed)
  - Didn't have a kinematics lecture before the midterm, so…
- Homeworks from here will be problem sets and writing
  - The project will be plenty of coding
- Schedule →

Apr 10	Project Milestone 2 due
Apr 12	HW 3 posted (midnight)
Apr 19	Project milestone 3 due
Apr 26	HW 3 due HW 4 posted (midnight)
May 3	Project milestone 4: final turnin
May 10	HW 4 due
May 15	Project milestone 5: writeup due

Project Next Steps

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- By now you should have:
  - Built Robot
  - Installed Raspbian
- Next important step: what will your architecture be?
  - Code and version control?
  - Message passing and comms infrastructure?
- Turnins
  - Writeup of architecture
  - Code to control servos and read sensors
  - Video of a small demo

Kinematics

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- What is kinematics?
  1. The study of the motion of objects.
  2. The study of the geometrically possible motion of a body or system of bodies (regardless of causes and effects of motion).
- Movement determines the (eventual) position and orientation of the robot
  - Mobile: position and orientation wrt. some initial frame
  - Manipulator: position and orientation of end effector

Review: Kinematic Models

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- Models how a system can move in the world.
  - With respect to one another and the world
  - Configuration: where are all the points on it?
  - State: and how are those points moving?
- Manipulators: links, joints, base
  - Manipulator links from a chain
  - Serial or parallel (mostly)
- Mobile robots: possible x/y/z movement
  - Omni wheels ≠ wheels ≠ flying

Review: Frames of Reference

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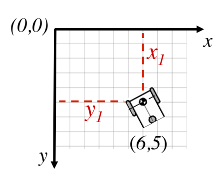
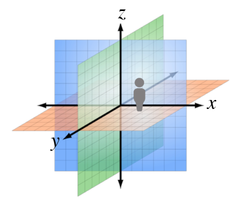
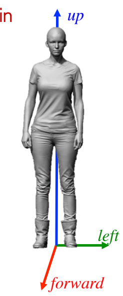
- A coordinate system plus point(s) that locate/orient it
  - Usually x, y, and sometimes z coordinates, lus origin
- Things move with respect to some frame of reference.







en.wikipedia.org/wiki/Frame_of_reference, study.com/academy/lesson/coordinate-system-in-geometry-definition-types.html

Kinematics and IK

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- Position and orientation of the robot
  - Mobile: position and orientation wrt. an arbitrary initial frame
  - Manipulator: position and orientation of end effector
- Forward kinematics: from parameters to configuration
  - A configuration is ________________
- Inverse Kinematics (IK): from a desired configuration to parameters that make it so

Forward Kinematics

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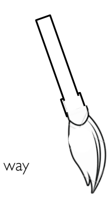
- Find position and orientation from parameters
  - Mobile: robot center
  - Manipulator: end effector
- Manipulator Forward Kinematics (angles to position)
  - Given:
    - Kinematic model *plus*
    - Angle/displacement of each joint
      - I.e., manipulator parameters
  - Find:
    - The position of any point
      - E.g.: Paintbrush is at *these* coordinates, pointed *this* way



Inverse Kinematics

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- Find parameters from position and orientation
  - Mobile: robot center
  - Manipulator: end effector
- Manipulator IK (position to angles)
  - Given:
    - Parameters and kinematics model
      plus
    - Desired position/orientation of some point on the robot
  - Find:
    - Parameters: angle/displacement of each joint to obtain that position

Inverse Kinematics

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- Find parameters from position and o
  - Mobile: robot center
  - Manipulator: end effector
- Manipulator IK (position to angles)
  - Given:
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      plus
    - Desired position/orientation of some point on the robot
  - Find:
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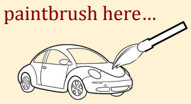
Why?

We have *direct* control over joints.

We have *indirect* control over robot's position in the world.

If we want the paintbrush here…



we need to know what to tell *joints* to do.

Position and Orientation

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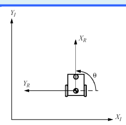
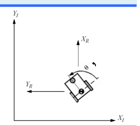
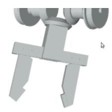
What do these mean for…	*Position: Where is it?*	*What's its orientation?*
Mobile Robot	On an $\{x,y\}$ plane 	Heading θ 
Manipulator	In some $\{x,y,z\}$ space 	$\{r/p/y\}$ of end effector 

More on Frames of Reference

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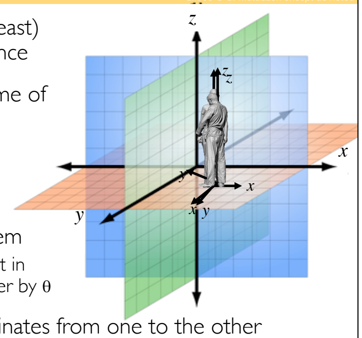
- We always have (at least) two frames of reference
- Global (or initial) frame of reference: the world the system exists in
- Local (or robot) frame of reference: grounded in the system
  - If she turns, they aren't in agreement – they differ by θ
- We transform coordinates from one to the other



en.wikipedia.org/wiki/Frame_of_reference, study.com/academy/lesson/coordinate-system-in-geometry-definition-types.html