OPEN-LOOP CONTROL & ODOMETRY

I. CONTROLS

Def^n: a field of science concerned w/ determining appropriate instructions for electro-mechanical devices that influences a systems' overall behavior in some desired fashion.

OPEN-LOOP SYSTEM

Def^n: a system which behaves in a manner based solely on "assumptions" or "prior knowledge" of the environment;
→ typically does not involve the use of sensors

Examples:

1. Assembly Line Robot
2. Irrigation System
3. Tivo

II. ROBOT ODOMETRY

A. INTRO: there exist many different ways to ~~measure~~ estimate a robot's position; robot odometry is probably one of the most basic/fundamental forms most roboticists are familiar w/.
→ some definitions are first in order before getting into the framework of "odometry".

B. Definitions:

1. Pose: position of the robot and its orientation

(x, y, θ) - 2D

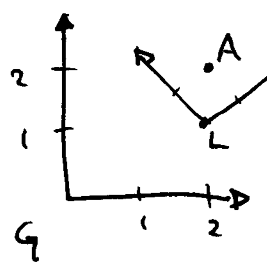
$(x, y, z, \text{roll}, \text{pitch}, \text{yaw})$ - 3D

2. Reference Frame : typically we distinguish between 2 reference frames in robotics :

(a) Global ref. frame : a frame of reference generally fixed in the world (on the globe) used for a "global" position measurement.

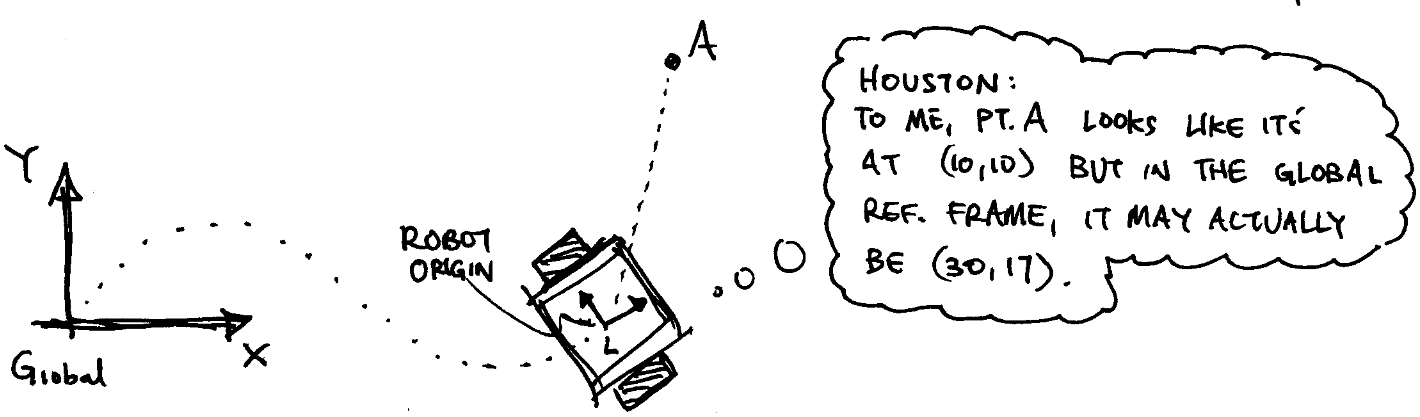
(b) Local ref. frame : in the context of robotics, a frame of reference fixed/pinned to the origin of the robot (all measurements are typically registered in this ref. frame).

ex



- in the global ref. frame, pt. A is located at (2,2)
- in the local ref. frame, pt. A might be located at (0.5, 0.5)

3. Origin : the "origin of a robot" is usually a physical location (on the robot) to which the LOCAL ref. frame is pinned.



C. **ODOMETRY**: a science of determining where a wheeled robot is in the world, simply by counting the number of rotations the wheels have turned; also, a science of determining the necessary control commands required to get a robot to go to a desired location.

(i) in many ways, this is a form of open-loop control; why?

(ii) we can think of ODOMETRY in two forms, similar to robot kinematics:

FORWARD MOTION

$$\begin{matrix} \alpha_L \rightarrow \\ \alpha_R \rightarrow \end{matrix} \boxed{\begin{matrix}\text{ROBOT} \\ \text{ODOM.}\end{matrix}} \longrightarrow (x, y, \theta) = ?$$

INVERSE MOTION

Go to (x, y, θ)

$$\longrightarrow \boxed{\begin{matrix}\text{ROBOT} \\ \text{ODOM}\end{matrix}} \begin{matrix} \rightarrow \alpha_L = ? \\ \rightarrow \alpha_R = ? \end{matrix}$$

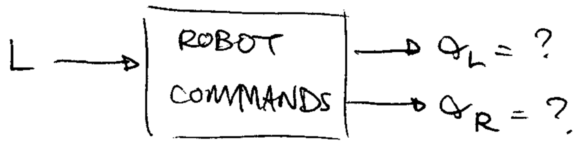
* math basics, unit conversions, etc.

["INVERSE" MOTION]

Robot Commands :

To keep things simple, let's just worry about what commands (α_L, α_R) need to be sent for FORWARD DISTANCE and TURN ANGLE.

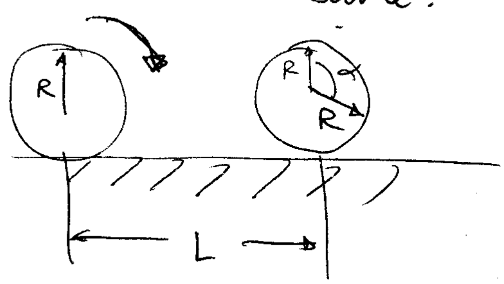
↳ FORWARD DISTANCE = L is desired forward distance.



TURN ANGLE = Θ_1 is desired turn angle

FORWARD DISTANCE :

① Note that for forward distance, $\alpha_L = \alpha_R$
→ so, we only need to solve for one (either α_L or α_R) and the other will be the same.



by the equation for arc length :

$$L = R\alpha \Rightarrow \boxed{\alpha = \frac{L}{R}}$$

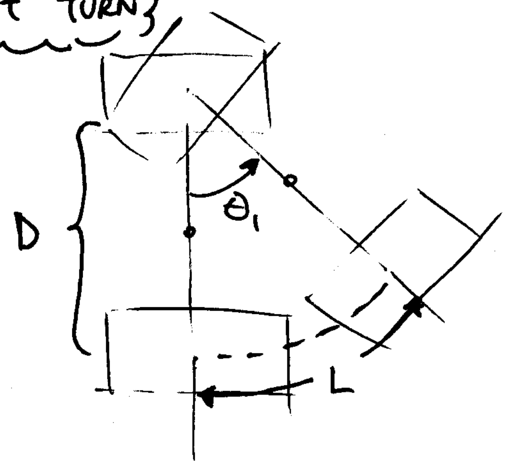
TURN ANGLE : θ_1

Again, there are two types of turns we can do here:

PIVOT TURN

- recall: we're given a desired turn angle θ_1, and we need to figure out what α_L and α_R are.

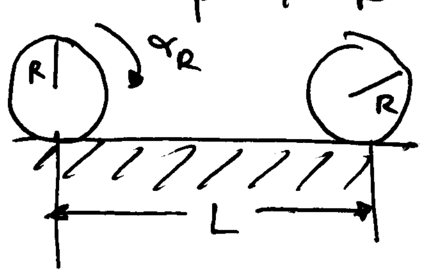
LEFT TURN



from the equation for arc-length:

$$L = D\theta_1$$

⊛ now how do we get from L to α_R?
- remember that L has the following relationship w/ α_R:



$$L = \alpha_R \cdot R \Rightarrow \alpha_R = \frac{L}{R}$$

$$\therefore \boxed{\alpha_R = \frac{D\theta_1}{R}}$$

$$\alpha_L = 0$$

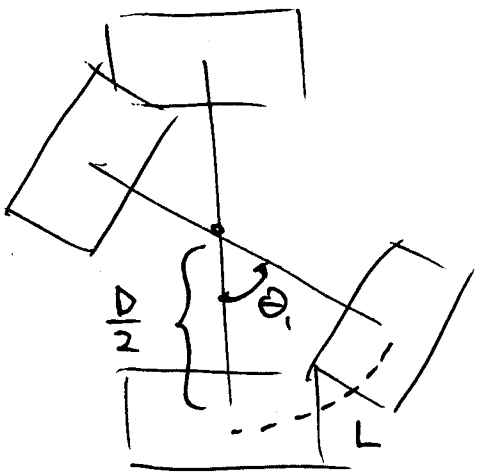
NOTE: for a RIGHT turn, the analysis is the same, except the α_L and α_R are flipped:

$$\alpha_L = \frac{D\theta_1}{R}$$

$$\alpha_R = 0$$

IN-PLACE TURN

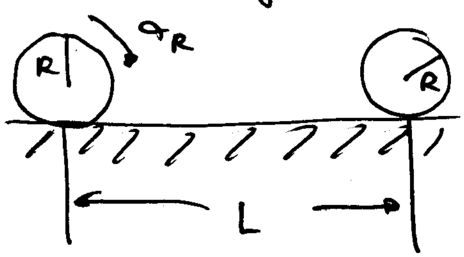
- recall: we're given a desired turn angle, θ_1, and we need to figure out what φ_L and φ_R are.



⊛ for in place turns, note that
$$\varphi_R = -\varphi_L$$

from the equation for arc-length:
$$L = \left(\frac{D}{2}\right) \cdot \theta_1$$

⊛ how do we get from L to φ_R?



$$L = \varphi_R \cdot R$$

$$\Rightarrow \varphi_R = \frac{L}{R}$$

$$\therefore \boxed{\begin{aligned} \varphi_R &= \frac{L}{R} = \frac{\left(\frac{D}{2} \cdot \theta_1\right)}{R} \\ \varphi_L &= -\varphi_R \end{aligned}}$$

NOTE: for clockwise turns,
$\theta_1 < 0$
and for counter-clockwise turns,
$\theta_1 > 0$