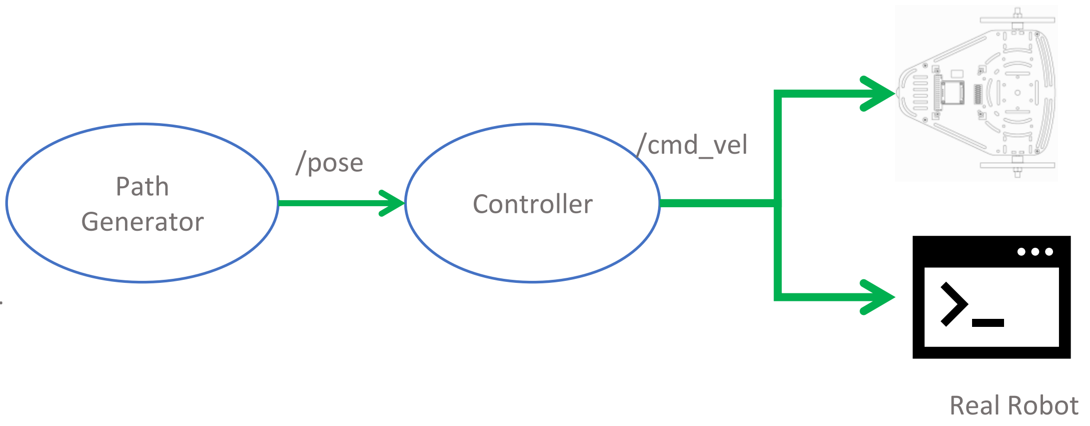
{Learn, Create, Innovate};

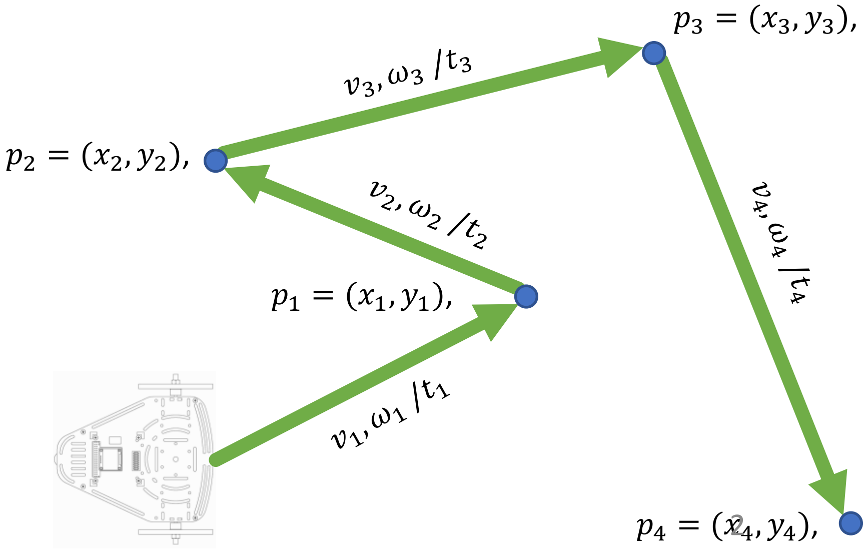
Closed Loop Control

Mobile Robot Control

Mini challenge 1

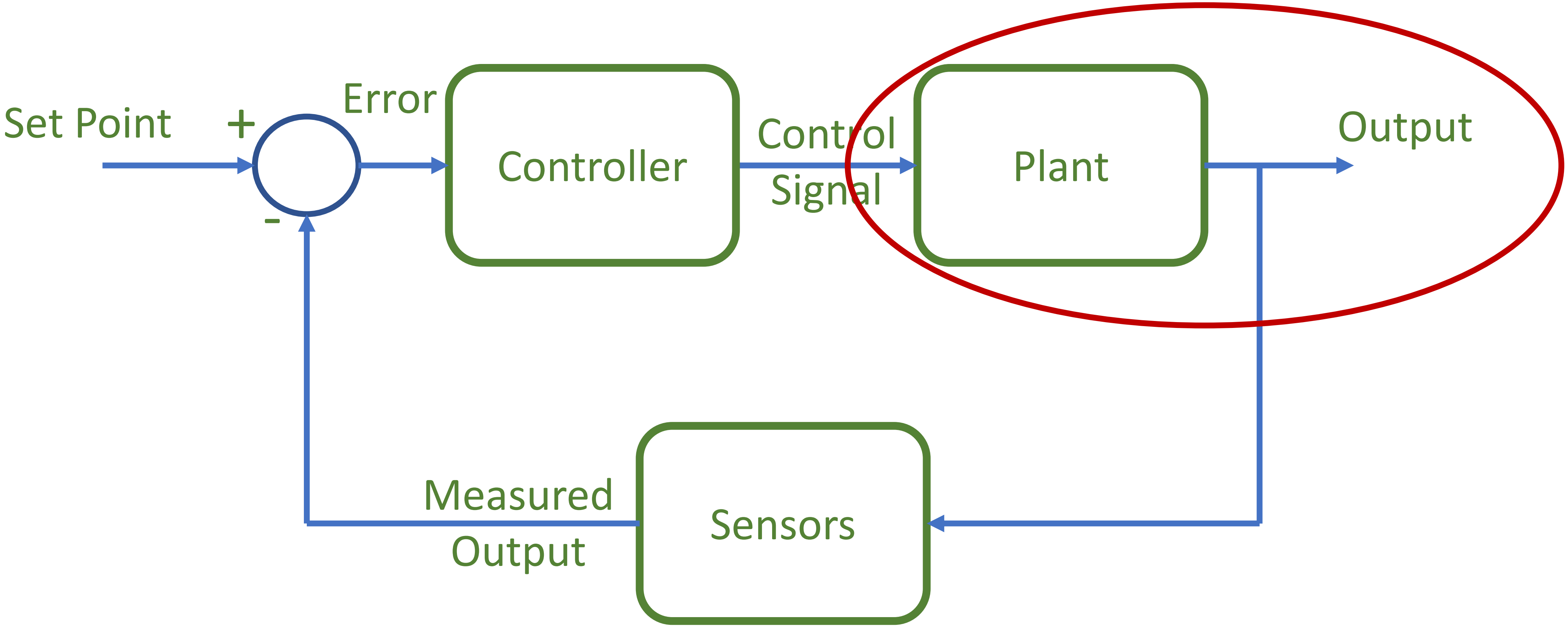
- Create a node that generates different paths according to a user.
- The path must be defined in the parameter files by the user. (3 or 4 are enough)
- The path must be defined by different points $p_k = (x_k, y_k)$, velocities of the robot, or a time $(v_1, \omega_1)/t$ (depend on the user).
    - For each point, the node must estimate the linear and rotational speeds in case a time is given by the user or estimate the time in case the velocities are provided.
- The node must let the user know if the point is reachable according to the dynamical behaviour of the mobile robot and the parameters that were input by the user $(v_1, \omega_1)/t$.
- The student must define what is robustness for this case, and the controller must take that into consideration.



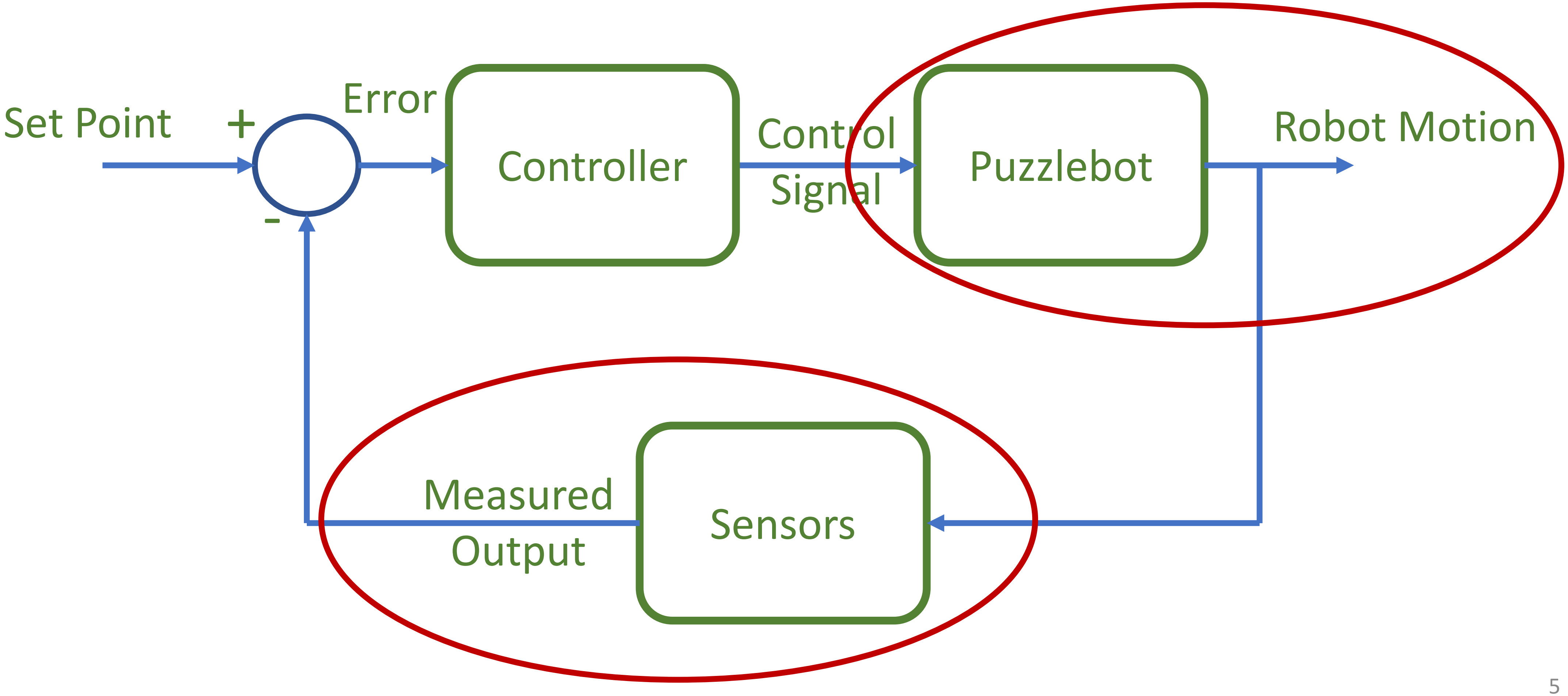


The Task

The Control System

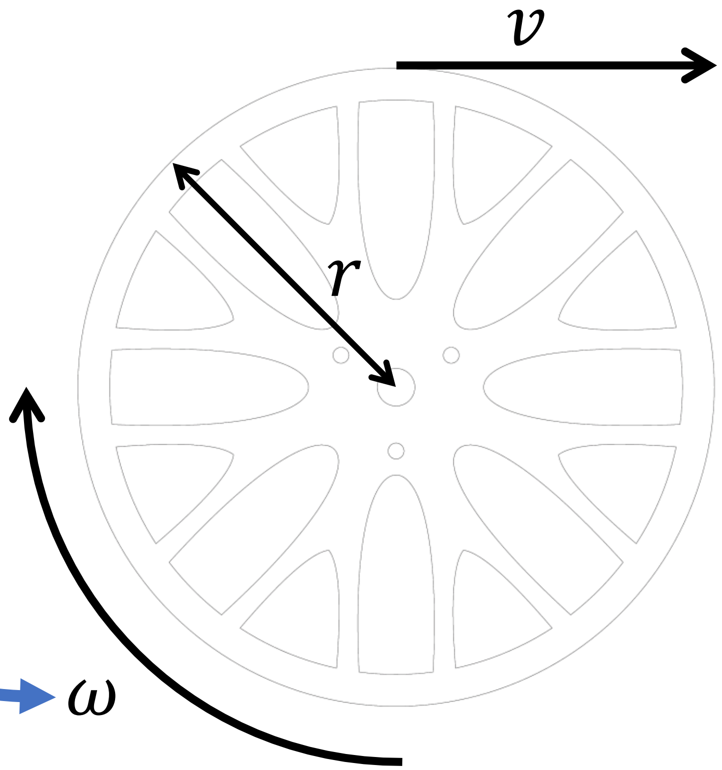


The Control System



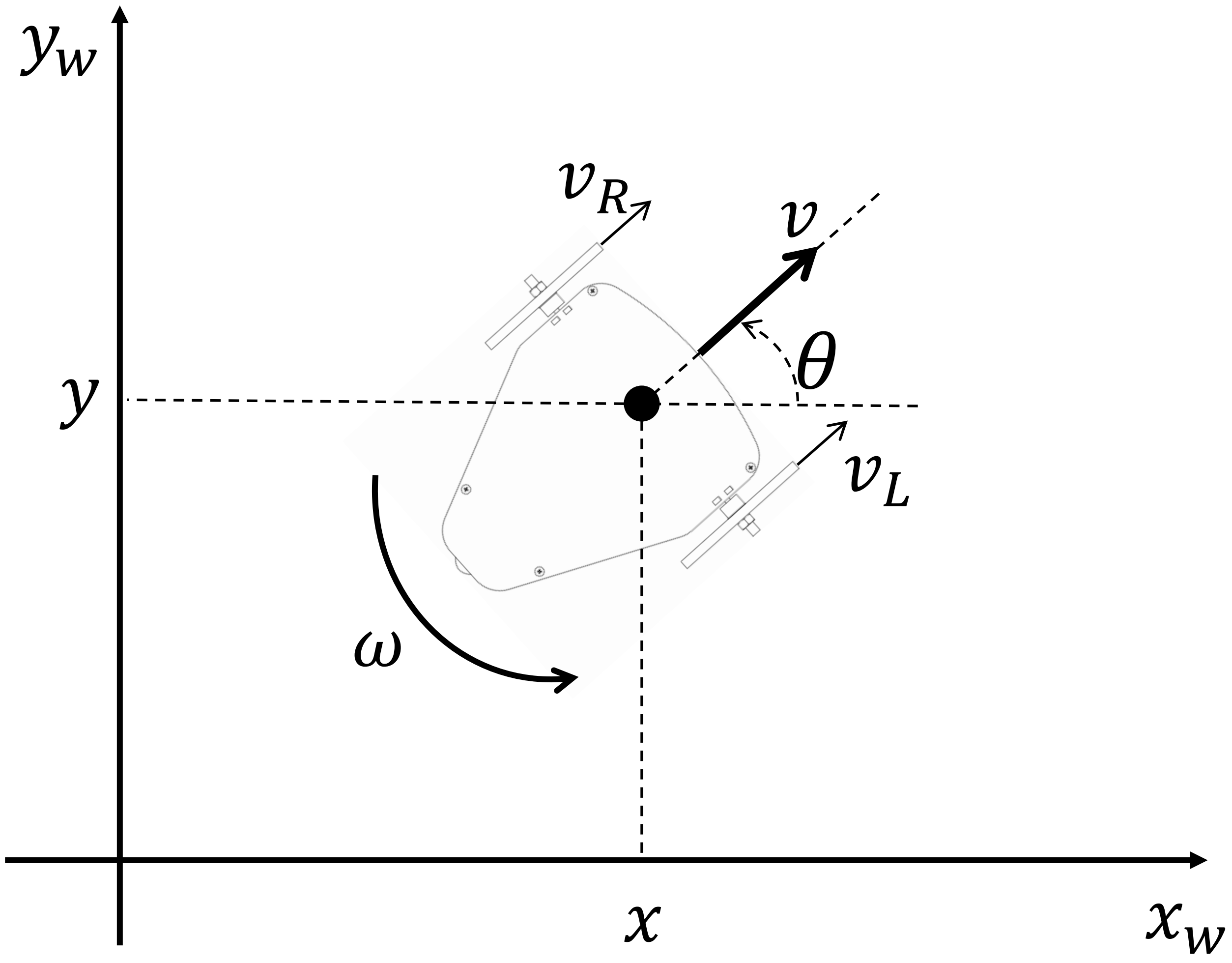
Determining the Robot Position

```
/cmd_vel
/diagnostics
/rosout
/rosout_agg
/wl
/wr
```



$$v_{Wheel} = r\omega_{Wheel}$$

Determining the Robot Position

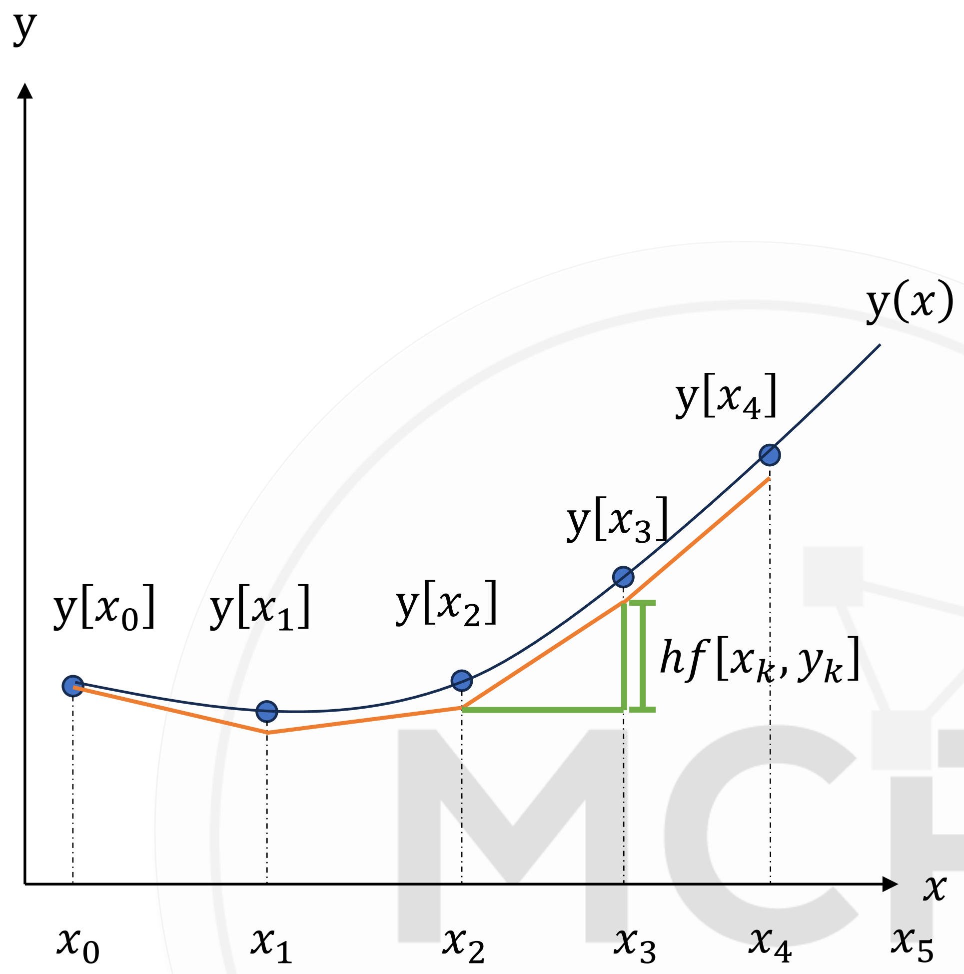


$$v_{Robot} = \frac{v_R + v_L}{2} = r\frac{\omega_R + \omega_L}{2}$$

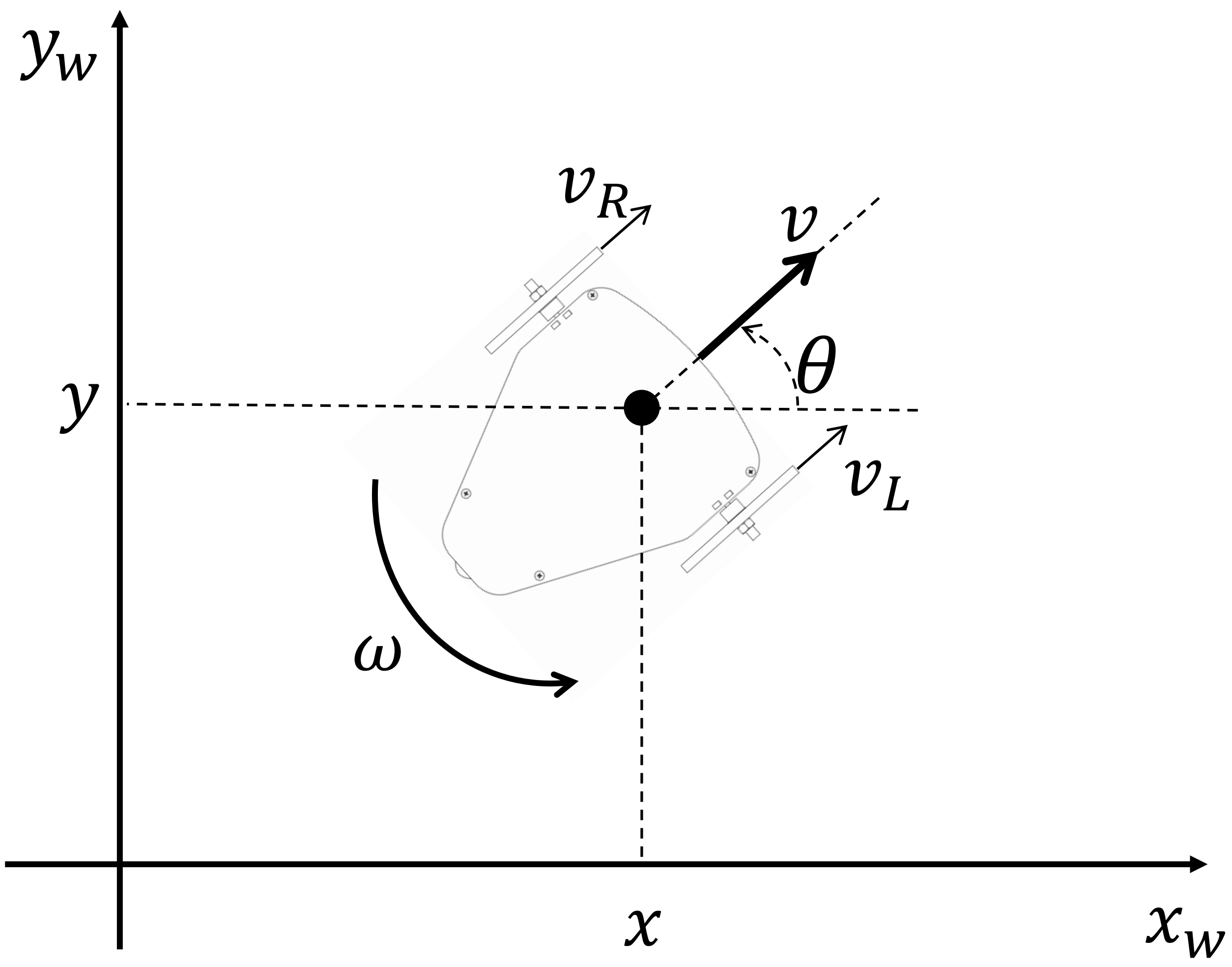
$$\omega_{Robot} = \frac{v_R - v_L}{l} = r\frac{\omega_R - \omega_L}{l}$$

Forward Euler method

- First order numerical procedure for ODEs
- Most basic method for numerical integration
- $y_{k+1} = y_k + \mathrm{h}f[x_k, y_k]$
- y_k - initial value



Determining the Robot Position



$$v_{Robot} = \frac{v_R + v_L}{2} = r\frac{\omega_R + \omega_L}{2}$$

$$\omega_{Robot} = \frac{v_R - v_L}{l} = r\frac{\omega_R - \omega_L}{l}$$

Determining the Robot Position

$$\boxed{\theta_{k+1}} = \boxed{\theta_k} + \boxed{r}\,\frac{\boxed{\omega_R - \omega_L}}{\boxed{l}}\,\boxed{dt}$$

$$\boxed{x_{k+1}} = \boxed{x_k} + \boxed{r}\,\frac{\boxed{\omega_R + \omega_L}}{2}\,\boxed{dt}\cos\boxed{\theta_k}$$

$$\boxed{y_{k+1}} = \boxed{y_k} + \boxed{r}\,\frac{\boxed{\omega_R + \omega_L}}{2}\,\boxed{dt}\sin\boxed{\theta_k}$$

Robot Location:
(x_k, y_k, θ_k): Pose of the robot at timestep k (m, m, rad).
Stored in memory, initial value 0

Robot Constants:
r: Wheel radius = 0.05 m
l: Distance between robot wheels = 0.19 m

Measured variables
$(\omega_\mathrm{R}, \omega_\mathrm{L})$: Wheel velocity (rad/s)
dt: Time between samples (s)

Values of θ must be contained within a single circle:
Either:

$$-\pi \leq \theta < \pi$$

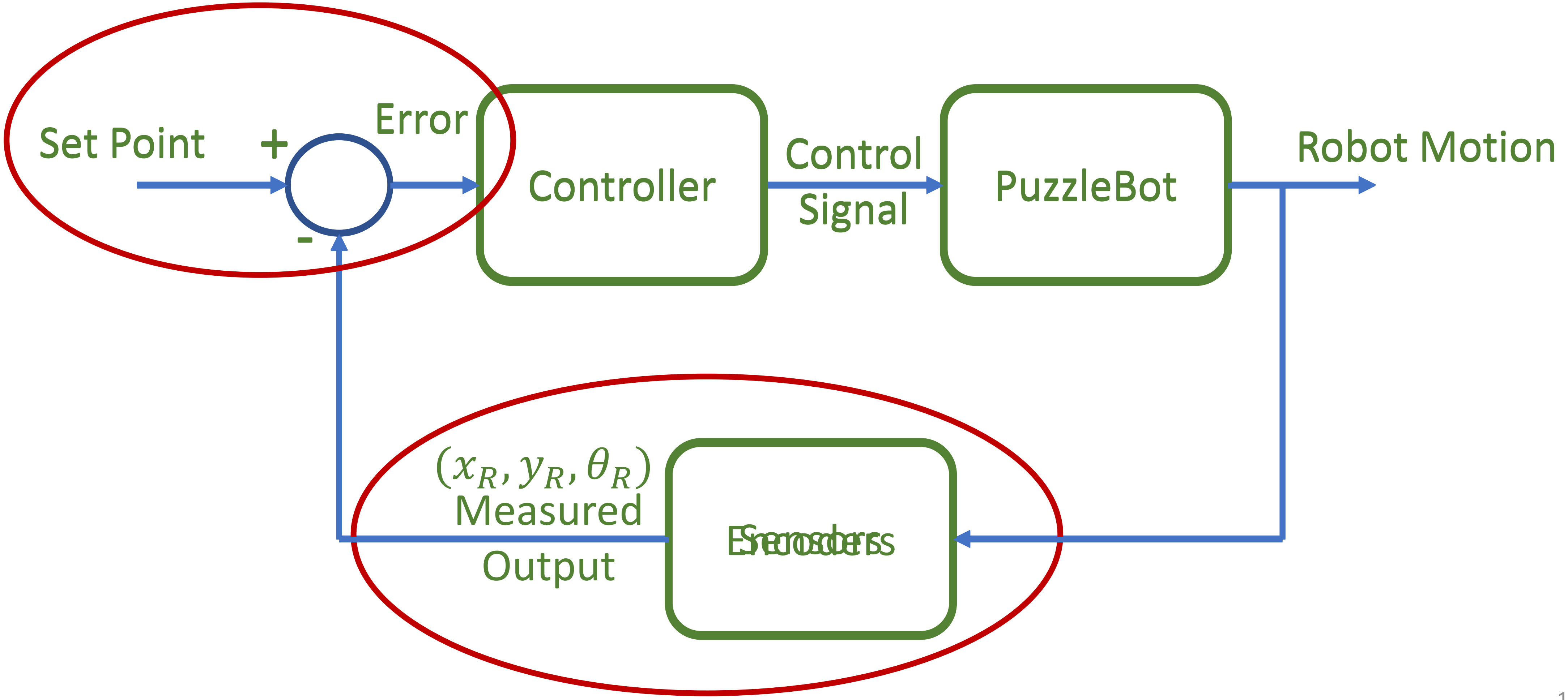
Or:

$$0 \leq \theta < 2\pi$$

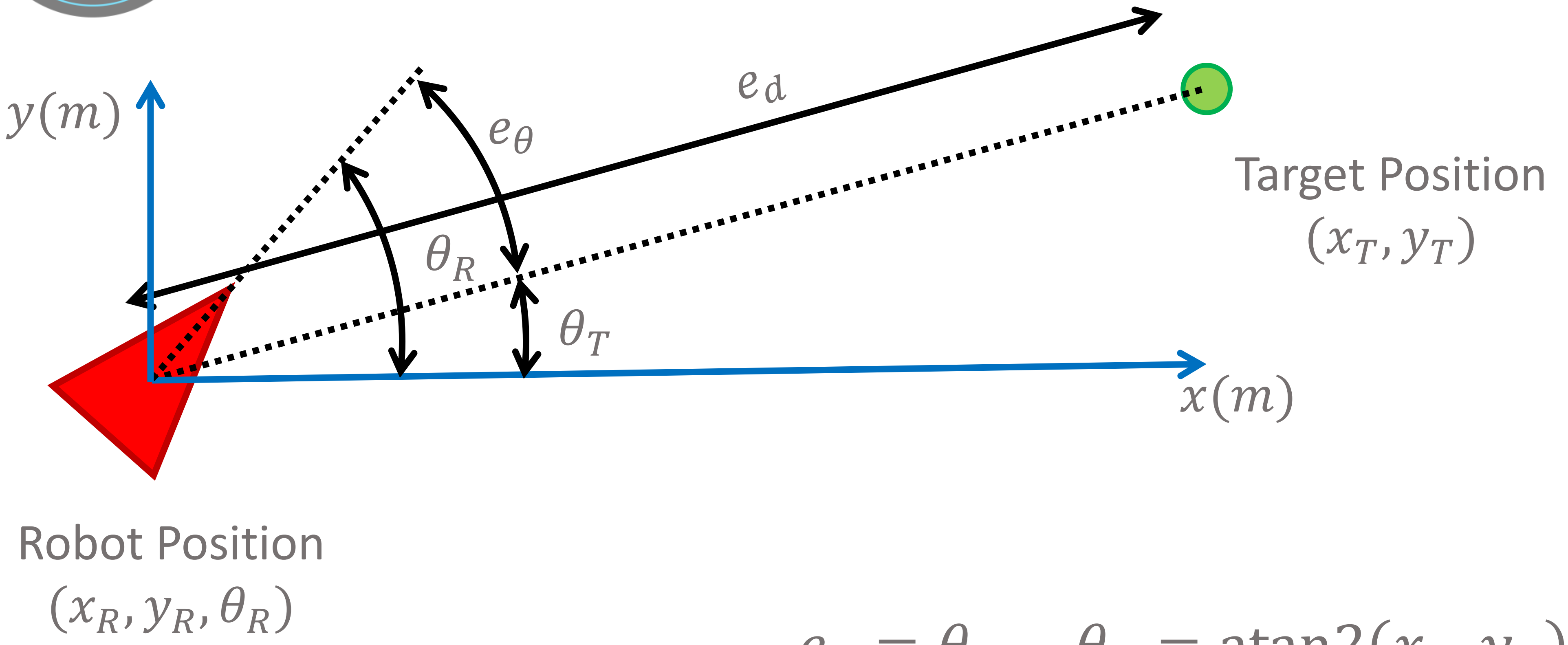
Activity 1

- Implement a ROS node that computes the robot location using the encoder data
  - It should subscribe to `/wl` and `/wr`, and publish the data to a suitable set of topics
  - The published messages could be a Pose2D message

The Control System



The Error

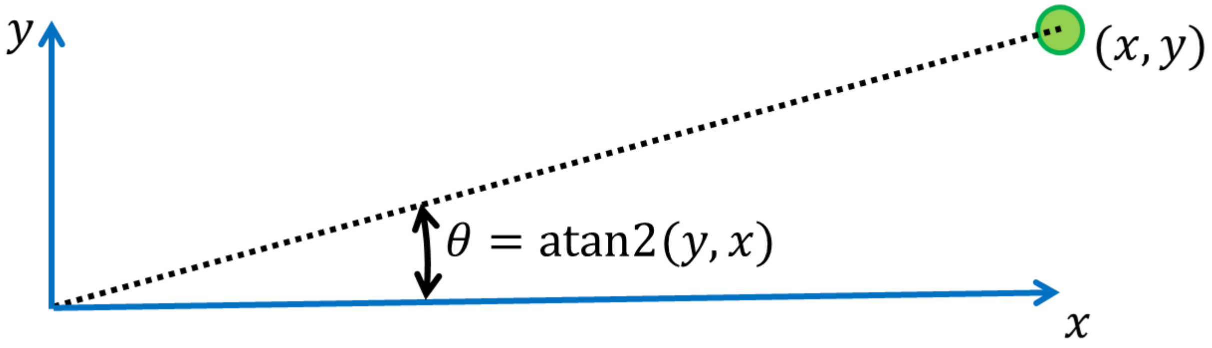


$$e_\theta = \theta_T - \theta_R = \text{atan2}(x_T, y_T) - \theta_R$$

$$e_d = \sqrt{(x_T - x_R)^2 + (y_T - y_R)^2}$$

atan2

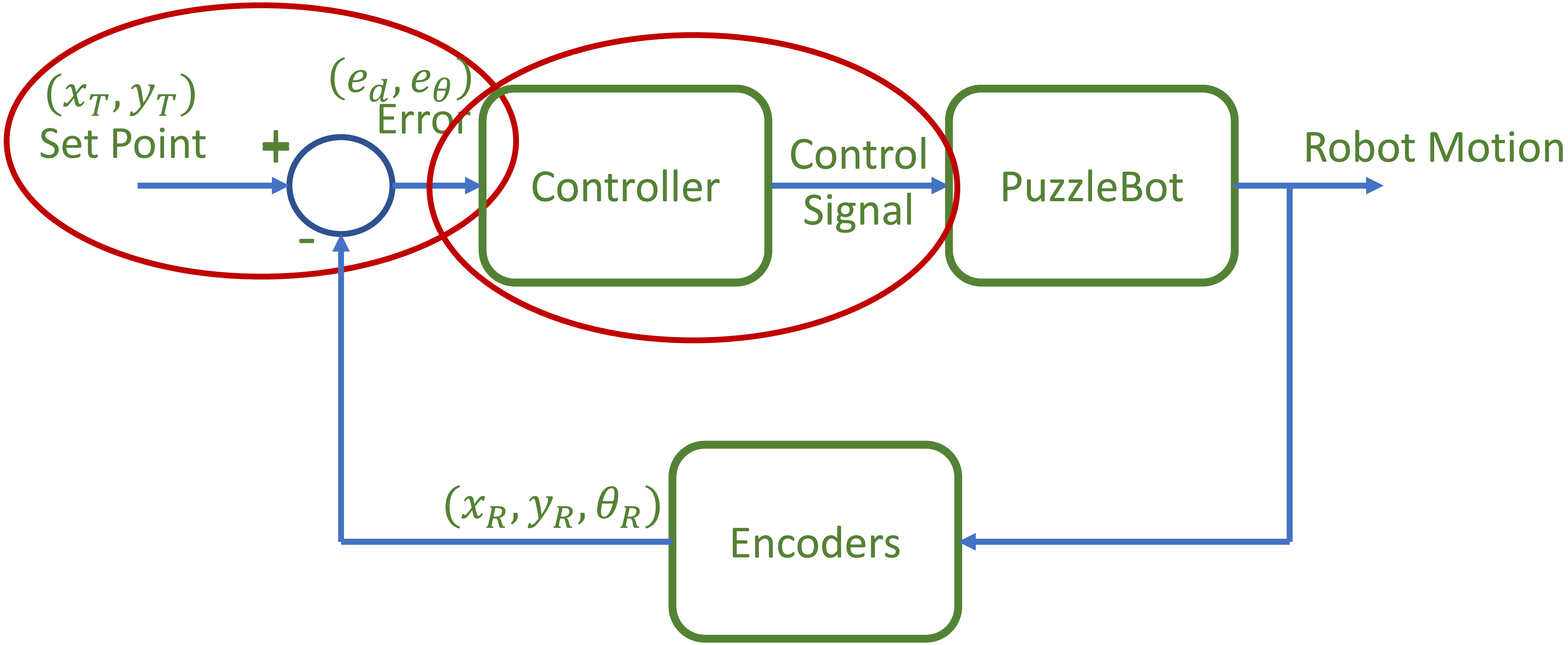
- The atan2 function is a special form of arctan or $\tan^{-1}$.
- It takes two arguments, y and x, and returns the angle to the x axis:



- It is included in most maths libraries, but it is recommended to use numpy, as numpy will be necessary later on in the course

```
import numpy
theta = numpy.arctan2(y,x)
```

The Control System



The Controller

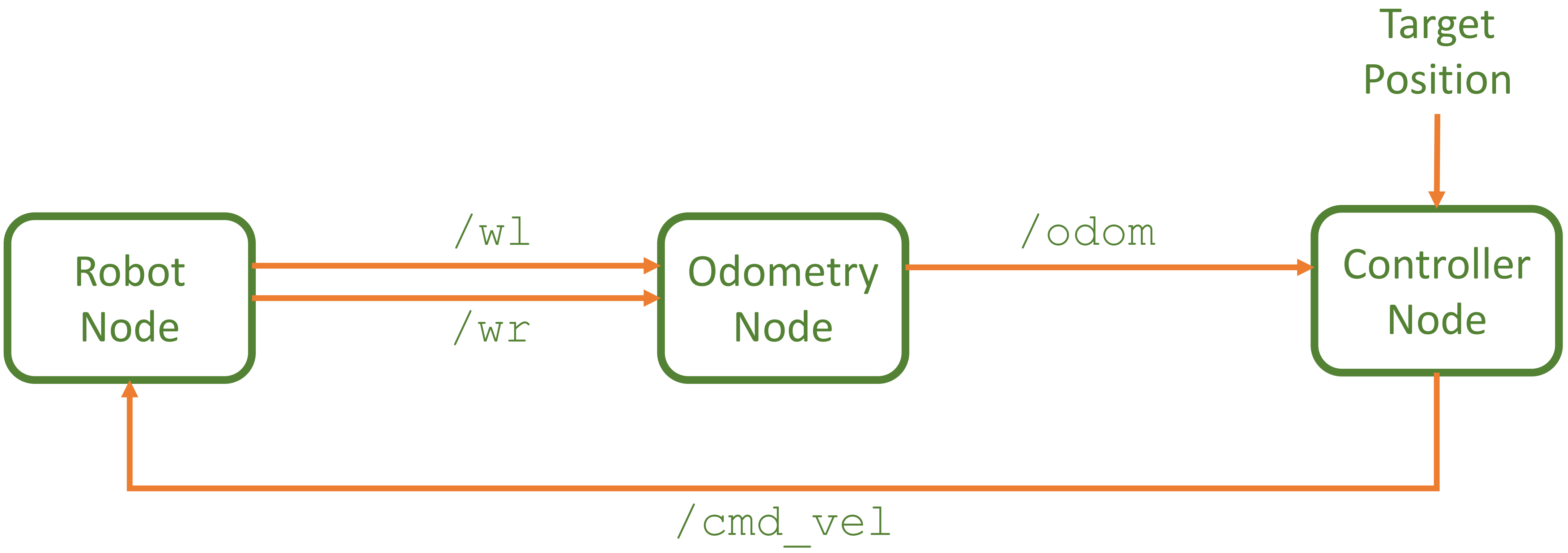
- Since the robot is inherently stable, a simple PID scheme should be sufficient.
- Start with a pair of proportional controllers:

$$v = K_v e_d$$

$$\omega = K_\omega e_\theta$$

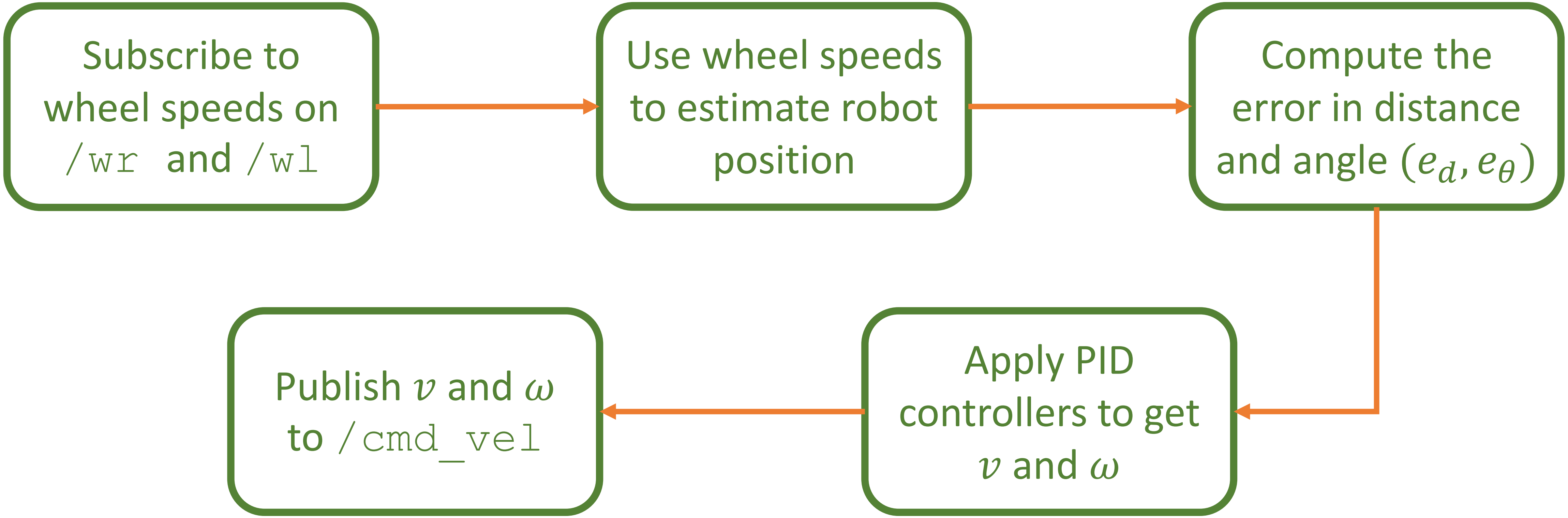
… and add integral and derivative elements if necessary.

ROS Setup



Target
Position
Robot
Node
/wl
/wr
Odometry
Node
/odom
Controller
Node
/cmd_vel

ROS setup



Subscribe to wheel speeds on /wr and /wl
Use wheel speeds to estimate robot position
Compute the error in distance and angle (e_d, e_θ)
Apply PID controllers to get v and ω
Publish v and ω to /cmd_vel

Activity 2

- Modify the previous node to publish e_d and e_θ.
- Set a target, and drive the robot around, checking that the angle to the target and the distance from the target are updated correctly
- Remember to wrap all angles to within 1 circle

Tips and Tricks

- Write and test your node with the PuzzleBot off the ground:
  - Use this to check the basics of your code are working correctly, such as the sign (+/-) of your controller parameters K_v and K_ω
  - Does the robot turn towards the goal?
  - Does the robot move towards or away from the goal?
- Tune one of the controllers at a time. You may find it easier to tune K_ω first, while setting your robot to move with a fixed forward speed.
- If in doubt, *lower* the value of the control constants.
- You may find it helpful to use a launch file to load your controller constants in from a config.yaml file.

Accuracy

- It will not be possible to tune the controllers such that the robot moves perfectly into position.
  - You will need a threshold after which your algorithm decides it has successfully arrived.
  - Suggested initial threshold: 10 cm
- Additionally, if you measure the position of the robot, it will likely not match up with the measurement computed from the encoders.
  - This is inevitable due to additive noise in the encoder readings.
  - The solution to this is to use sensors that can measure the position of the robot relative to its environment.

The Task

Thank You

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