{Learn, Create, Innovate};

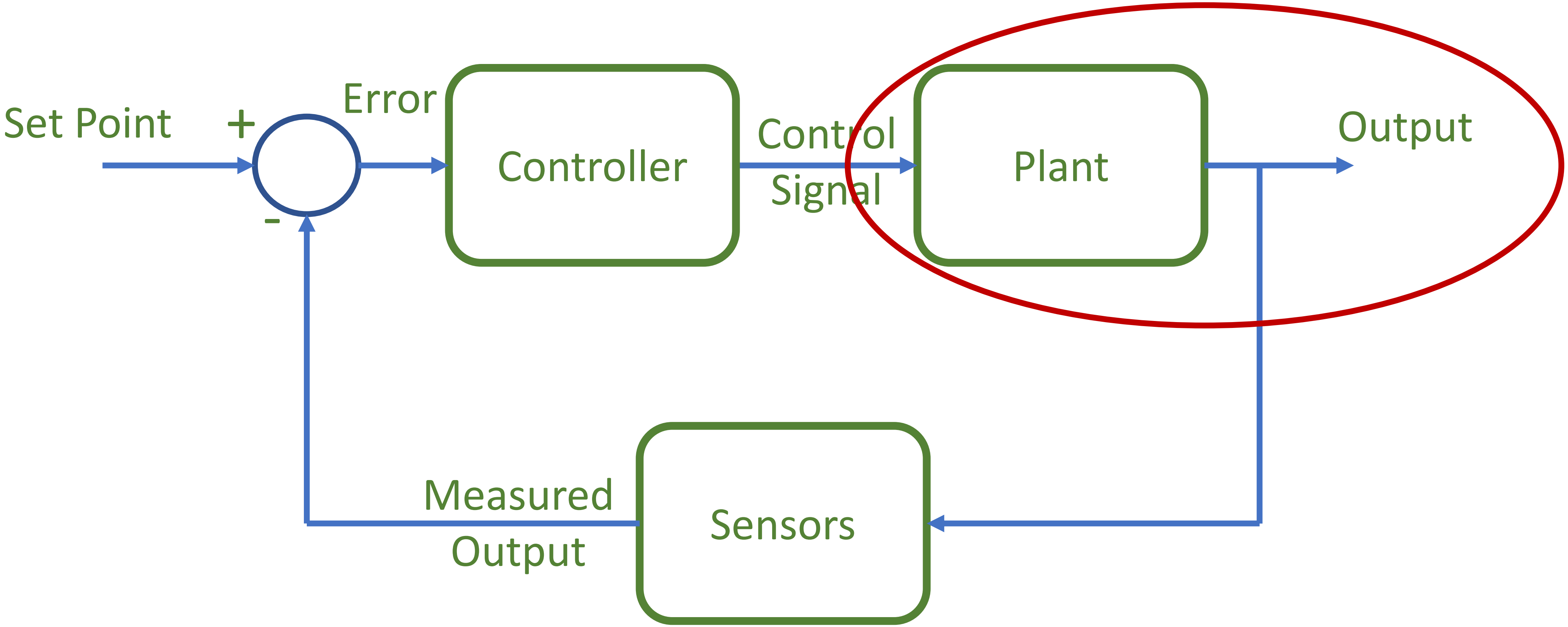
Closed Loop Control

Mobile Robot Control

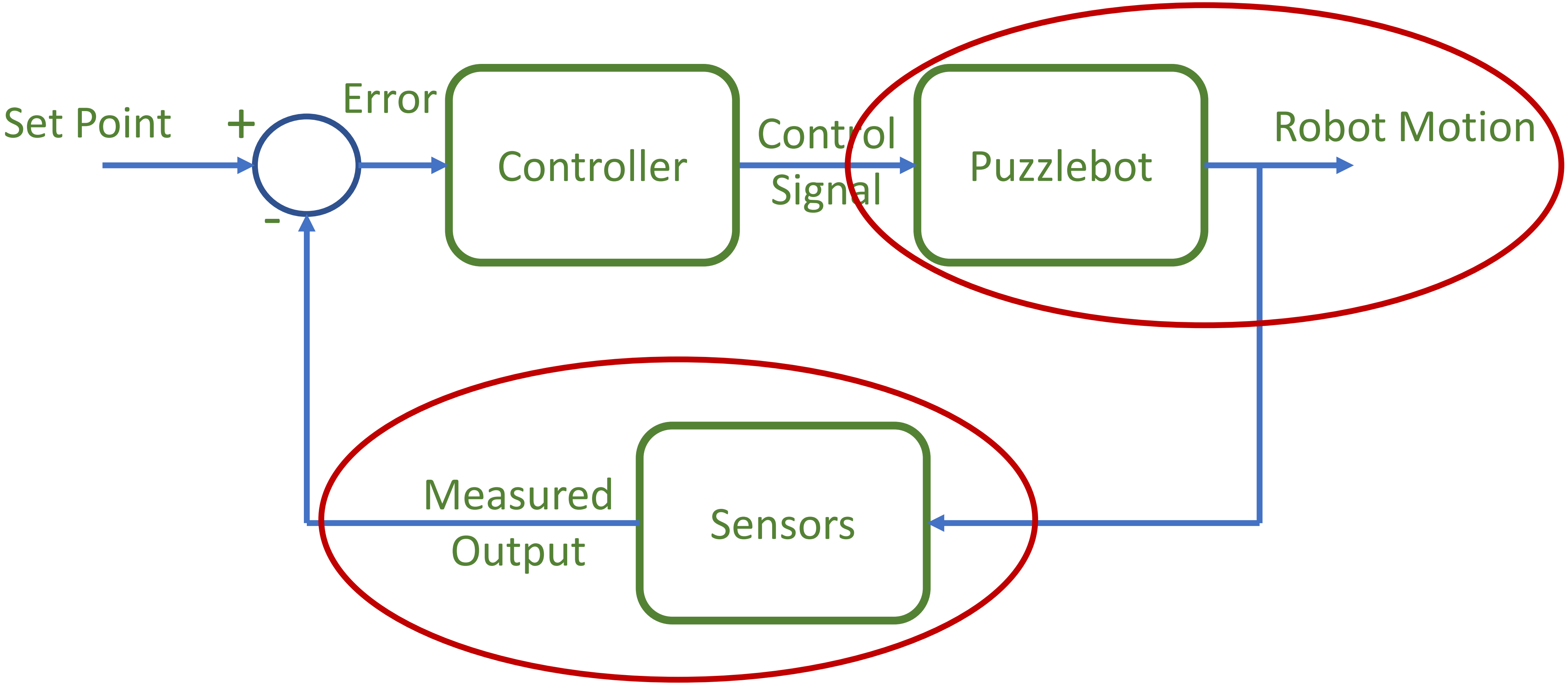
Manchester Robotics

The Task

The Control System

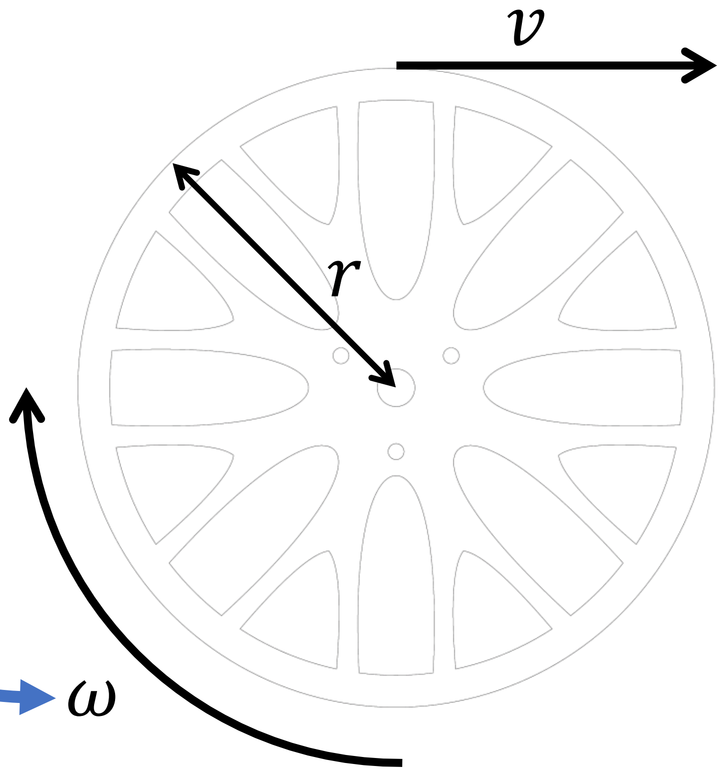


The Control System



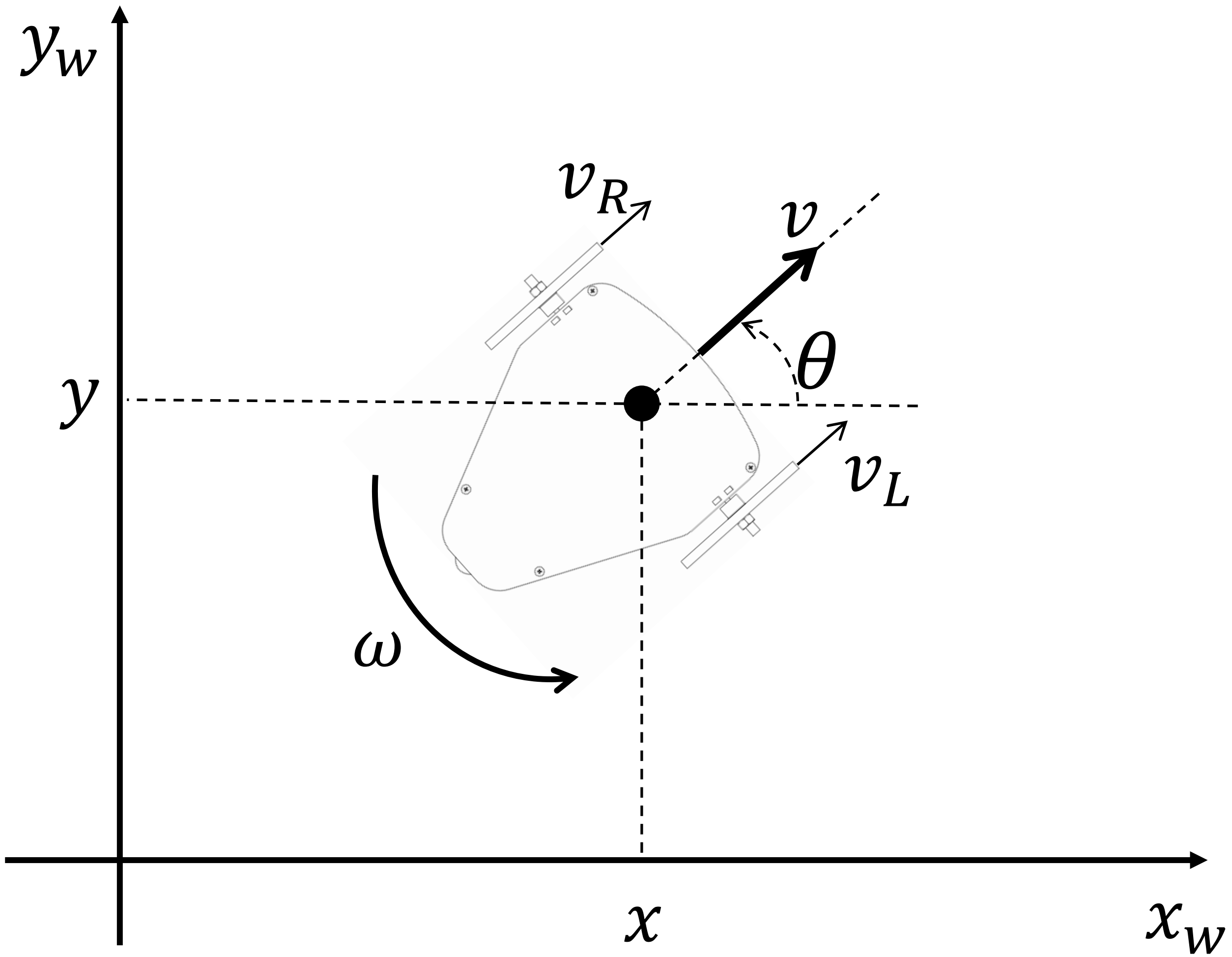
Determining the Robot Position

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



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

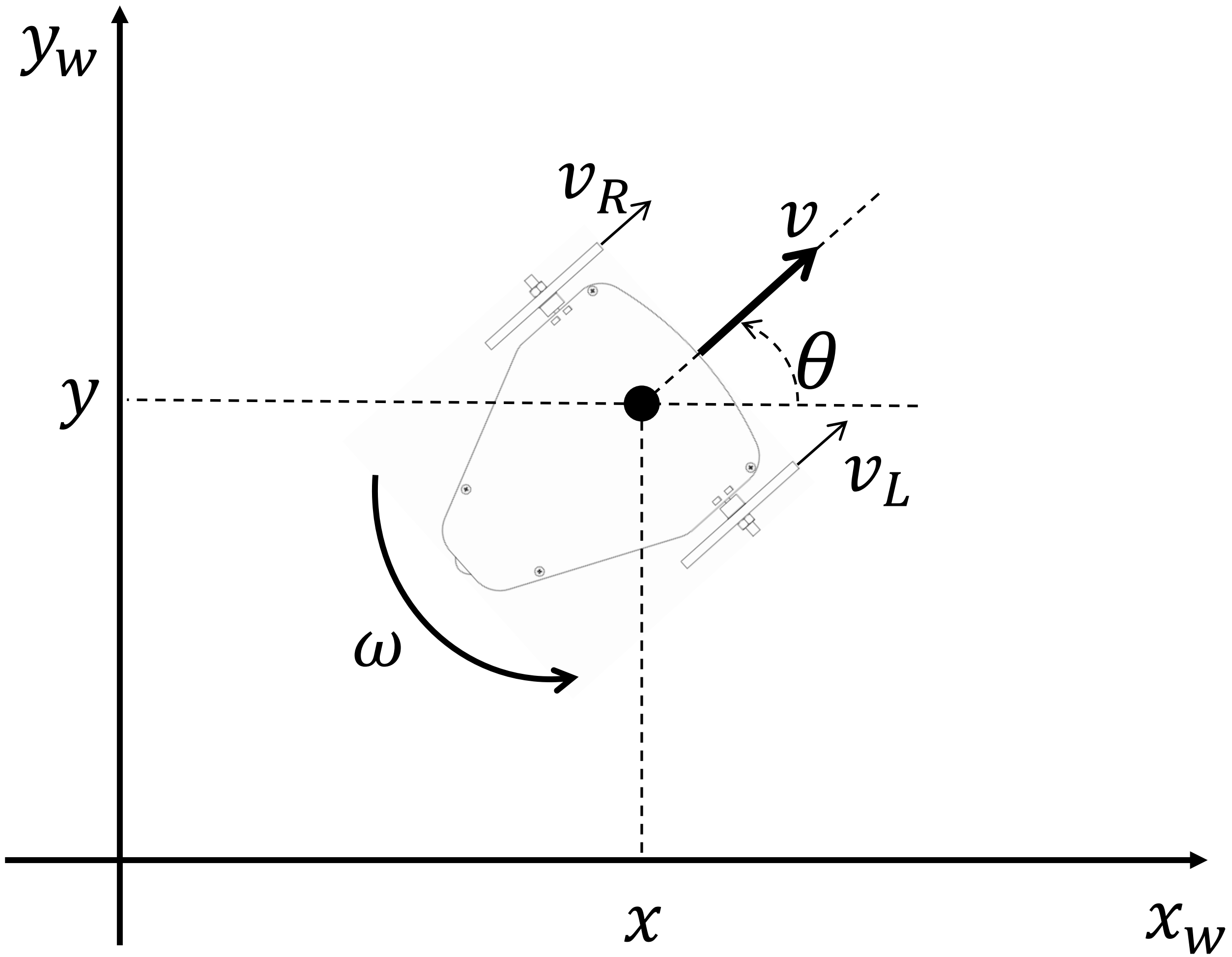
Determining the Robot Position



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

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

Determining the Robot Position



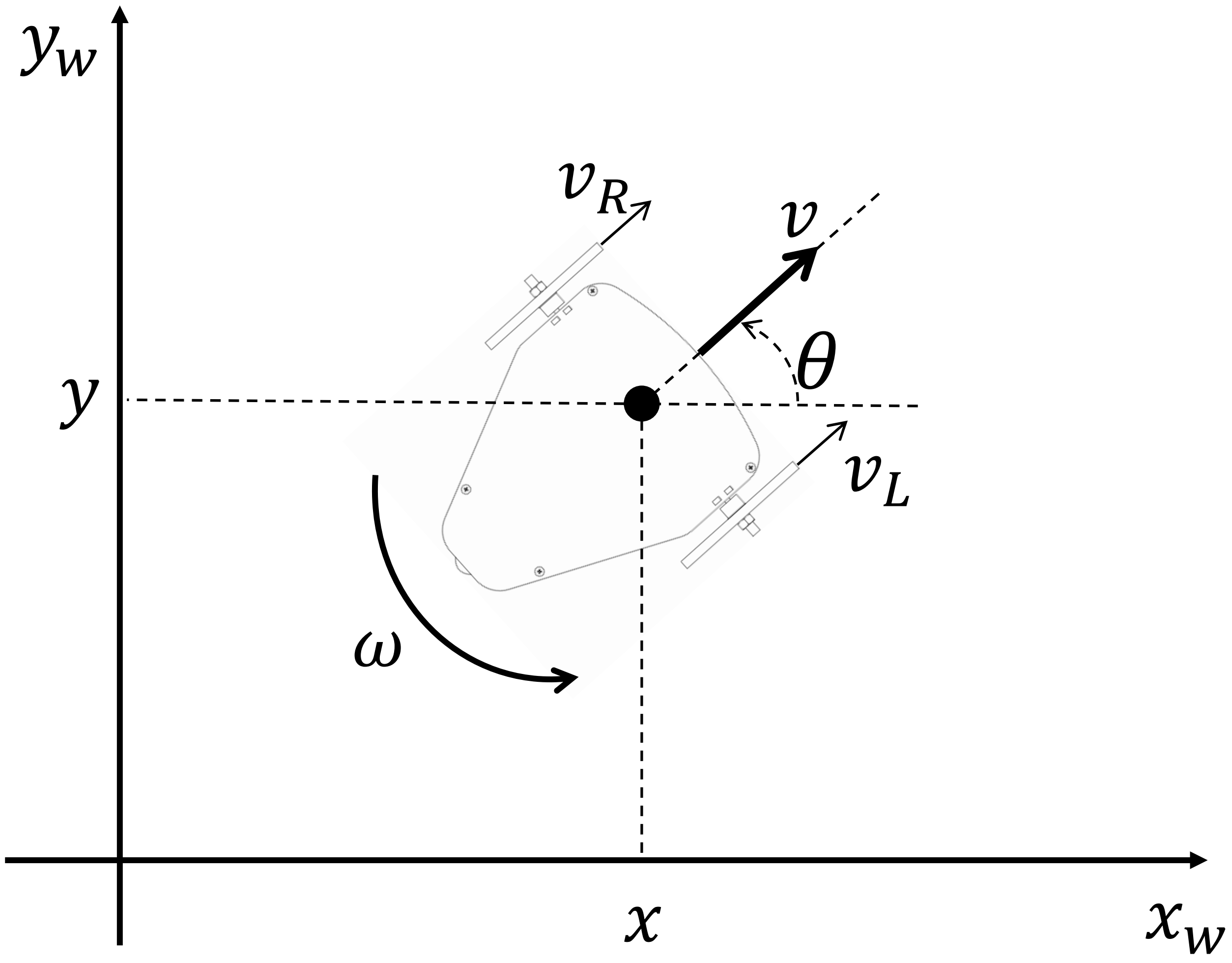
$$v_{Robot} = \frac{v_R + v_L}{2} = r\,\frac{\omega_R + \omega_L}{2}$$

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

$$\dot{x} = v\cos\theta = r\,\frac{\omega_R + \omega_L}{2}\,\cos\theta$$

$$\dot{y} = v\sin\theta = r\,\frac{\omega_R + \omega_L}{2}\,\sin\theta$$

Determining the Robot Position



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

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

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

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:

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

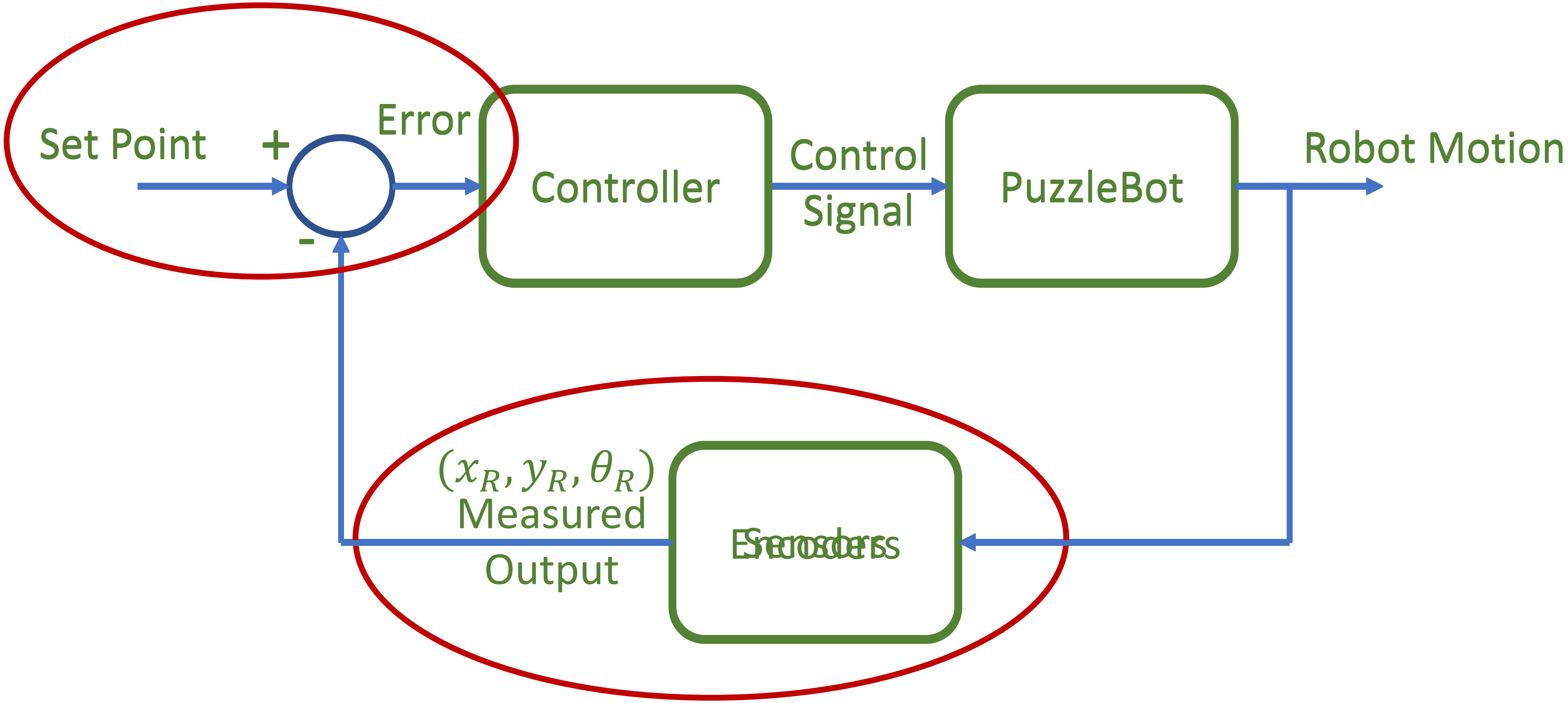
Or:

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

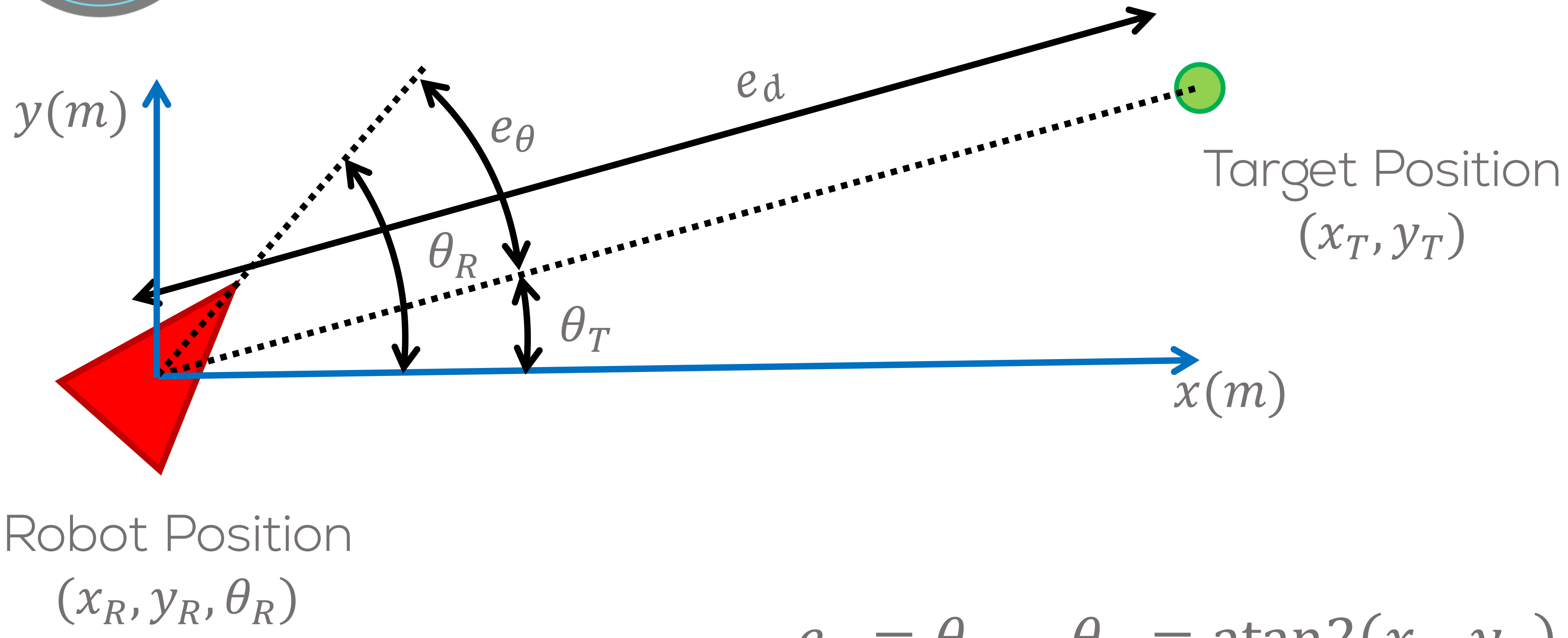
Activity

- 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 set floats, or you can combine them in any way you see fit

The Control System



The Error

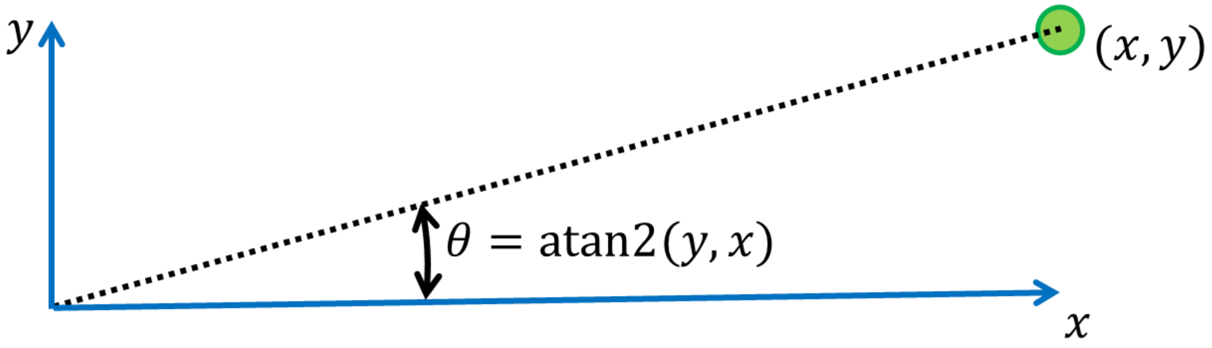


$$e_\theta = \theta_T - \theta_R = \text{atan2}(x_T, y_T) - \theta_R$$

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

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:



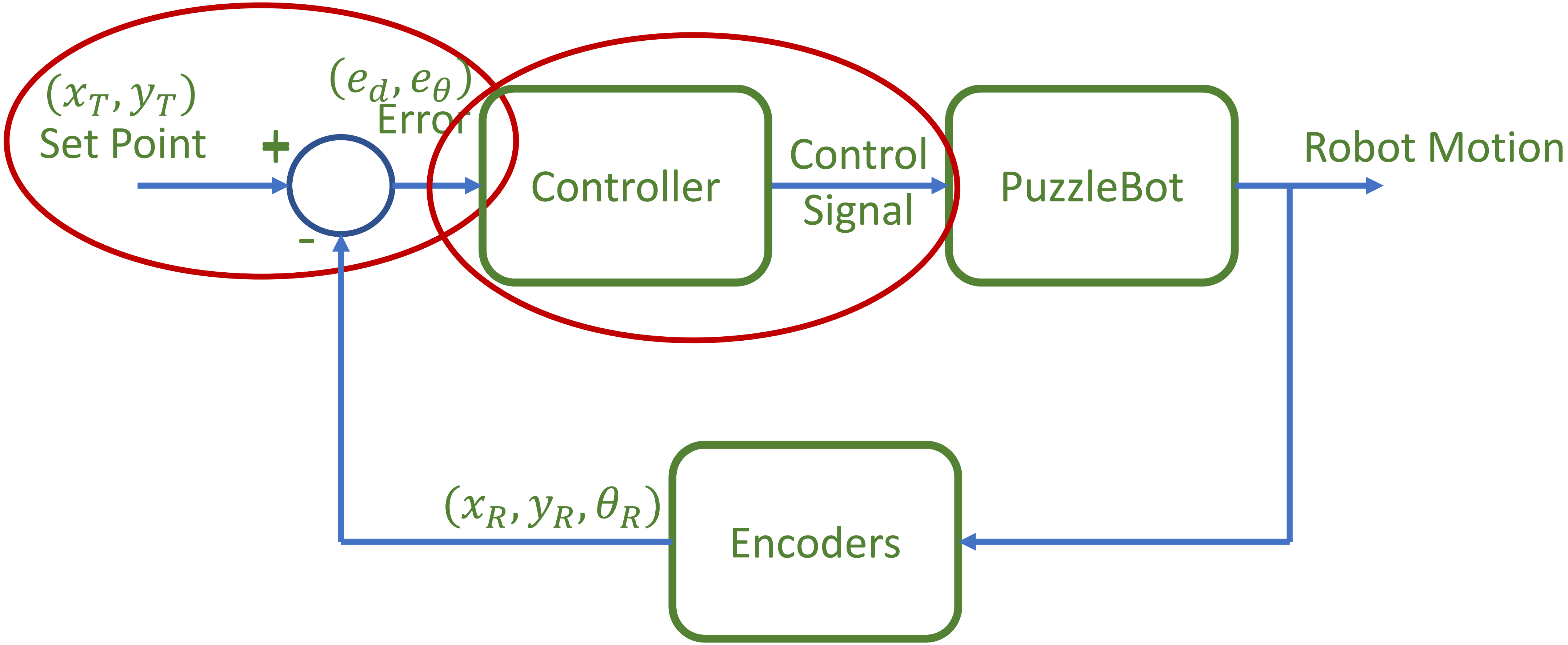
- It is included in most maths libraries, but it is recommended to use numpy, as numpy will be necessary later on in the course

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

Activity

- Modify the previous node to publish ed and etheta.
- 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

The Control System



The Controller

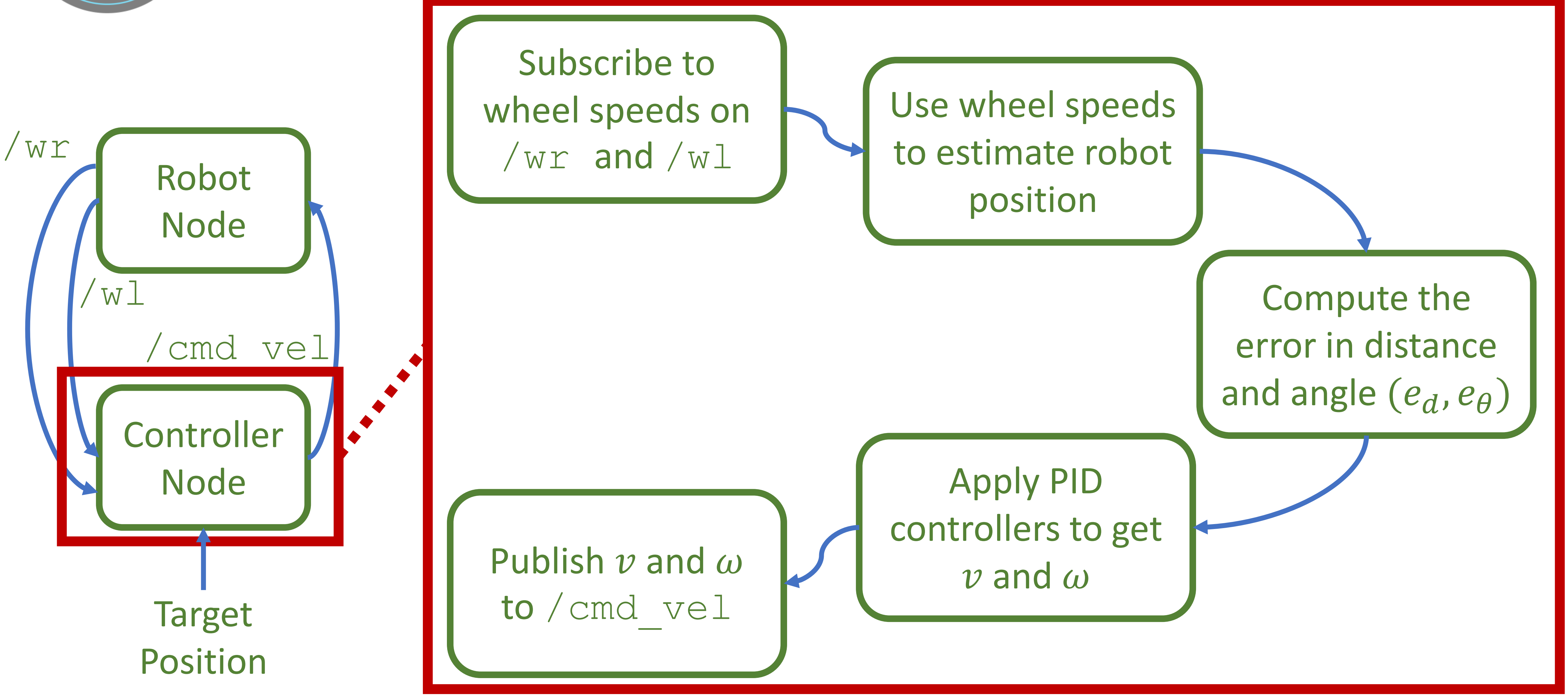
- Since the robot is inherently stable, a simple PID scheme should be sufficient.
- Start with a pair of proportional controllers:

$$v = K_v e_d$$

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

… and add integral and derivative elements if necessary.

ROS setup



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

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.

ROS Tools
ROS Launch Syntax

- Launch files are sets of commands written in xml that allow executing various scripts at the same time.
- The general syntaxis is the following

```
<?xml version="1.0"?>
<launch>
    [Body of the launchfile]
</launch>
```

- This syntaxis allows to run any object used within the ROS architecture and has a wide variety of tools that allow to parametrize the launch file so that it can be adapted to the requirements of you project.
- An extensive documentation can be found in http://wiki.ros.org/roslaunch

ROS Tools

ROS Launch code tools

- Running a node

```
<node name="listener" pkg="basic_comms" type="listener.py" output="screen"/>
```

- Running another file or launch file

```
<include file="$(dirname)/other.launch" />
```

- Set parameters

```
<param name="publish_frequency" type="double" value="10.0" />
```

- Pass args to the launch file

```
<arg name="camera_id" value="cam_3" />
```

- Load files into the system

```
<rosparam command="load" file="$(find package_name)/config/file_name.yaml" />
```

The Task