Machine (or Reinforcement): Learning to assist vessel docking in extreme environments

Bachelor defense

June 26, 2020

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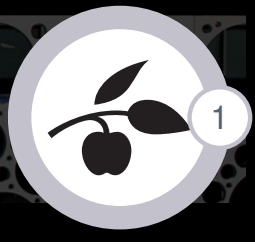
Agenda



- Quick introduction to the problem
- Reinforcement Learning
- Simplified model
- Results & Discussion
- Conclusion & Future work

Introduction
The Vessel and the problem

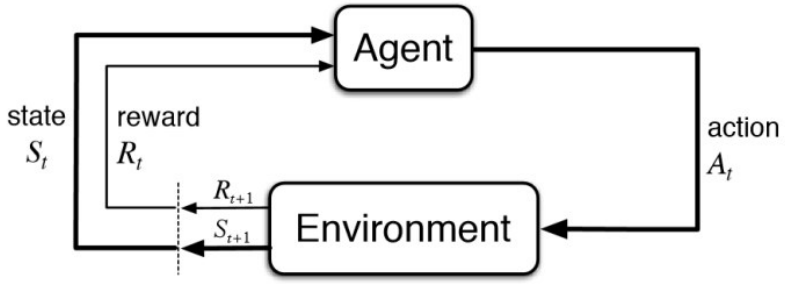
The issue is keeping the vessel stable enough to attach to the windmill during a storm.

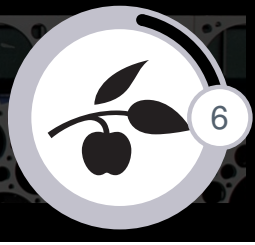
Introduction
The problem and the solution

Overview of the problem

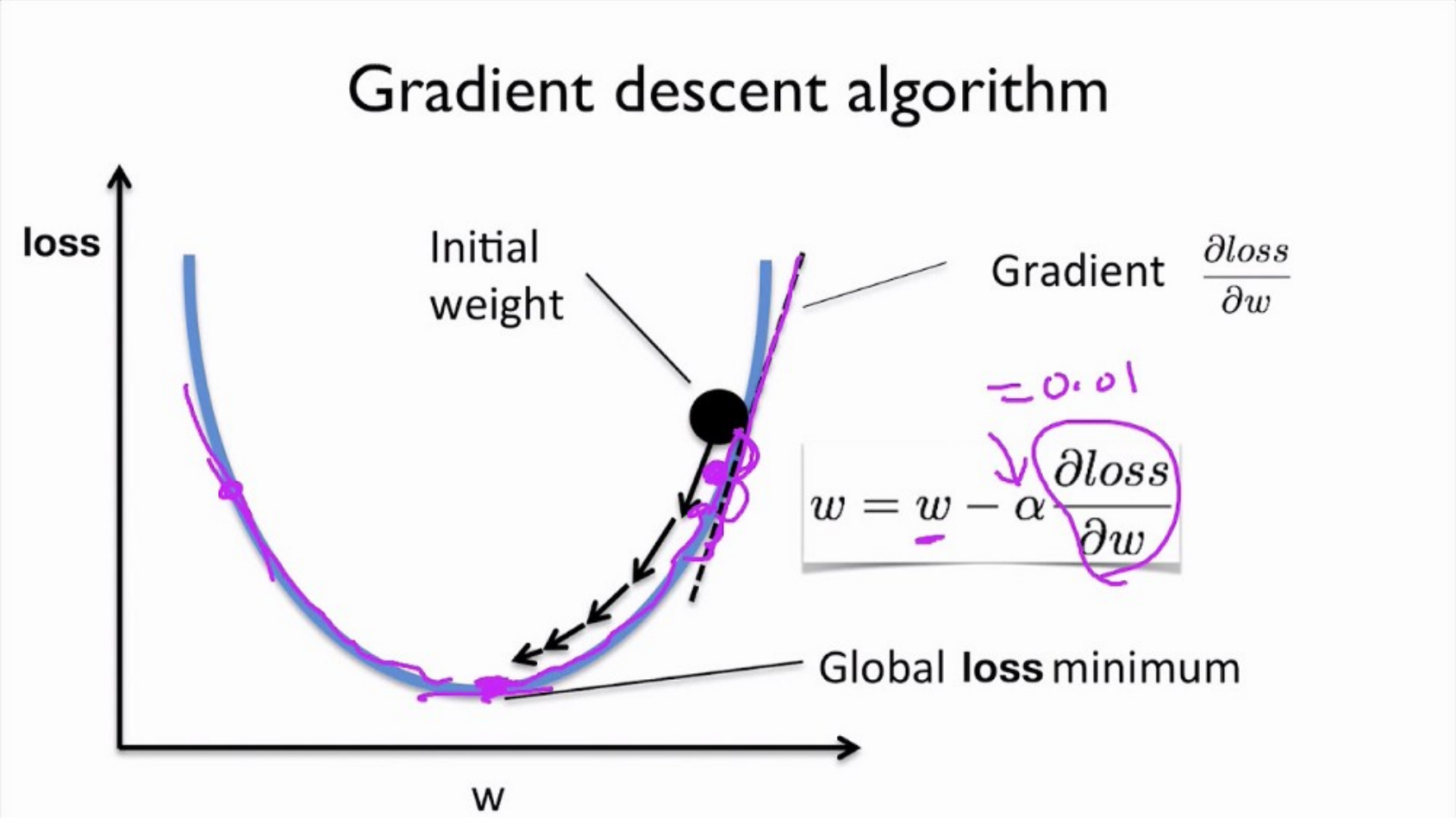
- Vessel stabilizer
- Why is a vessel stabilizer needed?
- What is Dacoma's current solution?
- The objective
- The approach

- Agent
- Environment
- States, Statespace, Actions & Actionspace
- Reward and Reward function
- Policy





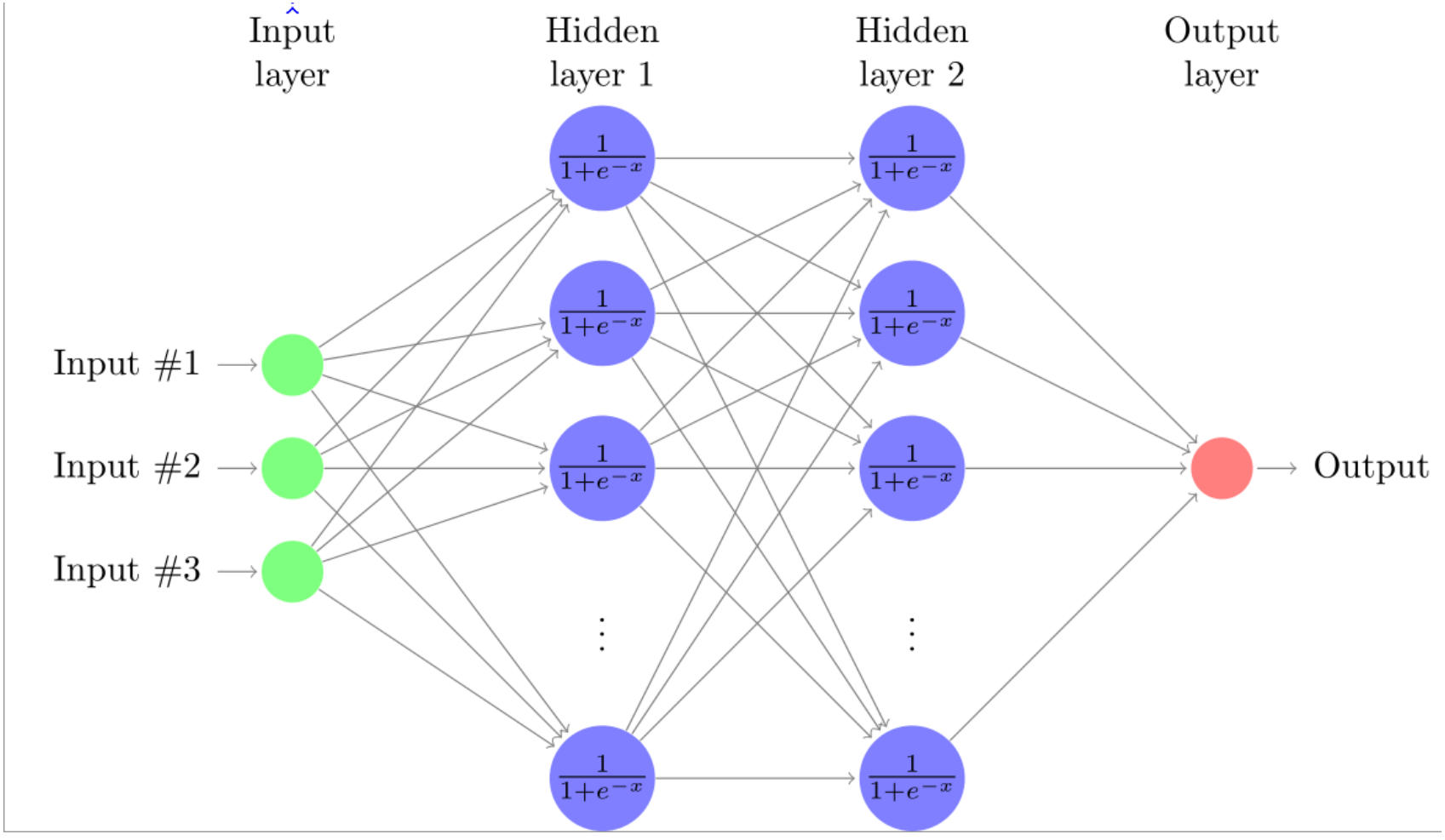
Why does classic Reinforcement learning not work for this problem?

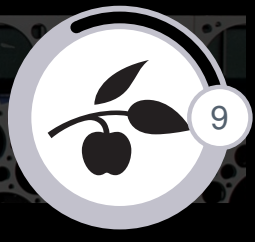


What makes Policy gradient well-suited for this task?

Reinforcement Learning

The Neural Networks





$$m_t = \beta_1 m_{t-1} + (1-\beta_1) g_t$$
$$v_t = \beta_2 v_{t-1} + (1-\beta_2) g_t^2$$

Moving averages of gradient and squared gradient.

$$\hat{m}_t = \frac{m_t}{1-\beta_1^t}$$
$$\hat{v}_t = \frac{v_t}{1-\beta_2^t}$$

Bias corrected estimators for the first and second moments.

$$w_t = w_{t-1} - \eta \frac{\hat{m}_t}{\sqrt{\hat{v}_t} + \epsilon}$$

Central difference ?

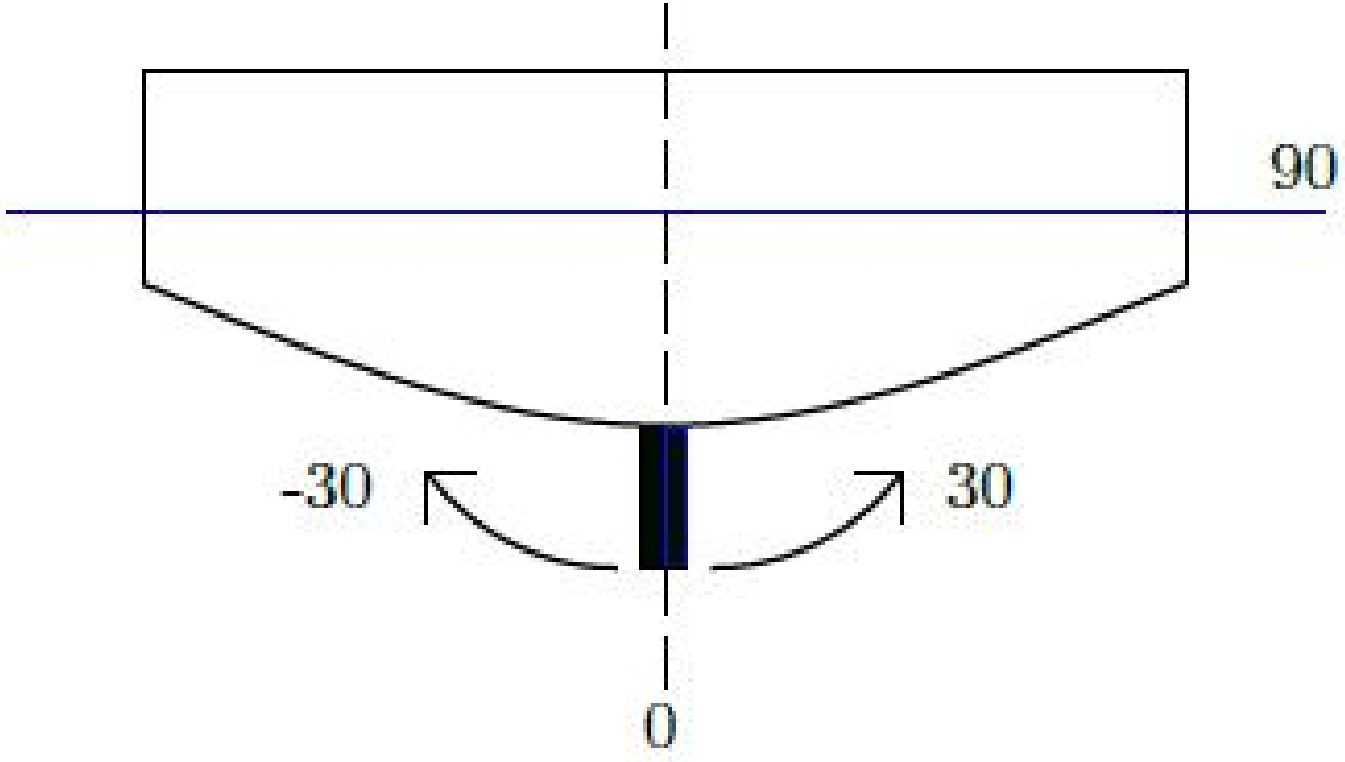
$$\Delta_h[f](x) = f\left(x + \tfrac{1}{2}h\right) - f\left(x - \tfrac{1}{2}h\right)$$

- Reward & Reward Function

Simplified Model

Intro

Using Archimedes principle and a adjustable air keel works to our advantages, the boat can stabilize itself.



Simplified Model
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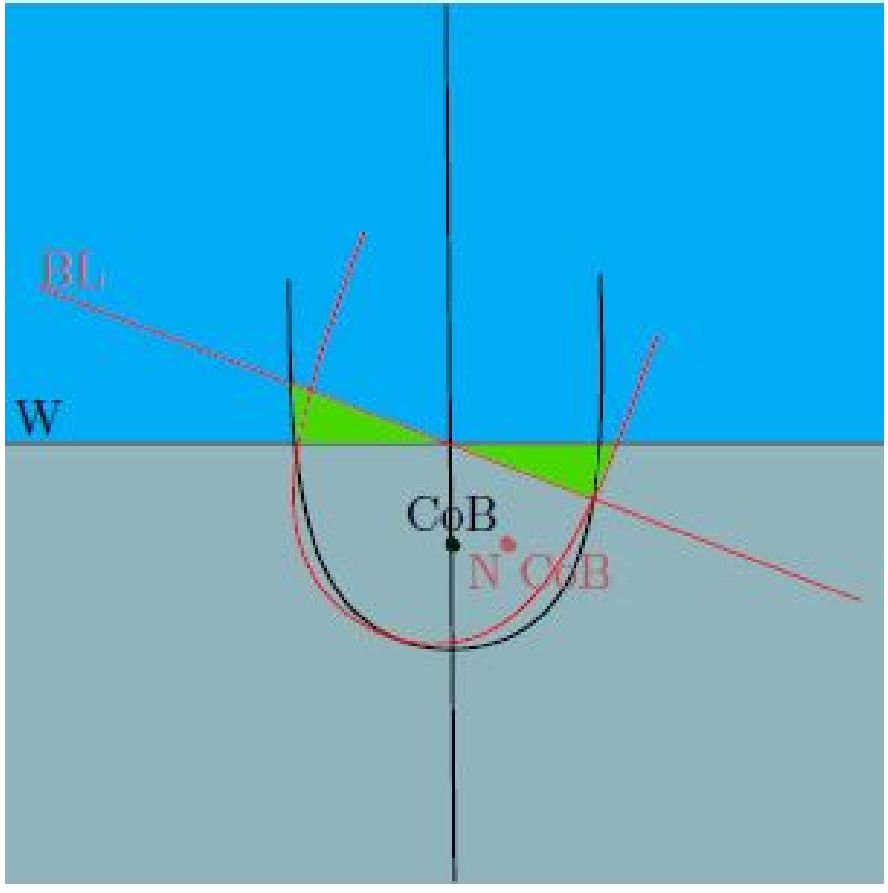
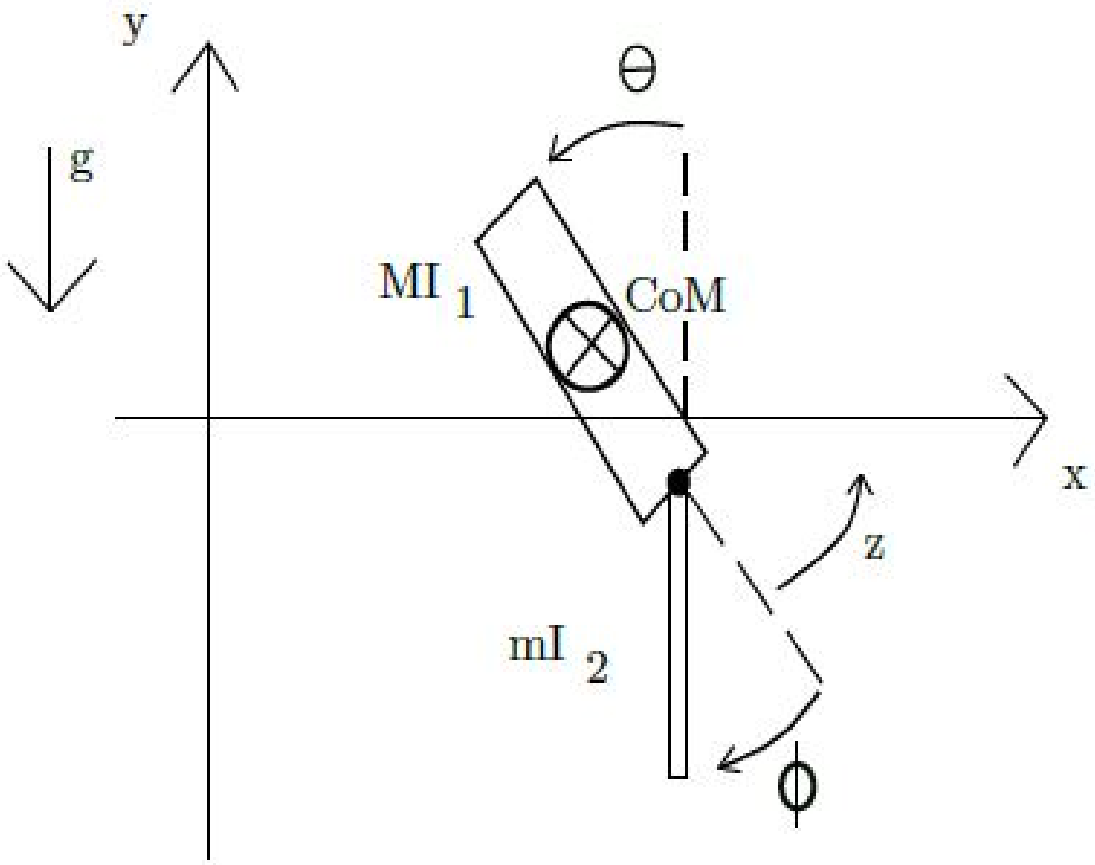


- Boat modelling



Simplified Model

The model

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + G(g)k_{\epsilon}q + B_F\dot{q} = \Gamma$$

where M(q) is the inertia matrix, C(q,$\dot{q}$) are the Coriolis terms, G(q) is the gravity vector, $k_{eqsilon}$ is a matrix with the elastic constants, B_F is the friction terms and Γ is the vector of generalized external forces applied, i.e $\Gamma^{\tau} = [0, 0, 0, z]$.

Limitations?

Training and testing settings and limitations

- 500 rollouts, 200 iterations and two simulations
- Random generated bias values
- Angle limitations for the keel (± 40) and boat (± 30)
- Angles randomly generated to be between ± 25.
- Activation function = Leaky ReLU
- Central finite difference, $\epsilon = 0.1262$
- Adam as optimizer
- Stopping criteria is ± 1

Tuning hyperparameters

- NN architecture
- Learning rate

	HL = 1 & NoN = 8 (HL1)	HL = 2 & NoN = 8,4 (HL2)	HL = 2 & NoN = 8,8 (
LR	0.1	0.01	0.001
LR	0.2	0.02	0.002
LR	0.5	0.05	0.005

Table: Displays the different learning rates tested with the three different architectural choices.

Results & Discussion

Tuning - NN architecture

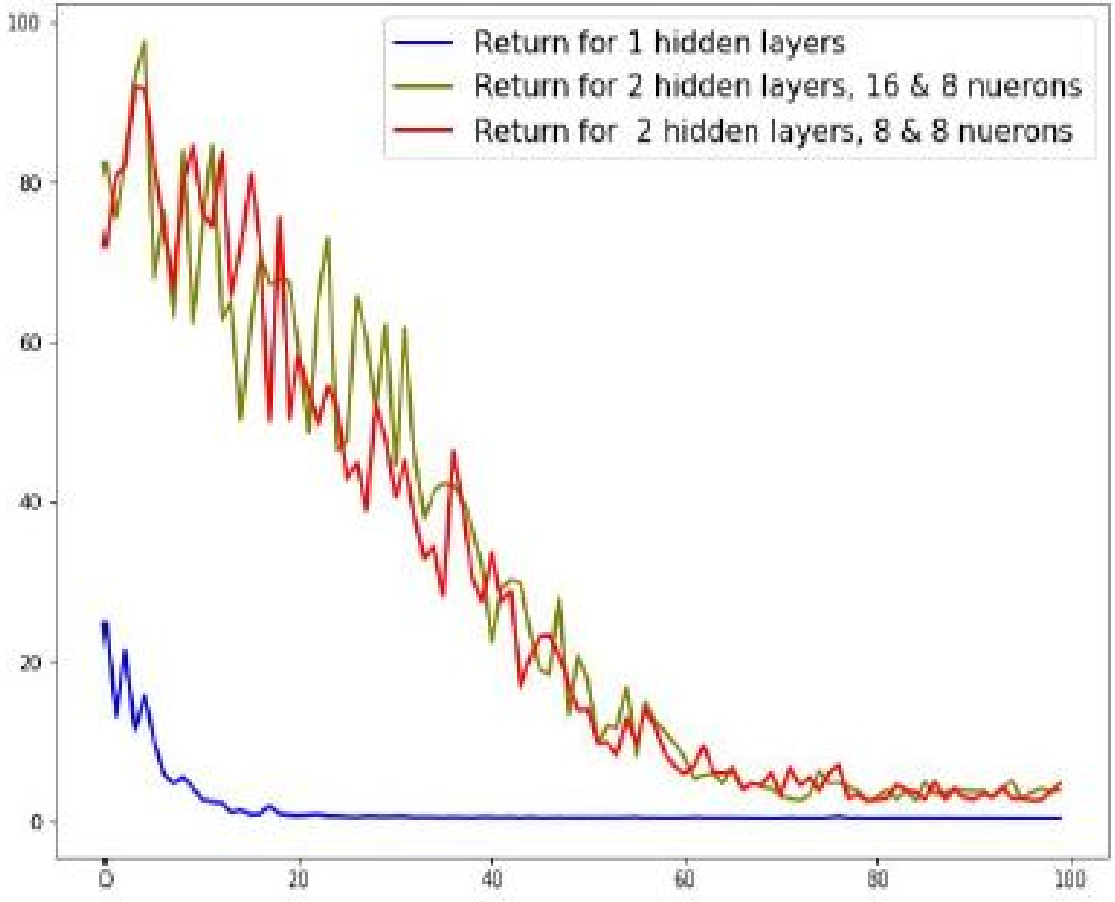


Figure: Learning rate: 0.001

Results & Discussion

Tuning - NN architecture

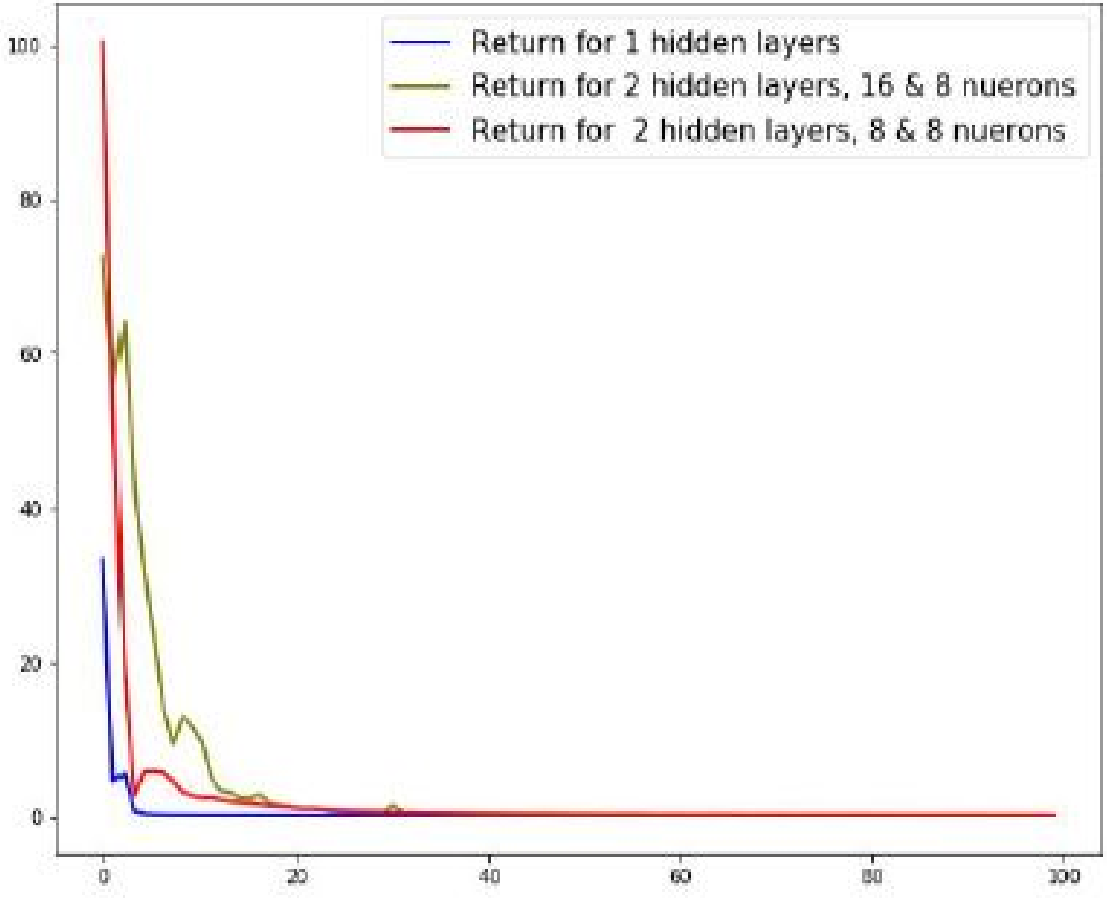


Figure: Learning rate: 0.01

Results & Discussion

Tuning - NN architecture

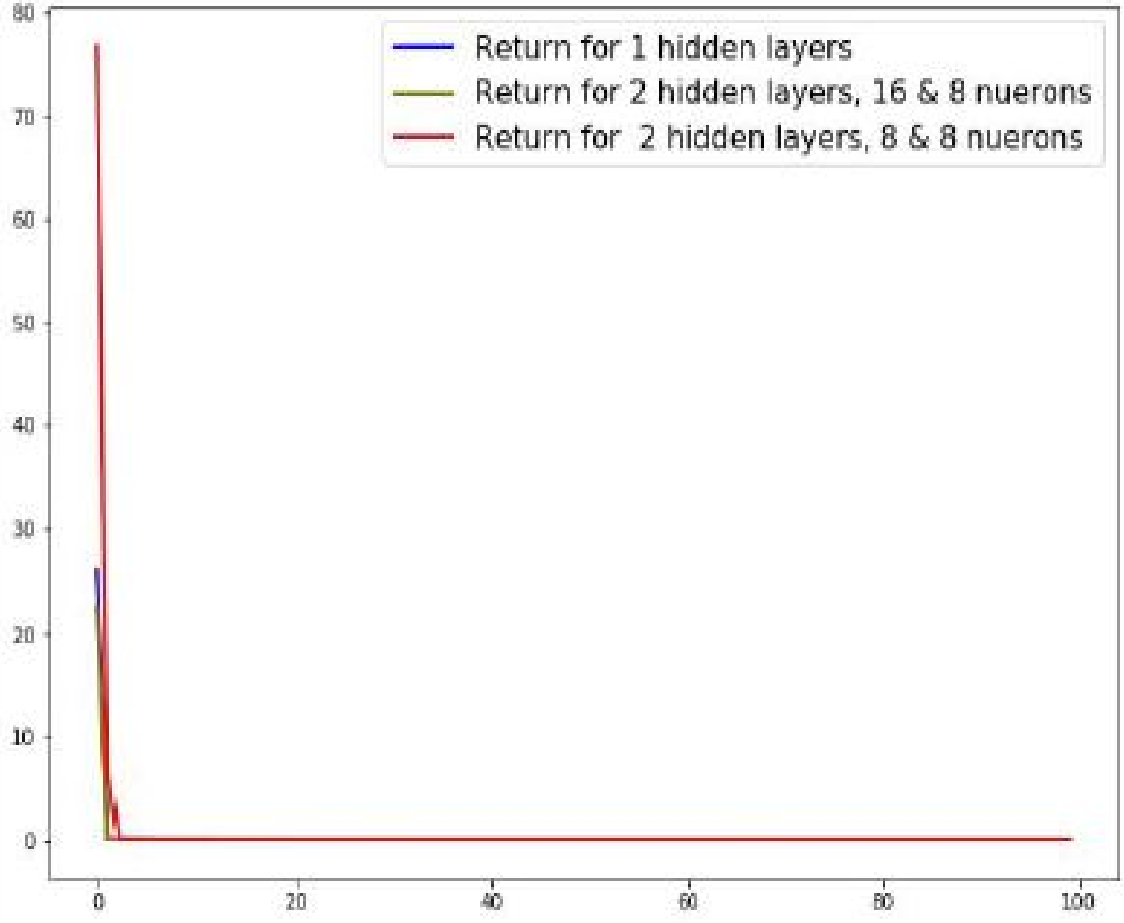


Figure: Learning rate: 0.1

Results & Discussion

Tuning - Learning rates

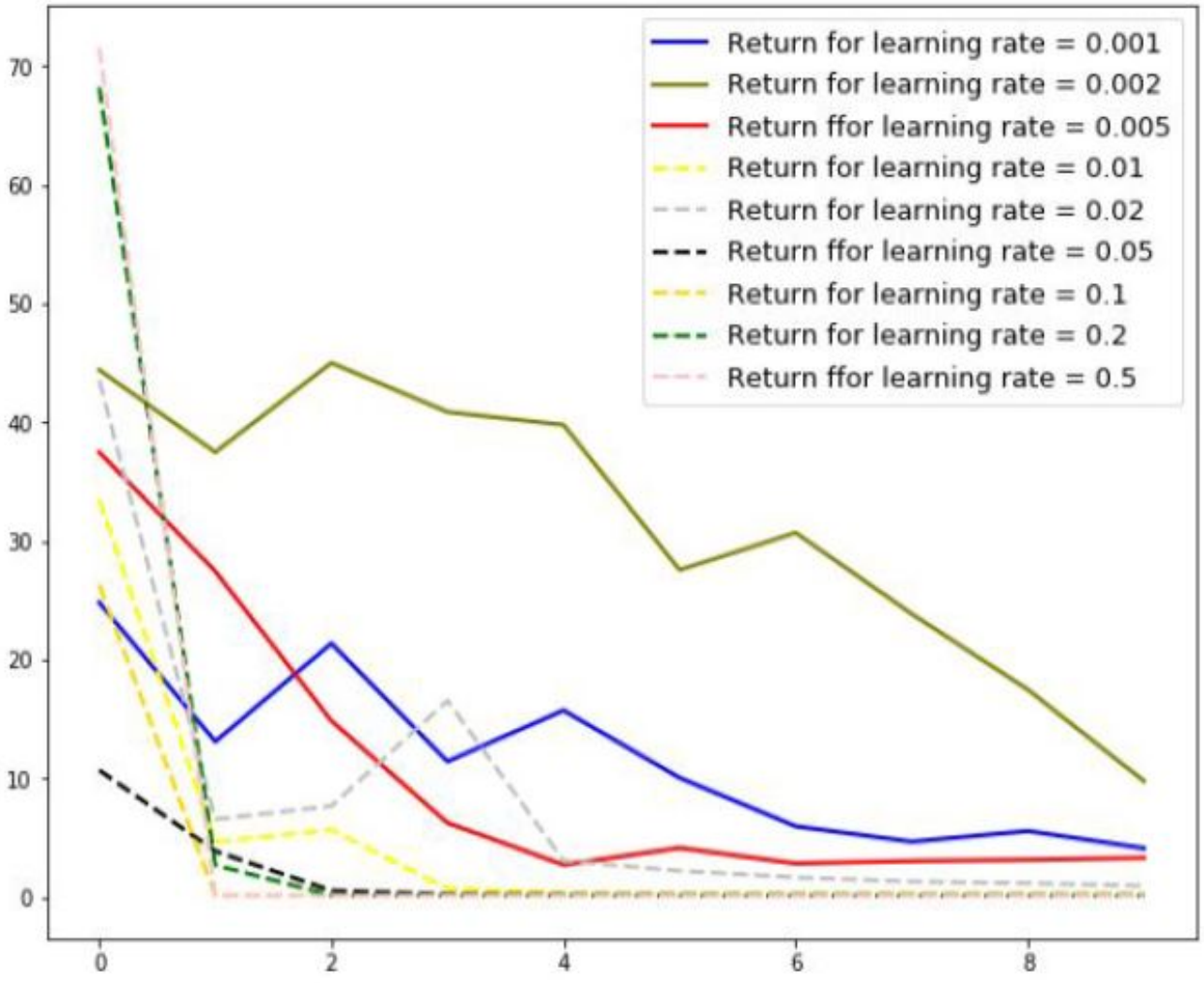


Figure: All learning rates cropped from 0 to 10 iterations

Results & Discussion

Tuning - Learning rates

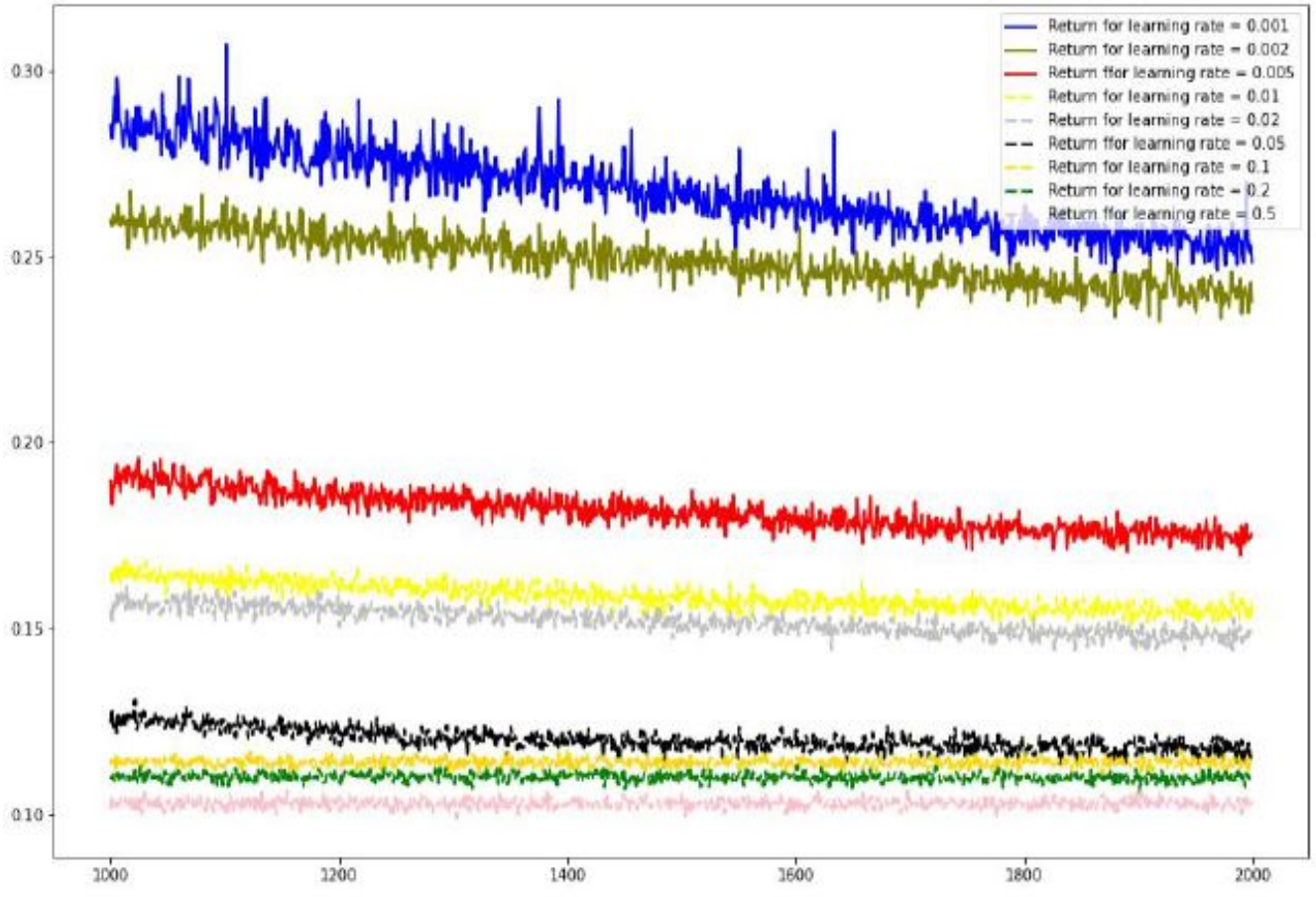


Figure: All learning rates cropped from 1000 to 2000 iterations

Results & Discussion

Tuning - Learning rates

Figure: Shows the weights from chosen learning rates

ϕ	θ
$0°$	$\pm 20°$
$0°$	$\pm 15°$
$0°$	$\pm 10°$
$\pm 5°$	$\pm 20°$
$\pm 5°$	$\pm 15°$
$\pm 5°$	$\pm 10°$
$\pm 10°$	$\pm 20°$
$\pm 10°$	$\pm 15°$
$\pm 10°$	$\pm 10°$
$\pm 15°$	$\pm 20°$
$\pm 15°$	$\pm 15°$
$\pm 15°$	$\pm 10°$
$\pm 20°$	$\pm 20°$
$\pm 20°$	$\pm 15°$
$\pm 20°$	$\pm 10°$

Test #	ϕ	θ	CC without torque limit	CC with torque limit
1	0°	-20°	0.1345	0.9
2	0°	-15°	0.1341	0.73
3	0°	-10°	0.1320	0.48
4	5°	-20°	0.1423	0.9
5	5°	-15°	0.1395	0.74
6	5°	-10°	0.1350	0.48
7	10°	-20°	0.1384	0.9
8	10°	-15°	0.1365	0.73
9	10°	-10°	0.1324	0.48
10	15°	-20°	0.1348	0.74
11	15°	-15°	0.1384	0.73
12	15°	-10°	0.1354	0.73
13	20°	-20°	0.320	0.91
14	20°	-15°	0.1315	0.91
15	20°	-10°	0.1321	0.9

- Use reinforcement to apply a torque to the air keel in order to keep the vessel stable.
- Derived a simplified model for simulation use.
- Trained and agent and found the best policy using the simplified modeled
- Added a mock limitation on the amount of torque which the agent could apply.
- Works well, maybe even a bit too well?

Conclusion & Future Works

Future works

- Torque limitations
- A model that includes the proper effect of Dacoma's air keel
- Adding waves to the model/training the model out in the sea