16-299 Lecture 10: Modeling the lab TWIP robot

Making a model is referred to as "system identification" in the engineering community, and as "learning" in the AI community.

What kind of model do we want to make?

We would like to use state space design techniques to design the controller and any filter. We want to identify a state vector, an action vector, and A, B, C, and D matrices for a discrete time system with some sampling rate.

- Direct regression to find A, B, C, and D components, guided by our prior knowledge of the dynamics, or by not assuming any knowledge. This is especially useful for
- Generating a frequency response of the system or its components, and then finding A, B, C, and D matrices which generate the same frequency response.

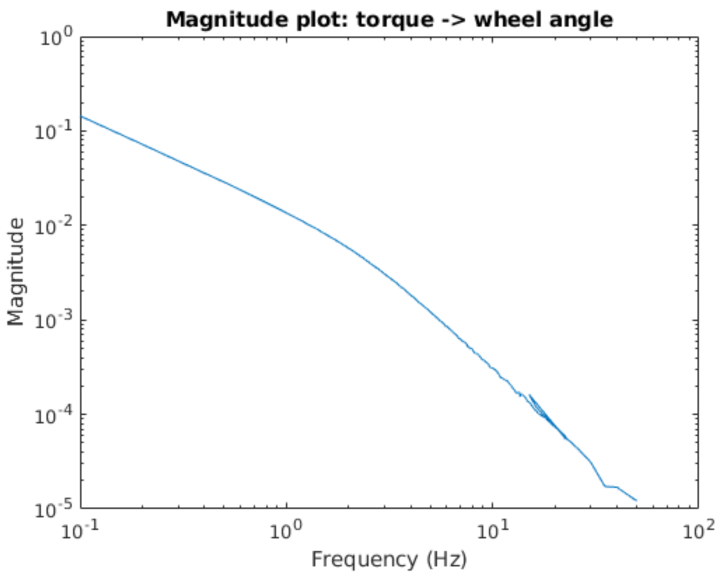
We could also design a controller using frequency domain techniques.

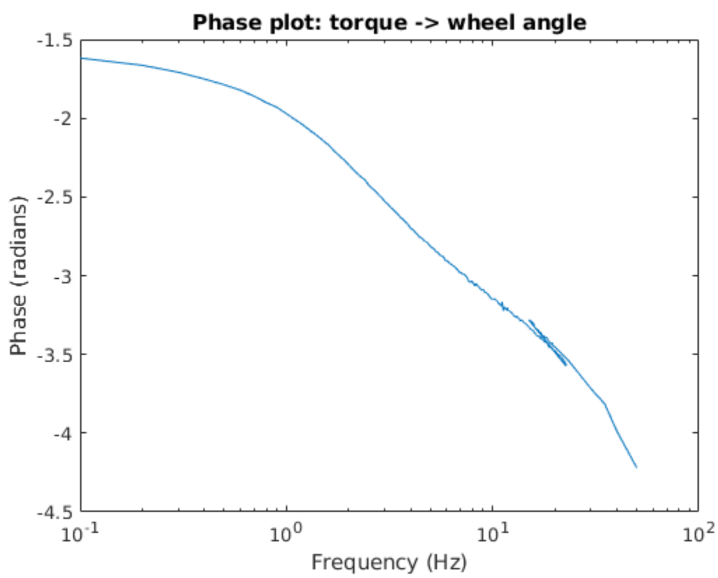
What should the model structure be?

Let's start be just considering the motor driving a wheel, and trying to understand the actuator dynamics.

- The obvious one where the state is (wheel angle, wheel angular velocity) and the action is motor torque. The problem with this choice of state is that we have no direct measurement of velocity, which makes the direct regression approach more difficult. We would first have to estimate a velocity signal. How would we do this?
- We can add past measurements and commands to handle delay and more complex dynamics. We could include any of angle(k), angle(k-1), angle(k-2), ... and torque(k), torque(k-1), torque(k-2), ... This boils down to ARMA modeling.

What does the frequency response of the motor/wheel system look like?





How do we convert measurements and commands into engineering units?

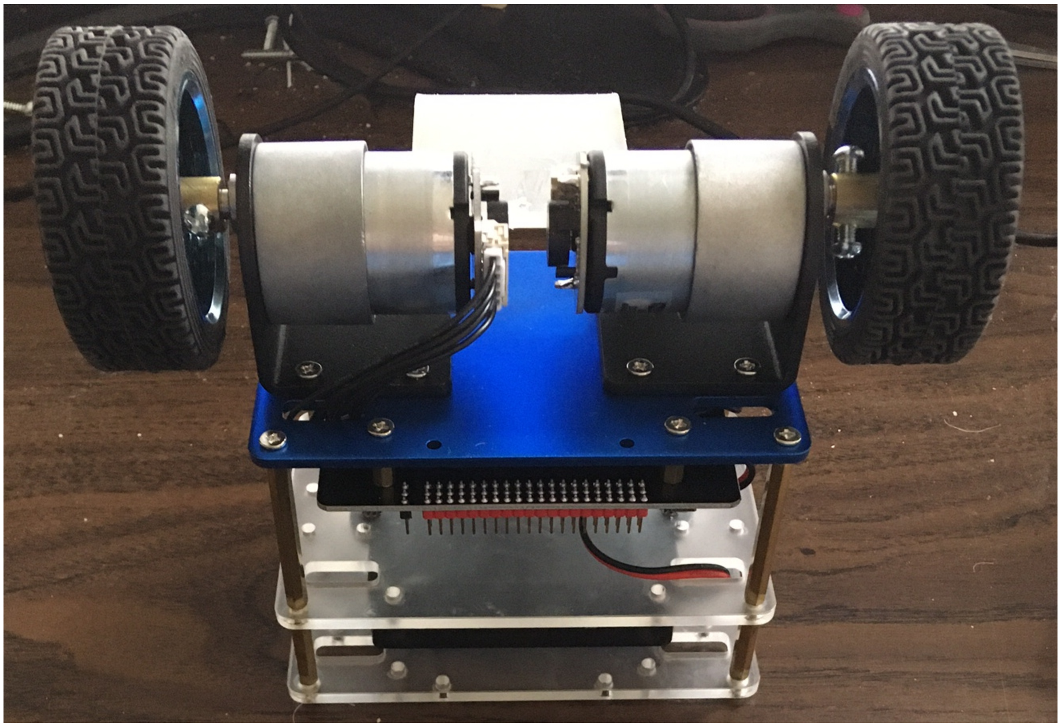
This is really only a problem with torques.

What changes when we swing the body?

Need to include IMU outputs. Need to correct bias of these.

What will the first lab assignment consist of?

Assuming the robot is upside down and the wheels are free:



Design a feedback-only PD controller to move each wheel 1 radian. Where does the velocity signal come from? How quickly can you reach the target without saturating the motors at any point (command ≥ 255)?

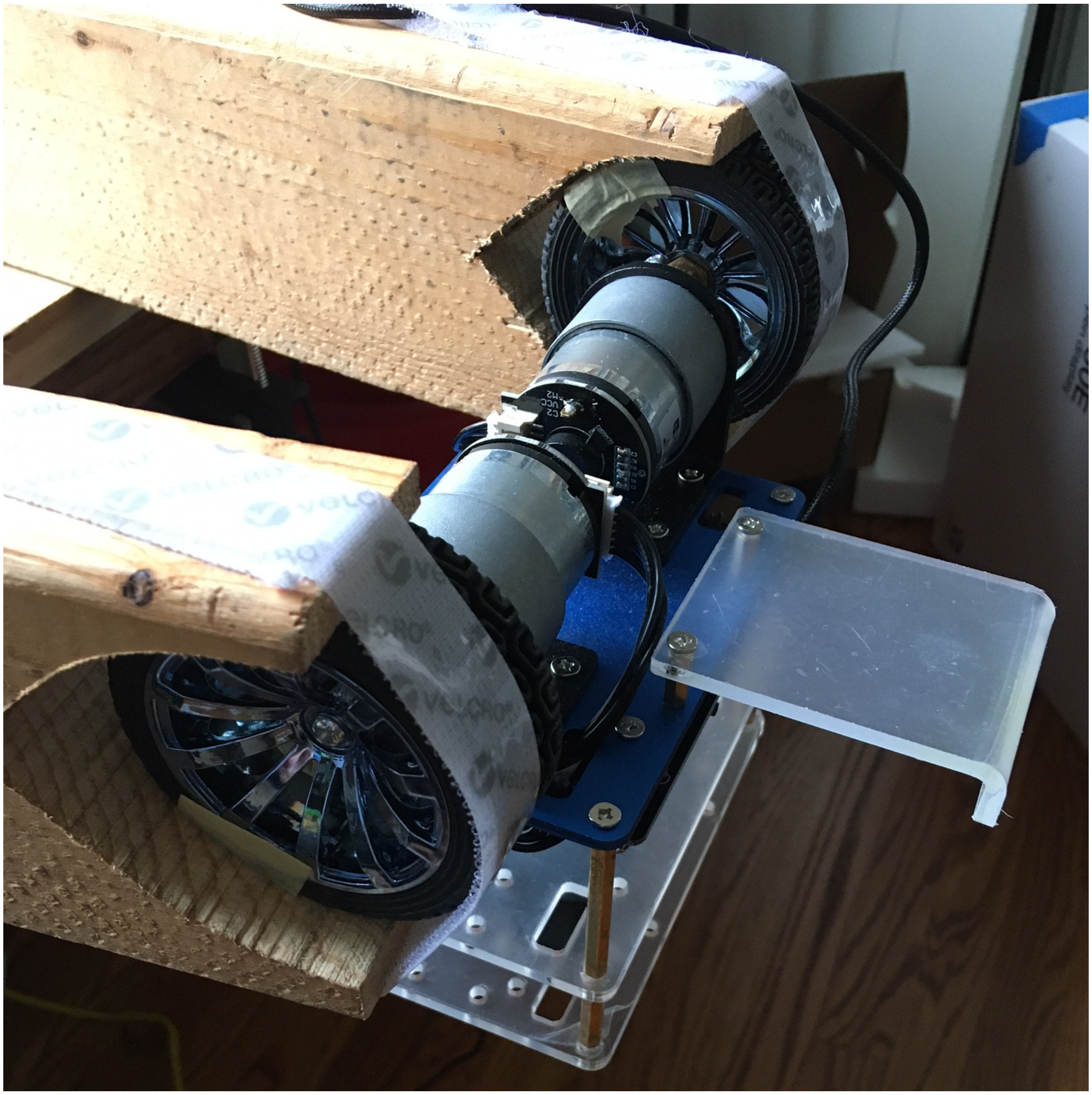
Identify a model of the robot based on the plant frequency response.

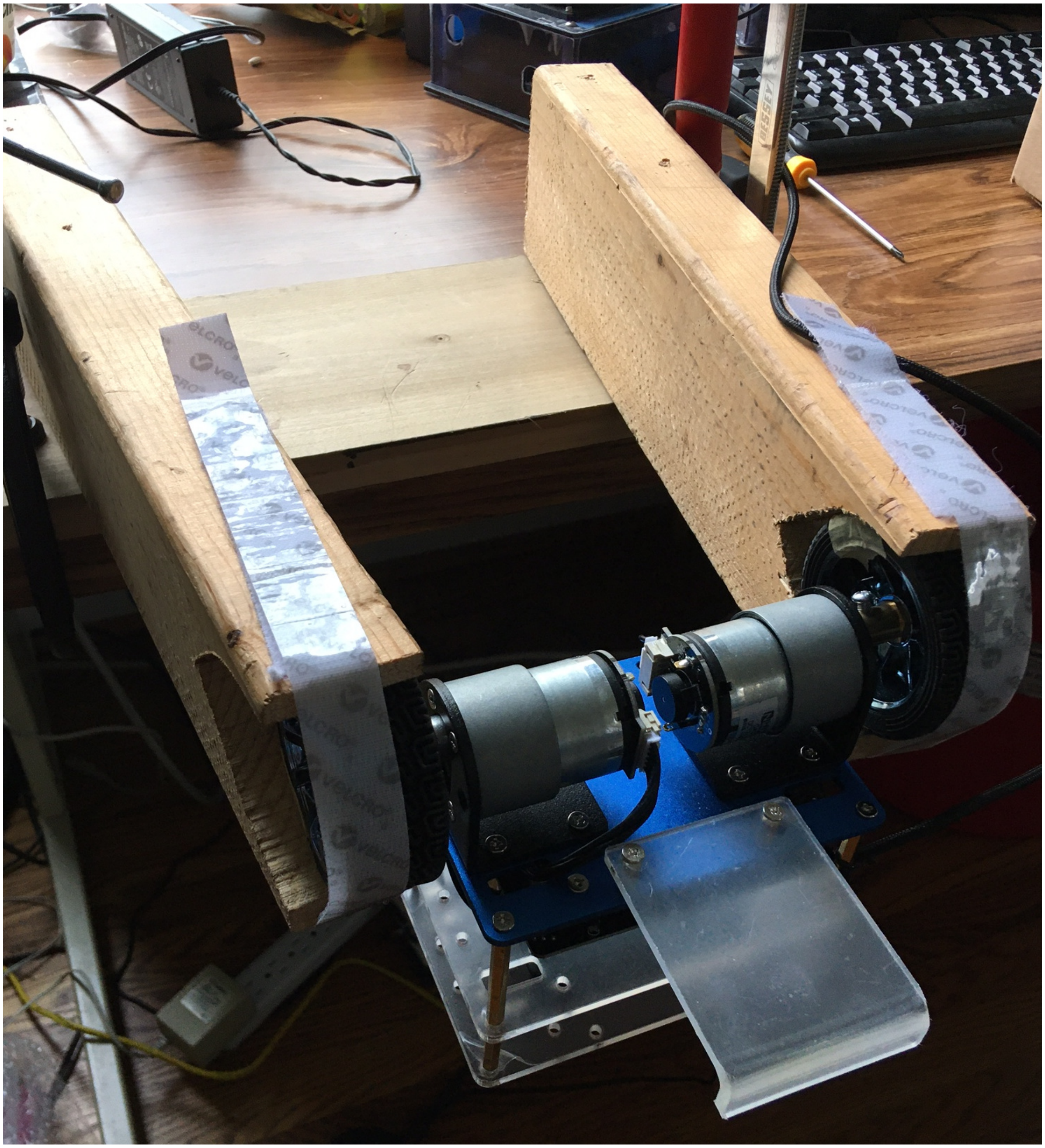
Identify a model of the robot based on direct regression to find matrix components.

Use state space techniques to design a controller to move each wheel 1 radian. How quickly can you reach the target without saturating the motors? Can this controller go any faster than the PD controller?

Does adding an observer such as a Kalman Filter to filter noise and estimate missing states help?

Can you “cancel” friction so the wheel turns freely? Note that you can try to separately compensate static and dynamic friction, or friction components due to the velocity, friction components that are just due to the direction of movement, and friction observed when the wheel is not moving.

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