Goals:

Use state of the art gait generation and motion planning to control Boston Dynamics Spot in Webots to walk on uneven terrain while being robust to various external pushes/forces. The evaluation of the system will be having Spot walk on unseen and technical terrain to reach a goal state, with added pushes at random times.

Technical Components

- Gait controller that is robust to technical terrain Confidence: $\frac{9}{10}$
- Add robustness to external forces Confidence: $\frac{8}{10}$

Note: Should be noted that this project can be very fluid as to what hurdles I run into or overcome. i.e. there are many different aspects I can take away/add that will make the project both sufficient for a final project, but also allow it to agree with my schedule and abilities.
For example, if it turns out the uneven terrain aspect of the project turns out to be too difficult to handle, I could keep the simulated world flat, and do challenges from the other final project environment that are altered for Spot.
Which is why the technical components section is tiny.

Roadmap

1.) Set up Webots sim in flat environment, use perfect sensors and actuators, and utilize MoveIt to have Spot walk around.

2.) Replace MoveIt with SOTA gait generation methods - (Alternate Method: Train multiple action policies with RL, have high level controller to choose specific policy)

3.) Add noisy actuators and sensors to more resemble reality

4.) Replace flat world with uneven terrain

5.) Make gait generation methods robust to external forces (First on flat world)

Teammates

- Chris Beggs - Took UMich's DL course, (Slowly) going through Sergey Levine's Deep RL course, plus I'm going through literature to prepare.

Stretch Goals/Things I could add

- Add obstacles to world and use SLAM
- Compare gait generation methods with Deep RL
- Various challenges from final project competition
- Socially Aware Motion Planning
- Add manipulator for object grasping

Motivation

I do want to work on a robot with joints/manipulators because it's an interesting problem. Robots like Spot are better equipped for technical terrain that cars are not able to reach. Also, smaller quadrupeds are able to achieve a better relationship with humans than cars. Plus I love dogs.

Timeline Risks

Mostly just some aspect of the project taking much longer than anticipated, like implementing some aspects of different papers, unexpected software issues, etc.

Related Work

- **Gait Generation, Joint Controllers:**
  - Discovery of Complex Behaviors through Contact-Invariant Optimization *Mordatch et al.*
  - Feature-Based Locomotion Controllers *Martin de Lasa et al.*
  - Fast and Flexible Multilegged Locomotion Using Learned Centroidal Dynamics (Source code included) *Kwon et al.* - http://calab.hanyang.ac.kr/papers/flexLoco.html
  - Gait and Trajectory Optimization by Self-Learning for Quadrupedal Robots with an Active Back Joint *Masuri et al.*
  - Automatic Gait Pattern Selection for Legged Robots, *Wang et al.*
  - Adaptation of Quadruped Gaits Using Surface Classification and Gait Optimization *Kim et al.*
  - A Robust Quadruped Walking Gait for Traversing Rough Terrain *Pongas et al.*
  - Robust Gait Synthesis Combining Constrained Optimization and Imitation Learning *Ding et al.*
  - Gait and Trajectory Optimization for Legged Systems Through Phase-Based End-Effector Parameterization *Winkler et al.*
- **SLAM**
  - ORB-SLAM3: An Accurate Open-Source Library for Visual, Visual-Inertial and Multi-Map SLAM
  - ORB-SLAM2: an Open-Source SLAM System for Monocular, Stereo and RGB-D Cameras