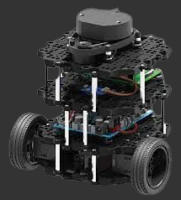
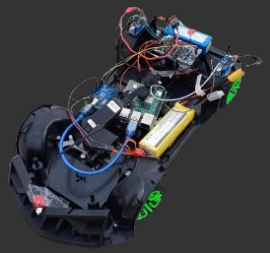
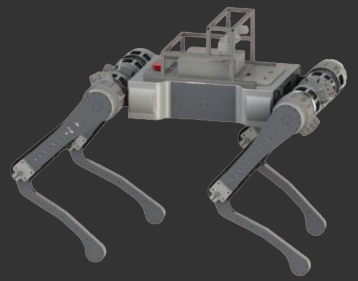
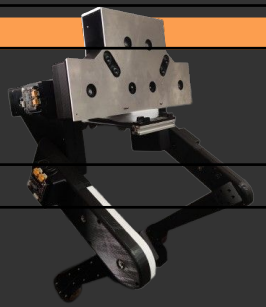
Safety Critical Control of Robots









By Manan Tayal

Lecture 1

Contents

- Motivation
- Meaning of Safety
- Ways to achieve safety
- Topics covered in this Course

Before we start !

Due to low retention rate of long lectures

I'll try to keep the lectures short
and
Each lecture will be divided into sub-lectures of **20-25 minutes** each

About Me

I am currently a PhD scholar (PMRF Scholar) at Stochastic Robotics Lab @IISc Bangalore

I am currently working on Safe Robot Learning and Control especially using Control Barrier Functions (CBFs).

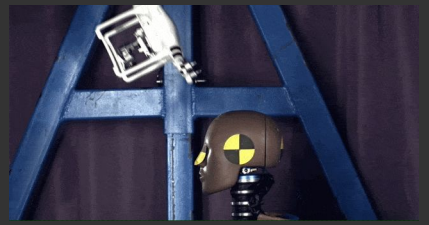
Motivation

Autonomous systems has exciting prospects in the present and future.

However, there is a minimum level of **guaranteed safety**.

We expect performance of Autonomous systems > Humans

For example, if we were to trust self driving cars, we would expect the vehicle to outperform humans in terms of detecting obstacles and avoiding them faster and more efficiently.



What is Safety?

The meaning of safety depends on the application

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For Self Driving Cars, it might mean maintaining a safe distance from the other vehicles and drive within the speed limits

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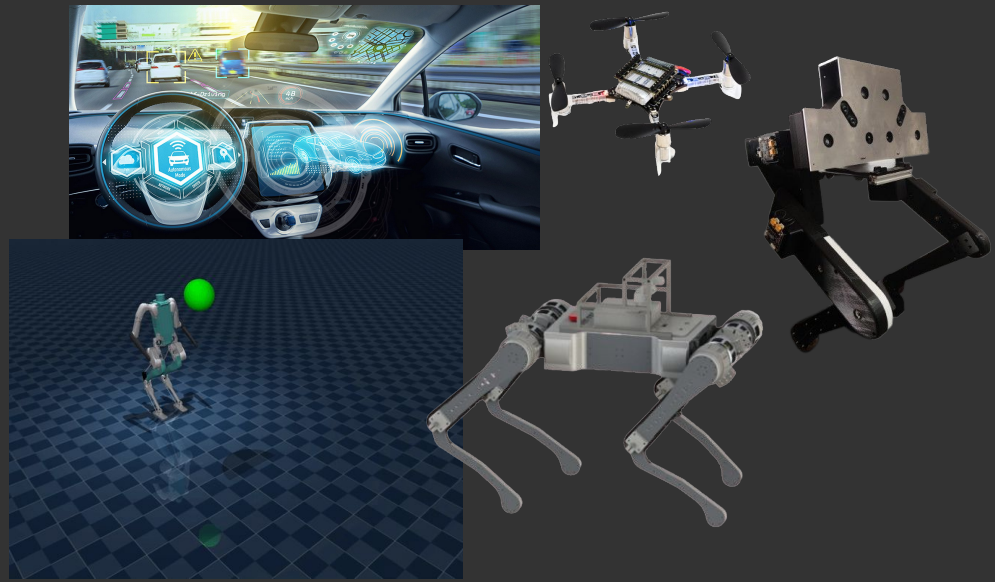
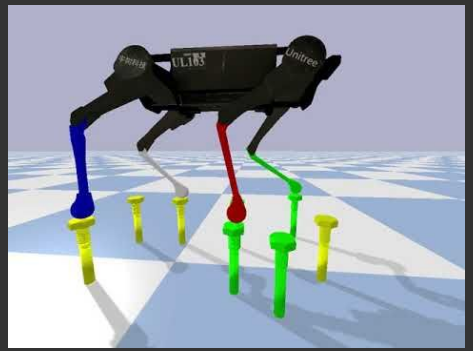
For Self Driving Cars and robotics systems likes drones, unicycle, legged robots, Safety might mean collision avoidance with other vehicles/robots



What is Safety?

The meaning of safety depends on the application

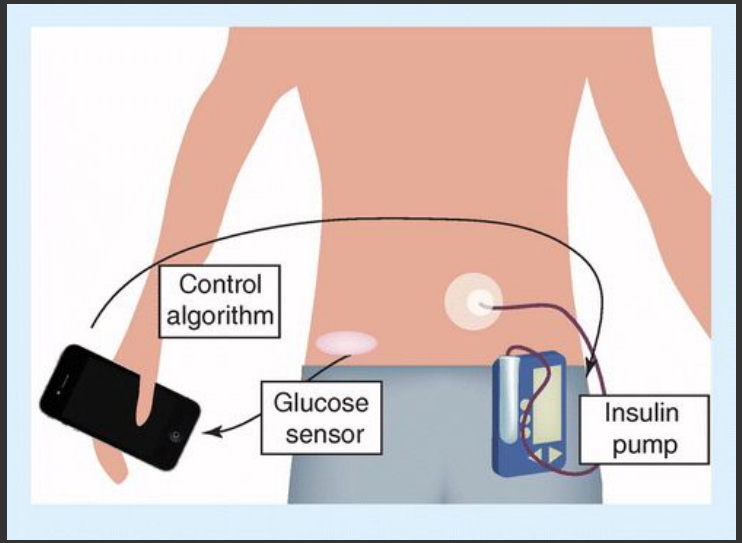
For legged robots, foot placements are critical in cases like stepping stones



What is Safety?

The meaning of safety depends on the application

In case of artificial pancreas, safety means not to release too much or too less insulin, that too at a safe rate, so that it does turn life threatening for the patient



Intuitively, safety means that nothing “bad” happens

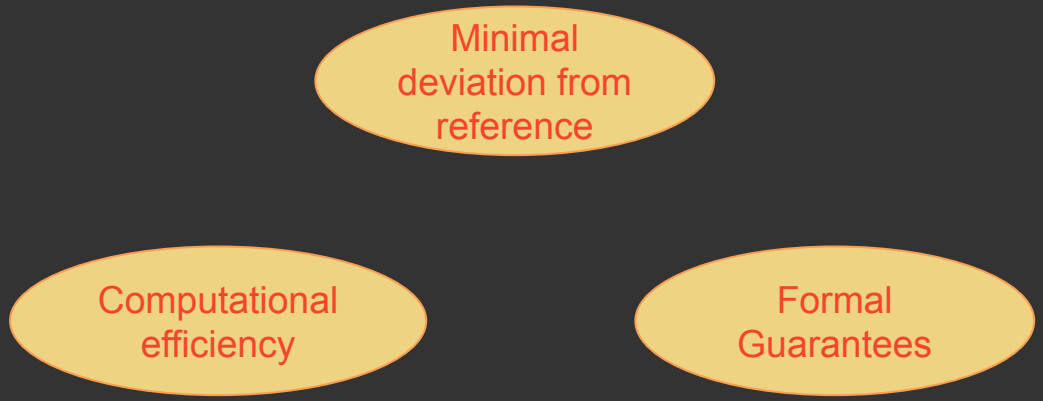
How do we achieve Safety?

Ensuring safety

- Safety Pilot (Human-in-loop)
- Backup Controllers (Laundry list)
- Formal Guarantees

Methods to achieve safety

What do we expect from an ideal safety controller(with formal guarantees)?



Methods to achieve safety

- Nonlinear Model Predictive Control (MPC)
- Artificial Potential Fields
- Control Barrier Functions

Topics in this Course

- Course Introduction and Motivation
- Constrained Optimization
- Basics of Linear Control Theory
- Nonlinear Control Theory
- Optimal Controls (LQR, iLQR, DDP)
- Non-linear MPC and safety
- Artificial Potential Fields
- HJ - Reachability
- Control Lyapunov Functions (CLFs)
- Barrier Functions and Control Barrier Functions (CBFs)
- Exponential CBFs and Higher Order CBFs
- Recent Research - Collision Cone CBFs
- Recent Research - Neural CBFs/ Safe RL

Thank You