Robotic Perception

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Basics

- 60 min lecture; 10 min intro; 5 minutes of questions
- T/Th 8:00 - 9:15 AM
- 5 Projects - 10% each
- Class Participation - 10%
- Group project – 40%
- Ask questions
- Course is fast paced
- Linear Algebra, Probability, some programming language

Outline

- Sensors and Sensing
- Least Squares
- Math Fundamentals (Quaternions, Linear Algebra)
- Kalman Filtering
- Bayesian Filtering
- Multi-Sensor Fusion and Localization (and mapping)
- Fusing IMU, GPS and LIDAR/RADAR
- Graph based Planning and Navigation
- Sampling based Methods

- Data is not costless; their acquisition or use requires the exchange of other resources, such as time or energy.
- Data is not equally useful; informativeness derives solely from the ability to resolve particular queries.
- Observations, realized as data, are like windows that permit partial glimpses into underlying states, whose values can never be exactly known and must be inferred.
- In assessing the informativeness of observations, it is not enough to consider the clarity of these windows; they must also face the right directions.

Perception

- State Estimation: This is the process of computing a physical quantity like position from a set of measurements.
- Any real-world measurements will be imprecise - develop methods that try to find the best or optimal value given some assumptions about our sensors and the external world.
- Parameter estimation: Unlike a state, which we will define as a physical quantity that changes over time, a parameter is constant over time.

History – 1801 Ceres

- At the start of the 19th century, astronomers believed there might be a missing planet between Mars and Jupiter.
- A group called the Celestial Police was formed to find this "missing" plane
- On January 1, 1801, Giuseppe Piazzi, an Italian priest and astronomer, spotted a moving object in the sky.
- Initially thought it might be a comet but realized it followed a planetary path.
- Named it *Ceres*, after the Roman goddess of agriculture.
- After a few weeks of observations, Ceres moved too close to the Sun to track.
- Young mathematician Carl Friedrich Gauss took up the challenge.
- Developed a revolutionary method: the *least squares method*.
- This method helped calculate the most likely orbit of Ceres from limited data.
- Gauss' calculations guided astronomers to rediscover Ceres in late 1801.
- The least squares method became a cornerstone of modern data analysis.
- Ceres is now classified as a dwarf planet and is the largest object in the asteroid belt.
- It remains a key target for space exploration, including NASA’s Dawn mission.

Least Squares method

- Gauss was so confident in his method that he didn’t even bother to publish it right away—it was the rediscovery of Ceres that proved its brilliance to the world!
- Imagine trying to predict the path of a ball thrown in the air, but you only see it at two points before it disappears into the clouds. Least squares is like filling in the gaps with the most logical trajectory for the ball.

What is Least Sqaures

- **What is the Least Squares Method?**
- It’s a mathematical technique that finds the best-fit solution to a set of equations, even when there’s noise or incomplete data.
- It minimizes the sum of the squared differences between observed data points and the model predictions, hence the name *least squares*.

Observations

- Mathematical models may be incomplete
- Physical measurements are inconsistent
- All that can be expected from computations based on inconsistent measurements are estimates of the truth
- Redundant measurements will reduce the effect of measurement inconsistencies
- Initial approximations to the final estimates should be used, and finally
- Initial approximations should be corrected in such a way as to minimize the inconsistencies between measurements (by which Gauss meant his method of least squares).

What this class tries to answer

- How many sensors are needed?
- How do you represent state?
- How do you combine multiple sensors?
- Errors, Uncertainties in sensing?
- Is there a best combination of sensors?
- What do we mean by best estimate (optimal estimate)?
- How do we plan and navigate in a world that is uncertain?

Next Class

- Sensors and Sensing
- Position and Orientation - Representation