Localization Quiz Review

Autonomous Vehicle Project (LTAT.06.012)

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Q1 – What is Localization?

- Localization is how an AV knows exactly where it is in the world.
- The AV can determine its precise relationship to all of the elements on the map.

[1] Intro to Localization https://youtu.be/-PMFFP7dEV0
Q2 – GPS Limitation

- GPS is not enough for self-driving car, because accuracy is between ~1-3 meters which is far too imprecise for a self-driving car [2]
- There is some cases if we are surrounded by top building or mountains or inside canyon, the GPS accuracy become more worse, ~10-50 meters [2]
- Low update frequency, around 10Hz (10 updates per second)
- Cyber security issue [3]

Q3 – Localization Approaches in AV

- **GPS/GNSS RTK [4]**
  - Pros: Accurate with RTK (Real-Time Kinetic), limit the localization to less than 10cm
  - Cons: Poor Performance in Urban Area and Canyons; Low Frequency Update

- **Inertial Navigation [5]**
  - Pros: IMU gives high update frequency, can give nearly real-time location information
  - Cons: Motion errors increases with time, we can only rely on IMU for only short period of time

- **LiDAR Localization [6]**
  - Pros: robustness, as long as we started with HD maps and we have working sensors, we should always be able to localize
  - Cons: the difficulty of constructing HD Maps and keeping them up-to-date

- **Visual Localization [7]**
  - Pros: image data is easy to obtain
  - Cons: the lack of 3D information and the reliance of 3D maps

[6] LiDAR Localization [https://youtu.be/LqRg9VWrJcg?t=196]
Q4 – GPS Parts

• **Satellites**
  • 30 GPS satellites operating in outer space that operating in any given time, located around 20,000 km from the surface of the earth

• **Receivers**
  • Receivers (exist in mobile phone, computer, car, etc), should be able to detect at least four GPS satellites at one

• **Control Stations**
  • Control Stations (are used for monitoring and controlling the satellites), main goal to keep system running and verify the GPS accuracy

Q5 – GPS Update Frequency

• 10 Hertz (10 updates per second)
• Since AV moves quickly, we may need to update our position more frequently than that
Q6 – Kalman Filter

• We can use Kalman Filter to make an educated guess, about what the system is going to do next in any place where we have uncertain information about some dynamic system.
• It is an iterative process that uses two step predict and update.
• It is mostly suitable for these type of operations because of the following factors:
  • It predict the next state based on the previous state only, no need of the history of data
  • computationally very fast making it well suitable for real time problems
  • even if lots of noise/error/uncertainty occurs in the environment, Kalman filter will give a good result using Gaussian distribution.

Q7 – Type of GNSS

- GNSS is a generic term for a navigation system, an abbreviation for Global Navigation Satellite System.
- GPS is the most common and widely used.
- Other GNSS:
  - BeiDou (China)
  - GLONASS (Russia)
  - Galileo (EU)

Q8 – Combination of GPS and IMU

• IMU compensates for the low update frequency of GPS
• GPS corrects for IMU motion errors
Q9 – Lidar Localization Pros and Cons

- As mentioned before in Q3 Review
  - Pros: robustness, as long as we started with HD maps and we have working sensors, we should always be able to localize
  - Cons: the difficulty of constructing HD Maps and keeping them up-to-date
The Normal Distributions Transform (NDT) is a technique which transforms a raw point cloud into a grid-based representation, where each grid cell is approximated with a multivariate Gaussian distribution [9].

The purpose of this representation is to provide a compact form for representing the point cloud [9].

- Doing so also permits the holistic representation of the scan matching, or scan registration problem as a differentiable optimization problem.

Normal distribution transform addresses the uncertainty in data [10].

- More robust to noisy data

Nice to Read

- Autoware.auto Localization documentation

- Baidu Apollo Localization documentation
  https://github.com/ApolloAuto/apollo/tree/master/modules/localization


- Self-Driving Cars and Localization
  https://towardsdatascience.com/self-driving-car-localization-f800d4d8da49
Thank you!