System Architecture Diagram

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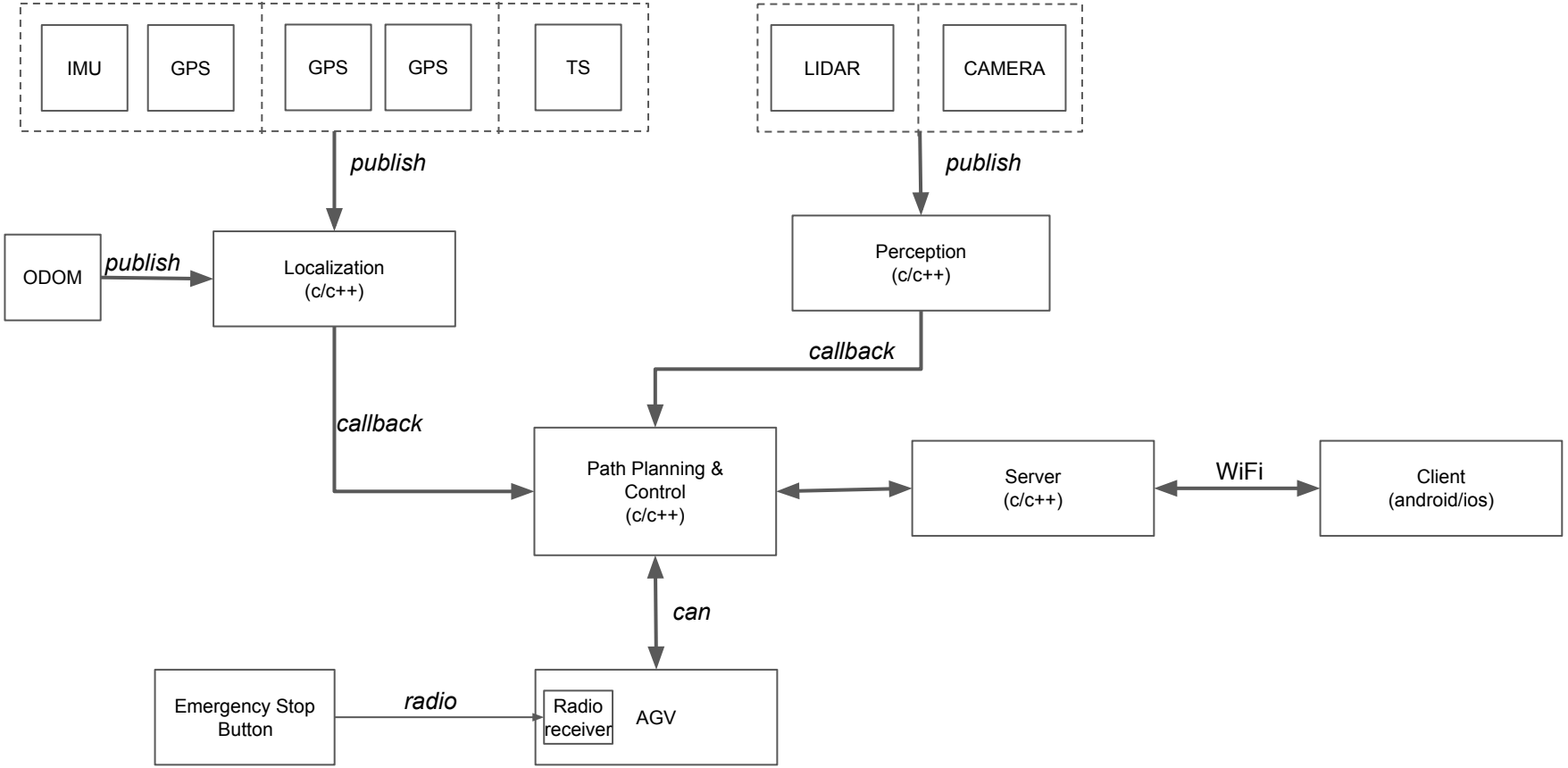
November 4, 2024

High Level Architecture



Component Breakdown

Localization

The localization module publishes current location and heading.

This component will utilize one of the following hardware combinations to determine this data:

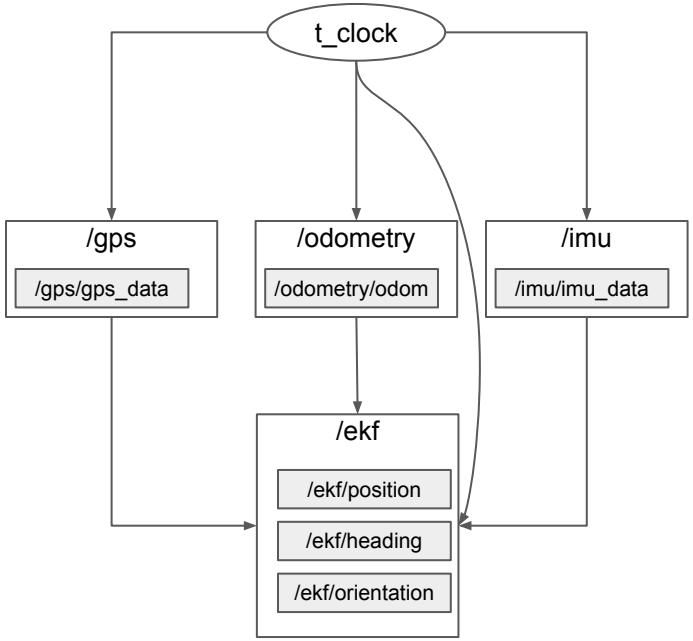
- IMU and GPS
  Fusing the IMU and GPS data can determine AGV orientation, heading, and position.

- Dual GPS
  Using dual GPS and get you heading and position

- Total Station
  In areas where GPS visibility is low or bad, a total station can be used to get the AGV's position.

Being that the AGV may be in a rough terrain, with the body tilting up and down, it will be beneficial to have an IMU to know the AGV orientation.

The odometry will be used to manage the IMU drift and compensate for GPS data outage or low visibility.



ROS graph using IMU plus GPS combination to publish position and heading

Perception

The perception module publishes current location and heading.

This component has the option to use a Lidar scanner or a Camera. Each technology has different strengths and weaknesses that depending on the application, one can be better than the other.

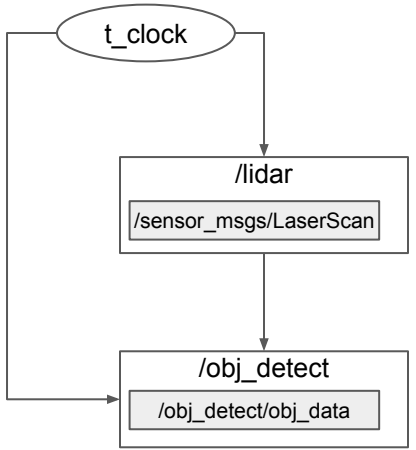
LiDAR

- LiDAR can perform well in low-light conditions, fog, rain, snow, and dust, where cameras can struggle.
- LiDAR can create high-resolution 3D point clouds of the surrounding area.
- LiDAR can determine the position, size, shape, and material of objects.

Cameras

- Cameras can provide detailed visual information.
- Cameras are cheaper in price than LiDAR.

Being that this AGV will operate on an open environment, such as factory yard or agricultural field, I'm choosing LiDAR as it can perform better under outdoor conditions.



ROS graph using LiDAR to detect objects.

obj_data is a new topic publish boundaries of obstacle

Path Planning - Control - Server

The **path planning** module will handle the AGV navigation, adjusting the travel path to avoid static and dynamic objects.

The **control module** will receive navigation data from the **path planning** module and generate PID to control the AGV travel path. It will also listen for server requests and publish system status.

The **server** module will the main point of communication to any client applications. The main purpose will be to manage remote monitoring, providing system status to clients.

Data Flow

Data Flow

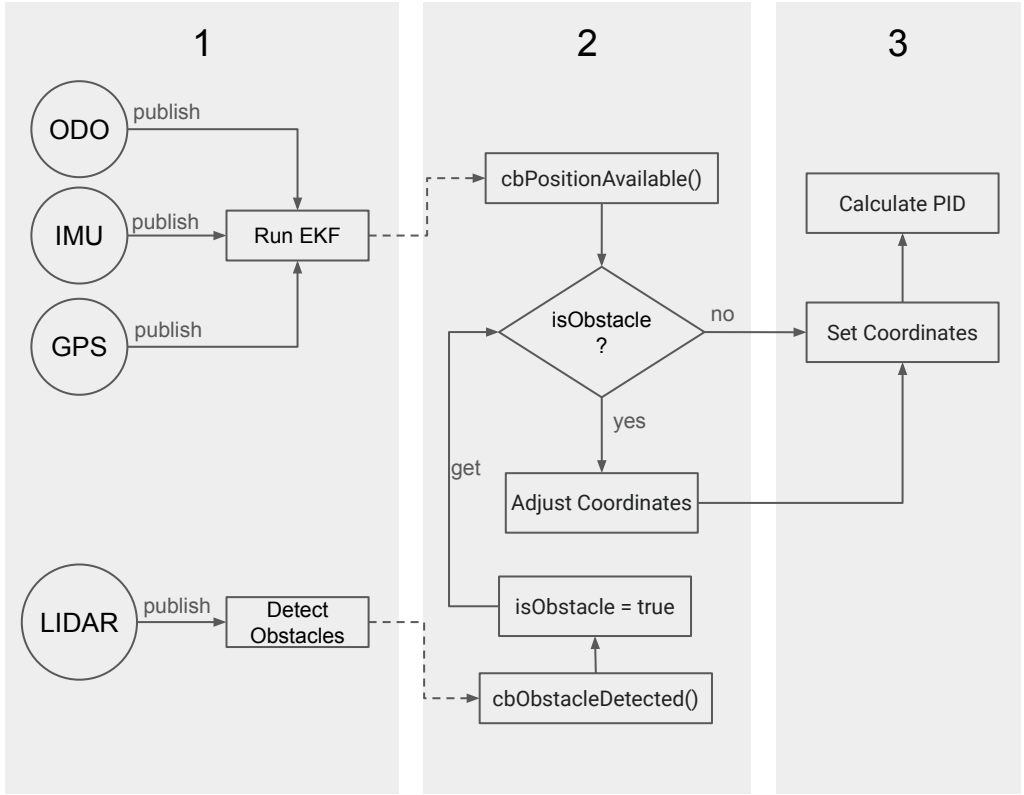
1. Each sensor will publish their data using ROS topics. The **perception** and **localization** modules are the subscribers to all the sensor topics.

   These two modules will perform their perspective tasks, run EKF and detect obstacles, with the data received and provide results to the **path planning** module. Callback functions will be used to share data with the **path planning**.

2. When the **path planning** module gets triggered by the **localization** callback, it will take the following steps:
   a. Check if there are any obstacles in the way of our path.
      i. If yes, adjust path to avoid obstacle.
      ii. If no, continue.
   b. Send path coordinates to **control** module.
3. **Control** module will get path coordinates and convert them to PID messages to guide the AGV.

Concurrently, the **server** module will checking the overall status and update the client.

Note: If we want to provide sensor statistics to the **client** such as IMU temperature or number of satellites visible by GPS receiver, we can setup the **server** module to connect to these topics.



Error Handling and Safety

Wireless Emergency Stop

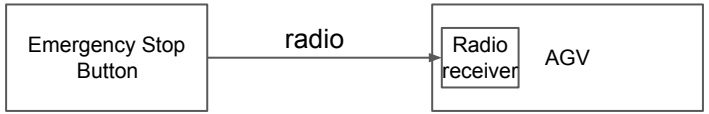
A wireless emergency stop (E-stop) is a device that allows a user to shutdown a machine from a safe distance in an emergency. Wireless E-stops can be used to:

- Improve safety: Operators can move away from danger instead of towards it.
- Protect equipment: Wireless E-stops can help protect costly equipment.
- Reduce risk: Wireless E-stops can help reduce the risk of accidents and liability.
- Integrate with existing systems: Wireless E-stops can connect directly to standard safety circuits.

Using a handheld remote with a long-range communication link like a radio, a user can easily send a ‘stop’ signal to the AGV.

In an open field with no big obstructions, radios with 5 watts of transmission power can typically communicate up to 6 miles apart.

We would have to mount a small radio receiver into the vehicle and have a wire connected to a gpio that controls the AGV power.



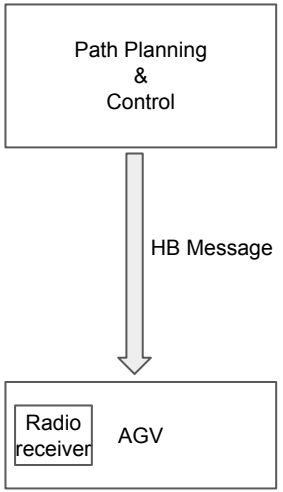
Heartbeat

In software development, a heartbeat (HB) is a periodic signal generated by software (or hardware) to indicate normal operation. It's a mechanism used to verify a communication channel is alive.

This technique can be used in our system to verify that the communication between our control module and AGV is active. If our software crashes, this mechanism will ensure the AGV stops.

If the vehicle doesn’t receive the heartbeat message from the control module within a certain time, then the AGV stops. The heartbeat message interval is 1 second. If the heartbeat message is not received after 3 seconds, the AGV will stop.

In the worst case (at 10 miles/h), the AGV would have travelled ~13.4 meters before stopping.



The heartbeat message would have be supported by the AGV. If not supported, we can write a small module on the radio receiver board and listen for HB messages.

Sensor Failures

The **perception** and **localization** modules are the subscribers to all the sensor topics. Data is expected from each sensor at a certain rate.

Data from each sensor is critical in guiding the AGV accurately and safely. If either module detects a data outage from any sensor, it will immediately raise an error flag and notify the **control** module.

The **control** module will then send a message to stop the AGV and set the system status flag accordingly. The **server** module will then notify the **client** to take further action.

If for some reason the **client** gets disconnected, the **server** module will notify the **control** module to stop the AGV. For safety and quality control, a **client** needs to be connected to monitor the AGV status and events.