Localization and mapping

From EKF to SLAM

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Roadmap

1. The perception problem

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The perception problem

Definition

To be able to operate autonomously, a robot must continuously answer the following questions:

- **Where am I?**
- **What is this place?**

Thus, it must be able to **perceive** the environment, gathering information useful to:

- **localize itself**, *i.e.*, continuously estimate its **pose** as **both position and orientation** in 3D space;
- **map the environment**, *i.e.*, build a **representation** of the environment useful to **navigate** within it.

The perception problem

Challenges

The perception problem is challenging because:

- the environment may be **partially observable**, *i.e.*, the robot can only perceive a **subset** of it, and need to update its information in real time;
- the environment may be **dynamic**, *i.e.*, it can change over time;
- measurements are always subject to **noise**.

The perception problem is usually solved by **sensor fusion**, *i.e.*, combining information from **multiple sensors** to obtain a more **accurate** and **reliable** estimate of the environment, possibly accounting for **sensor faults**.

The perception problem

Tools for the job

The tools that robots use to gather **measurements** from the environment are called **sensors**.

They can be classified as:

- **proprioceptive**, *i.e.*, measuring robotic interaction with the environment (*e.g.*, **encoders**, **GPS**, **IMUs**);
- **exteroceptive**, *i.e.*, measuring the environment itself (*e.g.*, **cameras**, **LiDARs**, **radars**);
- **interoceptive**, *i.e.*, measuring the robot's internal state.

The perception problem

Tools for the job

As any other measurement tool, sensors are based on **physical principles** and **energy exchanges**, translating the information they gather into **electrical signals** that can be acquired and/or processed by a computer.

They are usually characterized by at least:

- a **digital** or **analog encoding** of the measurement;
- a **frame of reference** in which the measurement is expressed;
- **accuracy** and **uncertainty** parameters.

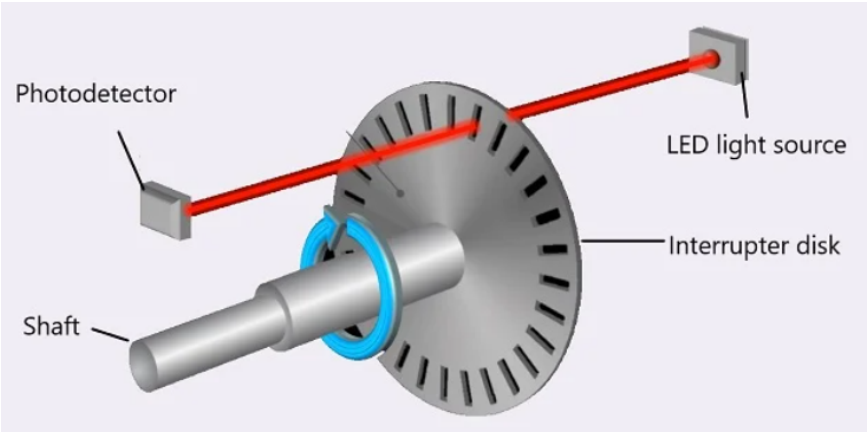

Figure 1: Rotary encoder working principle.

Figure 2: GPS module for drones.

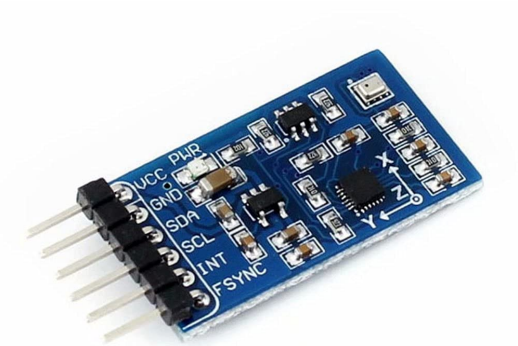

Figure 3: Inertial Measurement Unit (IMU).

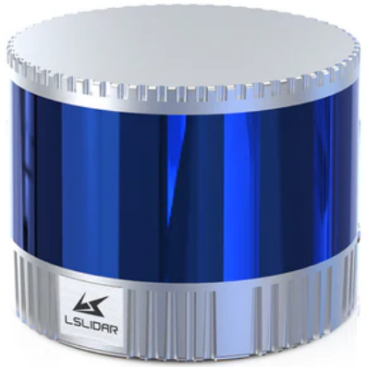

Figure 4: Light Detection and Ranging (LiDAR) sensor.

Figure 5: ZED 2i stereo camera.