Autonomous Drone Engineer

B3 – 3D and Visual Sensors

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The Perfect 3D Sensor

Sensor Goals

A drone can do a lot with an Inertial Motion Unit, a compass and a GPS.

To be autonomous and perform useful tasks, you may also need to:

- **Measure the distance** with a known surface
  Ex: sonar to measure the distance with the ground (height)
- **Detect** objects (but not map them) to avoid collisions
- **Scan and map** the environment in 3D. *Ex: LIDAR to map the ground*
- **Reposition** the drone inside a know volume, or compared to a surface

Each sensor has a specific goal
Drones usually carry multiple sensors
to solve different problems

Collision Avoidance *vs* Autonomy vs Payload

Different goals:

- Collision avoidance in exceptional cases. *Ex: Typhoon-H*
- Payload scanning the environment for remote analysis. *Ex: mining site 3D scan*
- Autonomous flight around objects, under human supervision
- Full 3D awareness for autonomous flight in unknown environments

Speed - range: do you need assistance for take-off/landing or cruise?

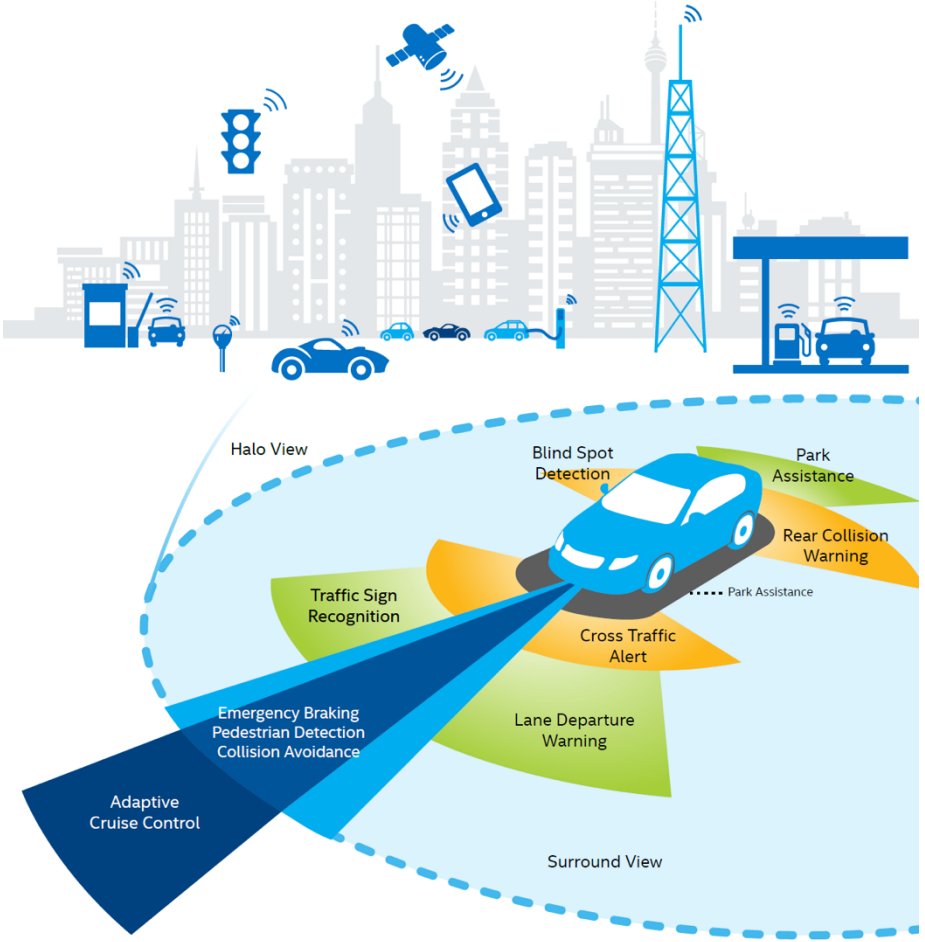
Efficiency - risk: perfect / good enough ?
Full mapping or simple repositioning in a known map?

There is not a single 3D solution for all needs

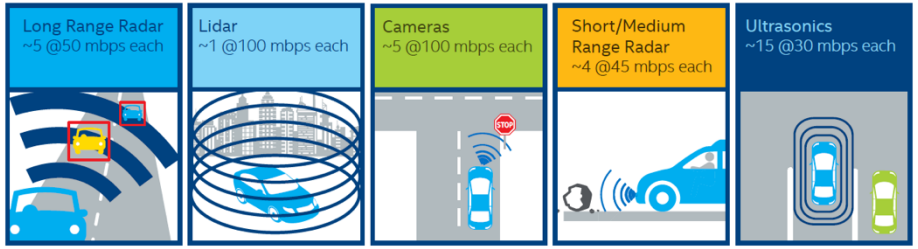
Fusion of sensors

There is no perfect sensor!

- Select the right mix for your case
- Reuse sensor and libraries from other sectors: automobile, robotics, …
- Know their blind spots
- Play to their strengths
- Work on **sensor fusion**

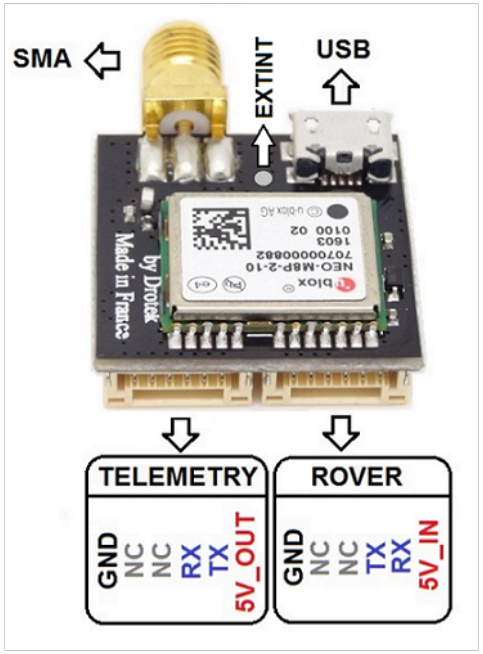


Cars will sense and connect with many things for 360° awareness.



Types of Positioning

Outdoor – D-GPS
Differential GPS (or "RTK")



Simple GPS receiver are not very precise: 1.5-3m.

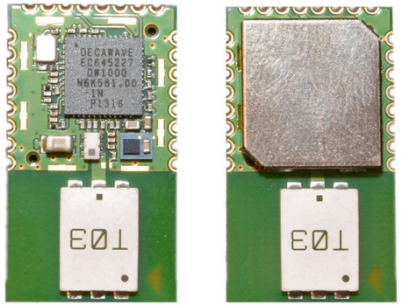
Most drones can benefit from Differential GPS:

- Use an improved GPS chip, designed for D-GPS (200$)
- Integrate precisely the GPS antenna to the chip
- Add a fixed base in a 20km radius with the same chip
- Add a radio/IP link to your drone

Result:

- The base station will communicate with your drone
- The drone will use the D-GPS chip to normalize the signal
- You'll get a position with 2-3cm precision

Indoor – UWB
UltraWideBand



It’s a time-of-flight system, not a signal strength system (like wifi/BT).

UWB wavelength allows for 10cm precision
inside buildings as large as warehouses.

There’s 2 ways to deploy UWB:

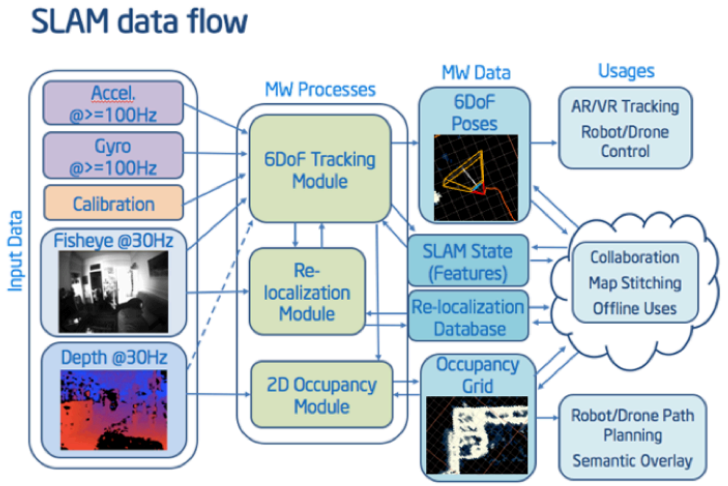
- Use a simple tag, and smart connected wall anchors will locate it.
- Use a smart receiver, and it will locate itself knowing where the (non connected, non smart) anchors are in the building.
  That’s the one we want for large drones.

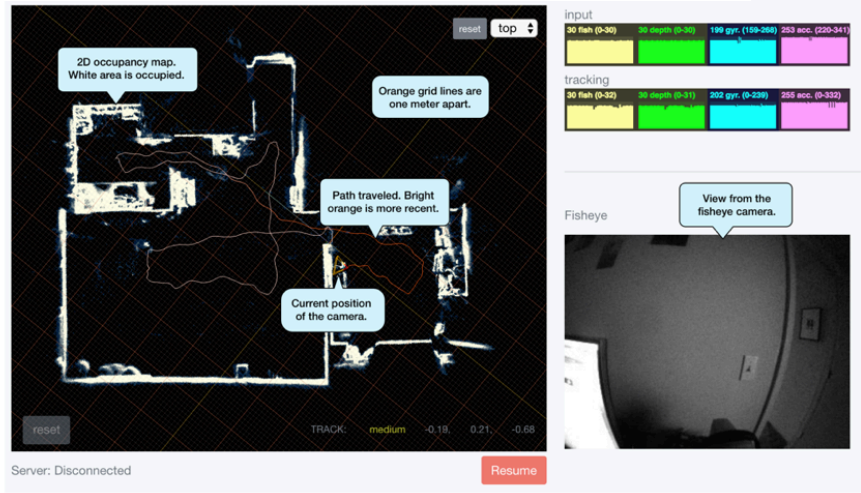
Indoor – SLAM
Simultaneous Localization And Mapping

Why: If you need indoor localization
but can't deploy UWB anchors
(because of cost, or unknown building)

Hardware: Use 3D sensors (like RealSense)
or a moving camera (harder) + inertial sensors

Software: stack adapted to your sensors,
performing a complex sensor fusion



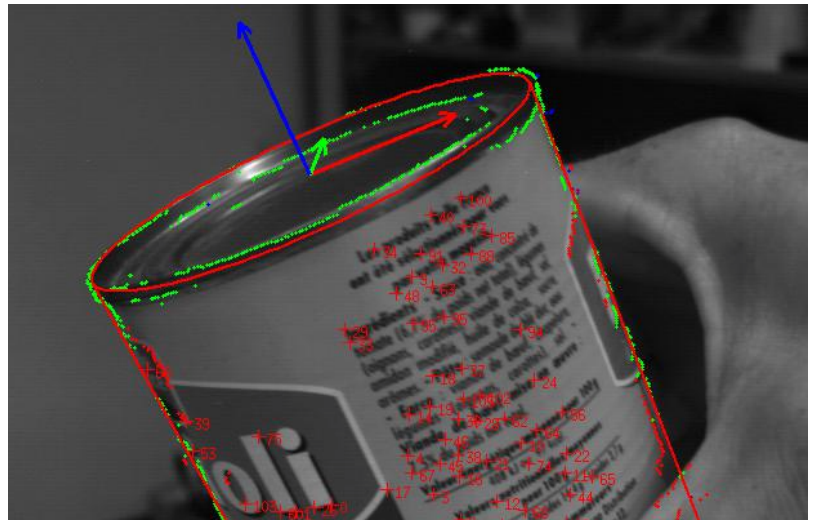


Indoor - Visual

What if you can't afford to deploy UWB, and SLAM is too complex?

Print and stick visual markers.

- Libraries: VISP, ARToolkit
- Robust, highly optimized code
- Return 3D positioning



Also works with 3D models of objects instead of BCHs

Sensors

1D: measure distance (with the ground)

A sonar or 1D laser can measure the distance with the ground.

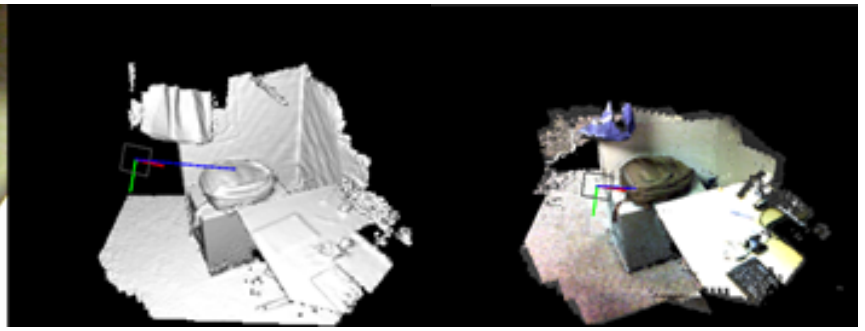
That's required for your drone can hover at a precise height, and perform a smooth landing.

Note: A barometer can provide you the altitude, which is not precise enough to land.

Photos:
MB1242 I2CXL-MaxSonar-EZ4
LIDAR-Lite v3 (we have doc on how to connect this sensor)

http://www.maxbotix.com/Ultrasonic_Sensors/MB1242.htm
https://buy.garmin.com/en-US/US/p/557294

3D sensor



By using 2 cameras you can recreate a 3D image. Two options:

- By running an intensive software on your CPU/GPU,
  but it takes space, increases the weight and it's expensive.
- Or by using a dedicated chip, bundled with the 2 cameras.
  It's compact, cheap and light.
  Ex: Intel RealSense, with infrared grid illumination technology.

As a result, you get :

- Format: directly a 3D depth map and RGB image
- Depth: 4-5m for the Intel R200
- Coverage: only shows what is on front of the sensor,
  E*xample: 120x60 degrees*
  but can bundle 3 sensors to get 360x60 degrees of coverage

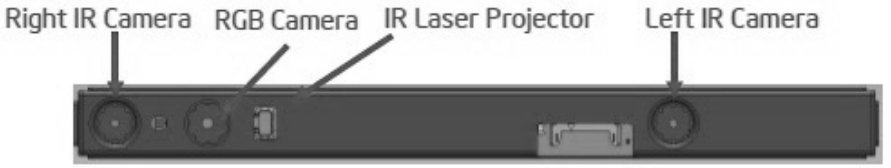
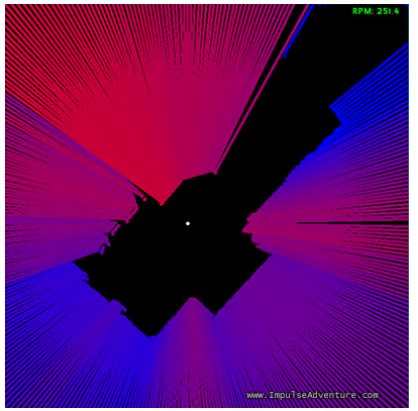


Photo: Intel R200 RealSense

3D reconstruction from a 2D sensor



Laser can go far and distance information is precise.

By rotating a laser, you get 1 dimension
of depth information, 360. That's a LIDAR.

By rotating over 2 axis, you can go a little further.
Ex: 360x15 degrees.

By embedding the rotating on a drone
and flying you can accumulate data and build a 3D model.
Ex: mapping a construction site.

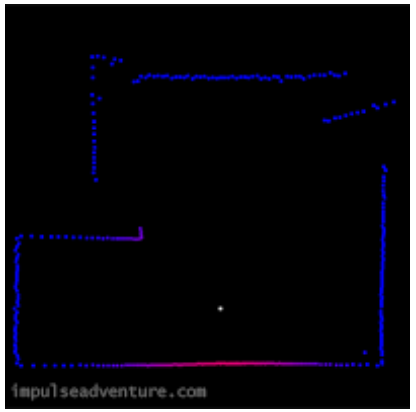
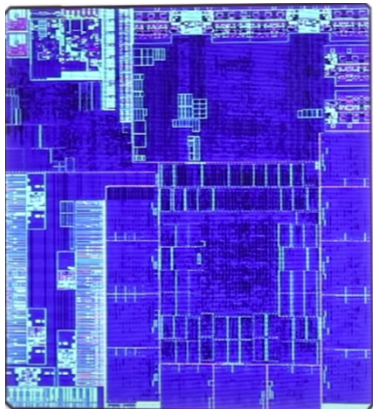


Photo: Velodyne* PUCK™ LIDAR VLP-16

*Other names and brands may be claimed as the property of others
http://velodynelidar.com/vlp-16.html

Computer Vision: Collision Avoidance



With 1 camera and a succession of shots taken while moving in **1 direction**, you can reconstruct what's in front of you in 3D.

- Great if you're moving fast, or want to see far ahead
- Works great for simple collision avoidance
- Cheaper, lighter than LIDARs

Ex: Intel® Movidius chips

Photo: Intel Movidius Myriad 2 VPU in DJI Spark* Drone

*Other names and brands may be claimed as the property of others
https://newsroom.intel.com/news/intel-movidius-myriad-2-vpu-enables-advanced-computer-vision-deep-learning-features-ultra-compact-dji-spark-drone/

Computer Vision: Structure from Motion

With 1 camera and a succession of shots taken while moving **around an object**, you can reconstruct this object in 3D.

- Typically used as a payload to 3D scan the outside of a building
- Usually done offline, with high-resolution photos and heavy computations to get the best model possible.
  But can be deployed in flight under certain conditions.

Ex: Pix4D, FPV* Camera, Drone Deploy*, …*

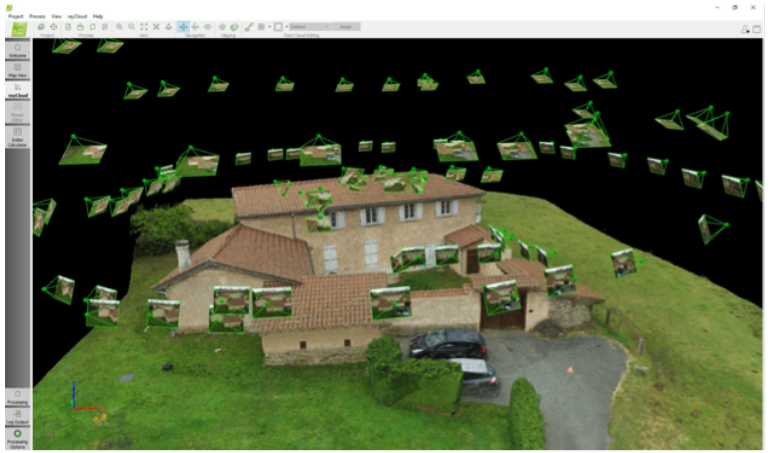


Photo: Pix4D* example

*Other names and brands may be claimed as the property of others
https://pix4d.com/a-new-era-for-landscaping-and-exterior-design/

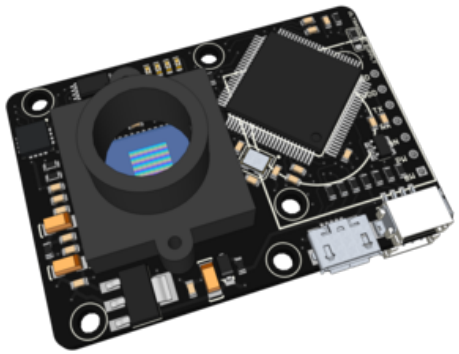
Computer Vision: Visual Piloting

You can also use a camera to recognize objects, barcodes, patterns …

Ex: With 1 camera facing downward, you can recognize the ground and make the drone hover without driving: "Optical Flow".
It is typically linked to the flight controller itself.

Ex: With 1 camera or laser reader, you can read barcode.
Can be useful in a warehouse inventory scenario.

Photo: PX4Flow*



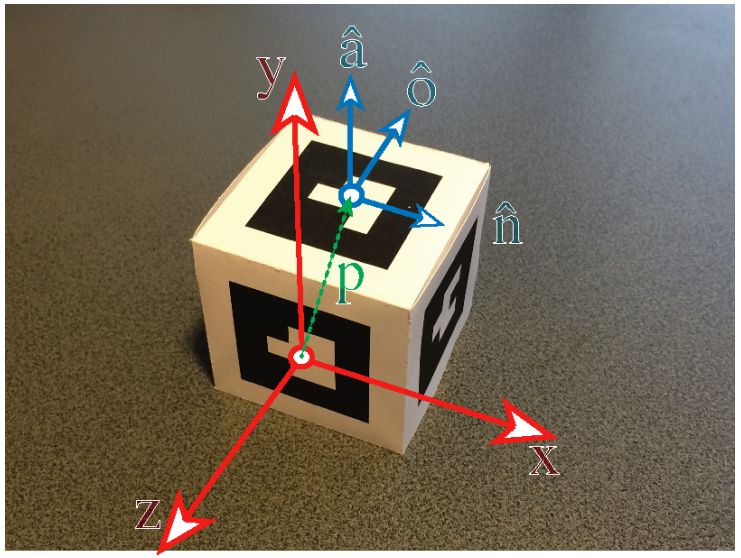
*Other names and brands may be claimed as the property of others
https://pixhawk.org/modules/px4flow

Computer Vision: Augmented Reality

With 1 camera and an advanced library, you can go further and detect where you are in 3D, how objects around you are moving.

Such libraries usually come from the Augmented Reality world, after adaptation to robotics.

Photo: Artoolkit*, VISP*



*Other names and brands may be claimed as the property of others
http://visp.inria.fr
https://artoolkit.org/

Conclusion

Conclusion

There is **no perfect sensor** able to see everything

Each sensor has **specific features**

Be clear about your goals,
regarding the **flight stack** and **user payload**

Your drone will use **several sensors**

You'll have to **fusion the data** from several sensors

Thanks

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https://intel-aero.github.io