

# AI Robotics

## Sensor Data Fusion



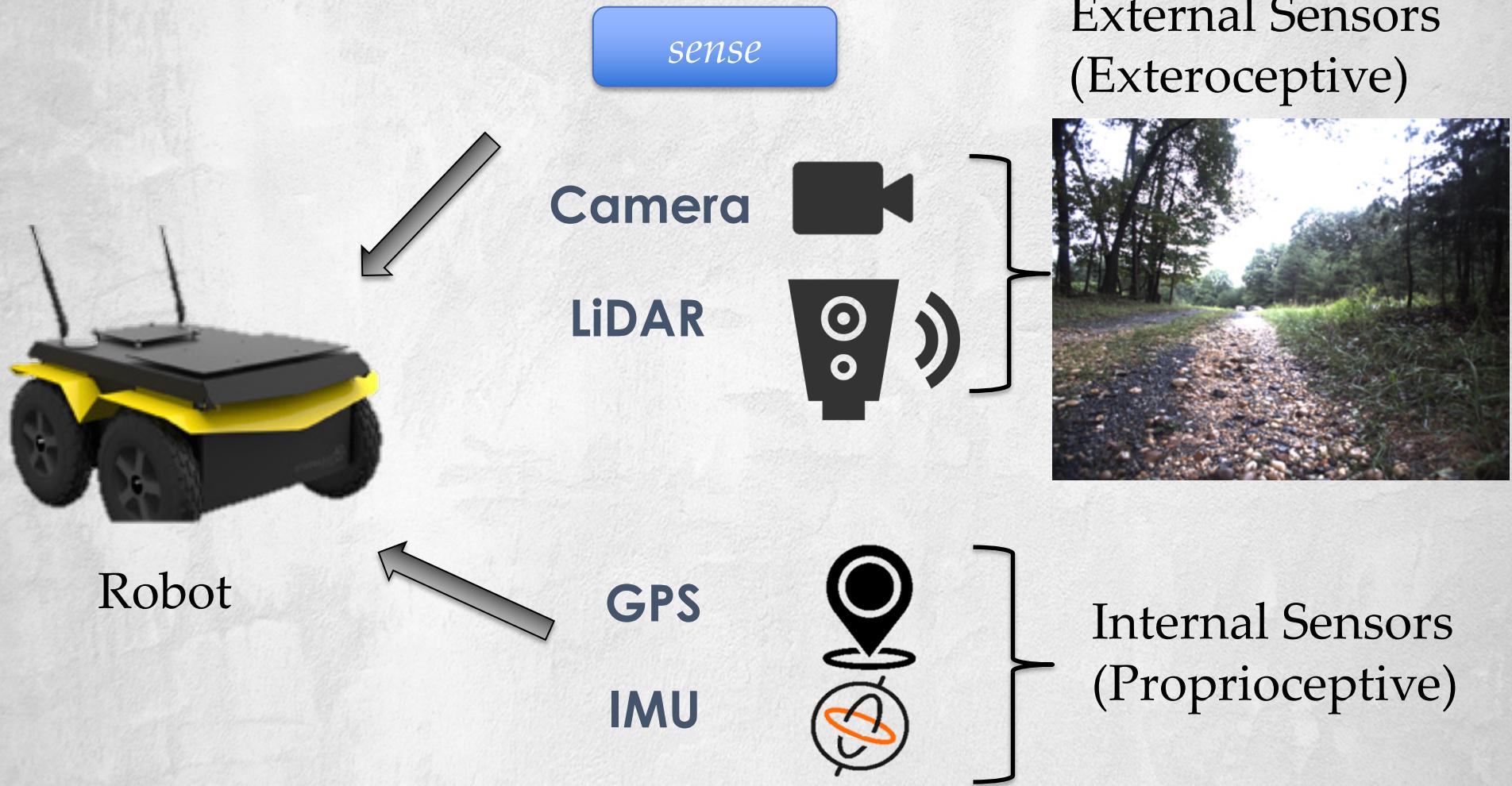
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# Overview



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# Robot Model



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# Pros / Cons of Different Sensors

Sensor	Data Type	Pros	Cons
GPS	Position	Measures position globally	Poor signal indoors
IMU	Position + Orientation	Can measure orientation accurately	Vulnerable to measurement drift
Camera	Image	Cheap. High resolution	Vulnerable to shadows and lighting changes
LiDAR	Point Cloud	Able to measure distances	Expensive. Sparse measurements



# Pros / Cons of Different Sensors



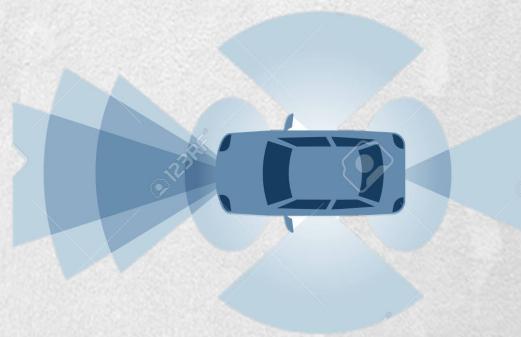
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# Need for Data Fusion

1. Combine data acquired from different locations from the same sensor
2. Combine data acquired from different sensors
  - Get a complete map of the surrounding environment
  - Overcome limitations of individual sensors



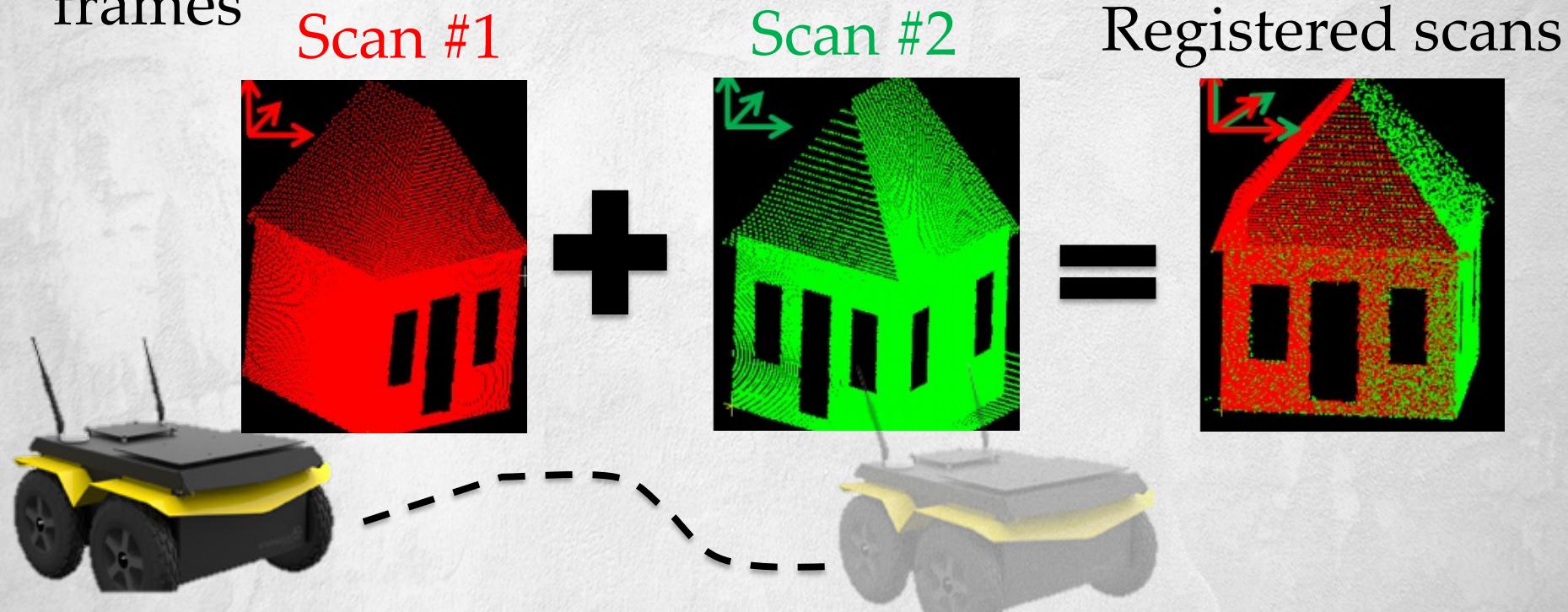
# Single Sensor



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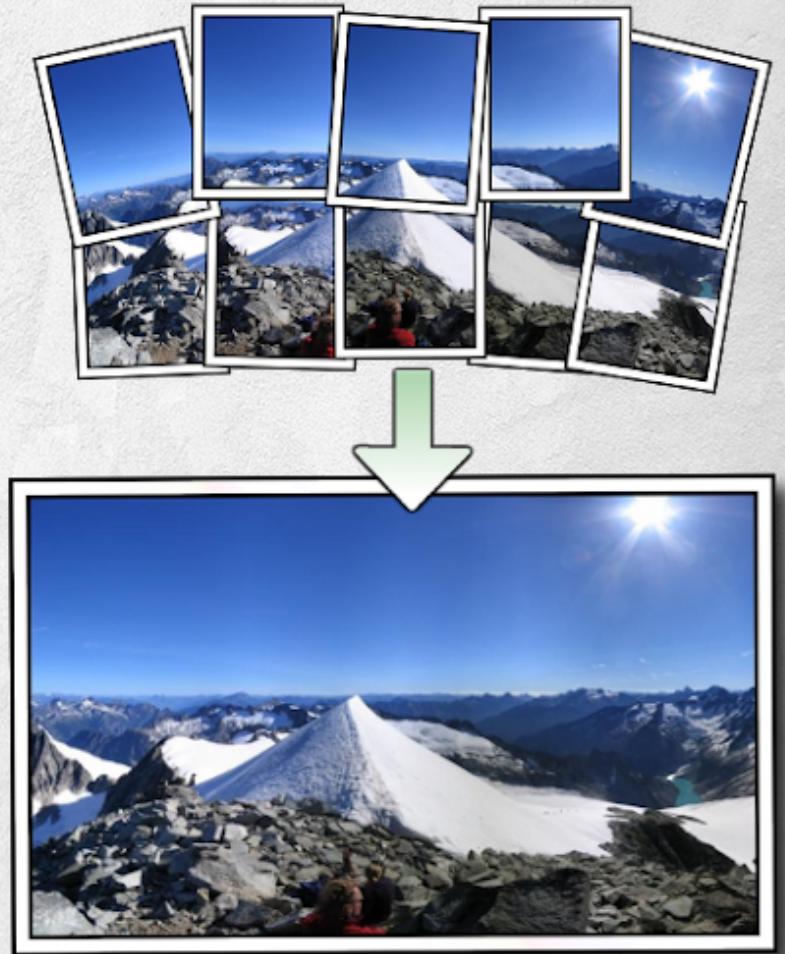
# Data Alignment / Data Registration

- Merge multiple data frames into a globally consistent model / coordinate frame
- Need to find the spatial transformation between data frames



# Image Stitching

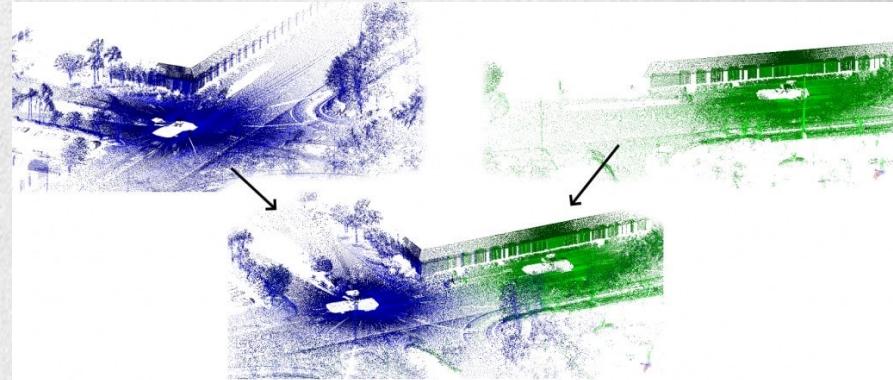
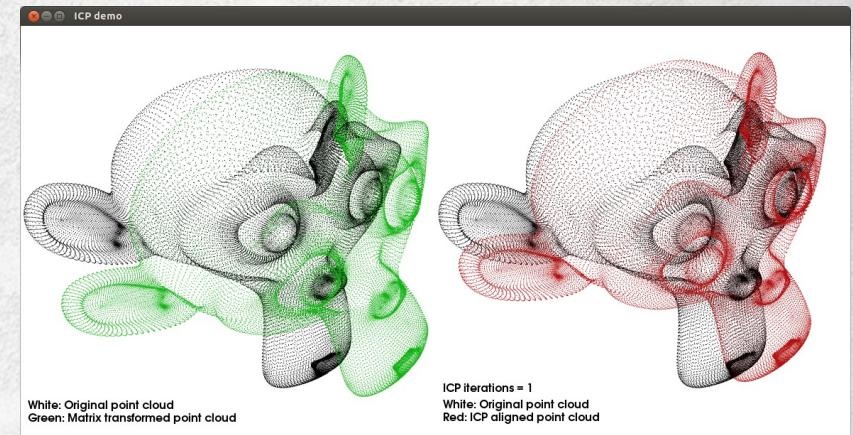
- Panoramic images / images with horizontally elongated fields of view. Sometimes known as wide format photography.
- Made by joining multiple photographs with slightly overlapping fields of view
- <https://www.picmonkey.com/blog/how-to-take-a-panorama-with-your-phone>



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# Point Cloud Registration

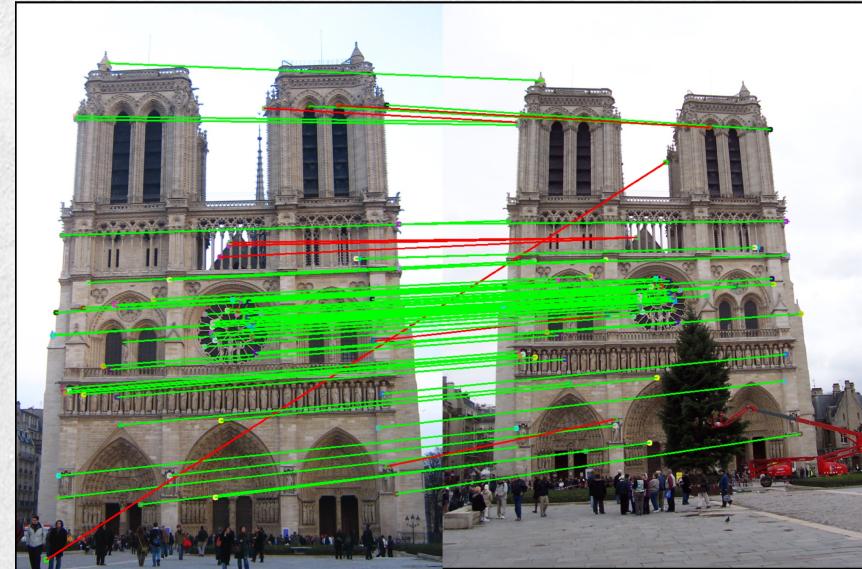
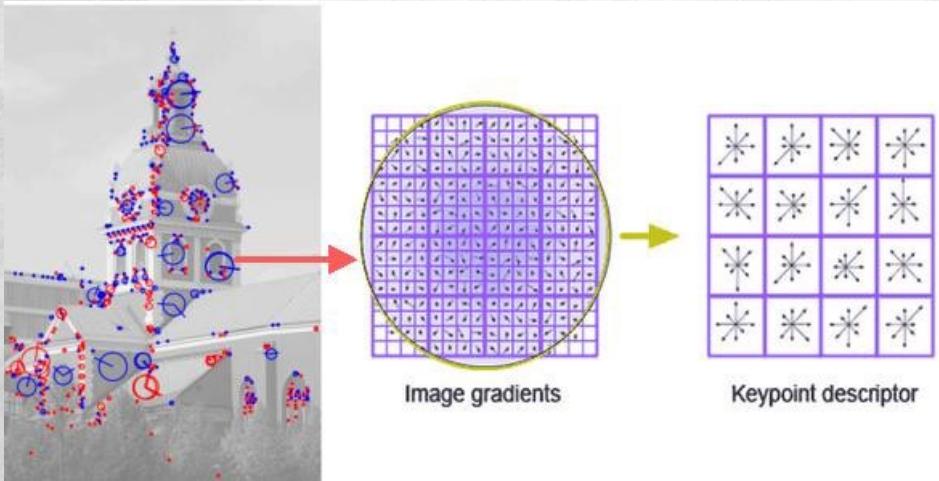
- Also known as point set registration or scan matching
- The process of finding a spatial transformation (e.g., scaling, rotation and translation) that aligns two point clouds
- Multiple applications in 3D reconstruction, AR/VR, Simultaneous Localization and Mapping, etc.



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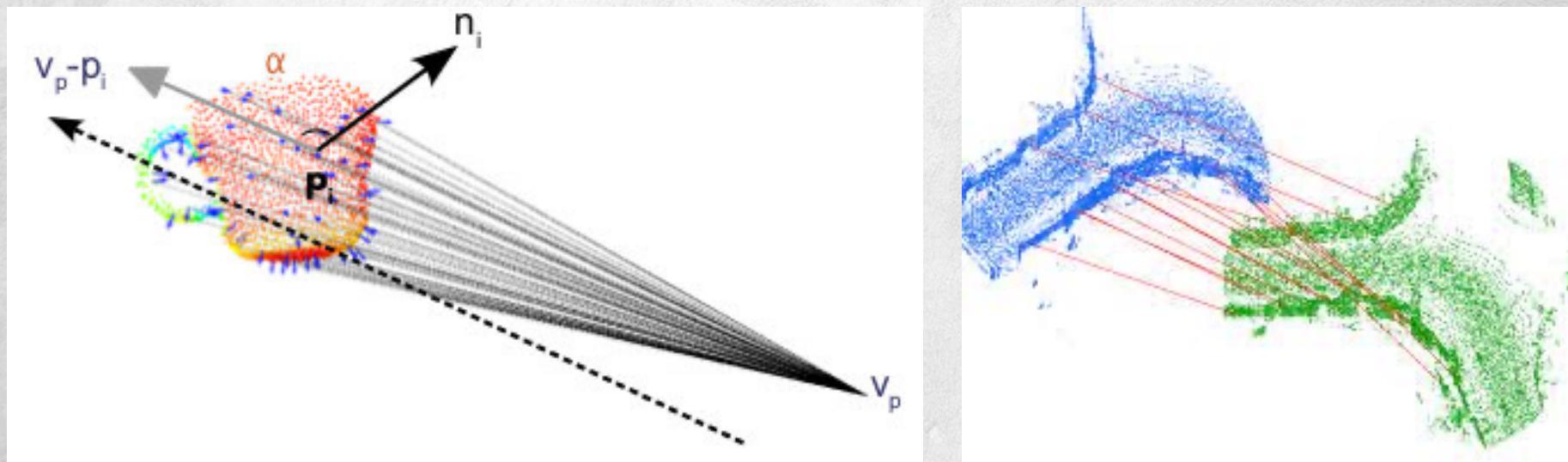
# 2D Feature-point Matching

- Image feature points measure the local characteristics of each pixel (color, intensity, gradients)
- Matching is performed by finding pixels with similar features



# 3D Feature-point Matching

- 3D feature descriptors measure the local characteristics of each point (normal, curvature, smoothness)
- Matching is performed by finding points with similar features



# Photogrammetry



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# Photogrammetry

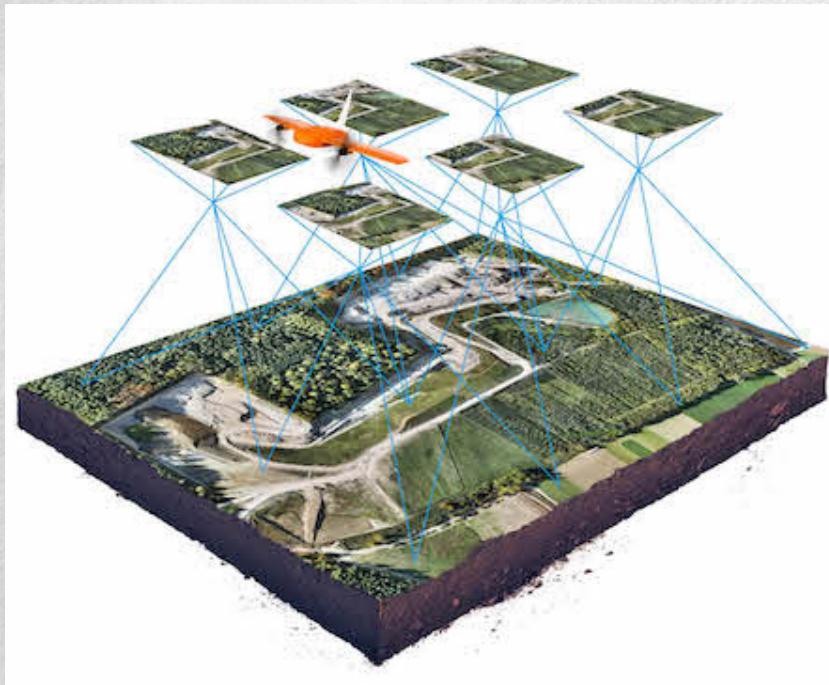
- 3D reconstruction from 2D images
- This process is also known as **Structure from Motion (SfM)**



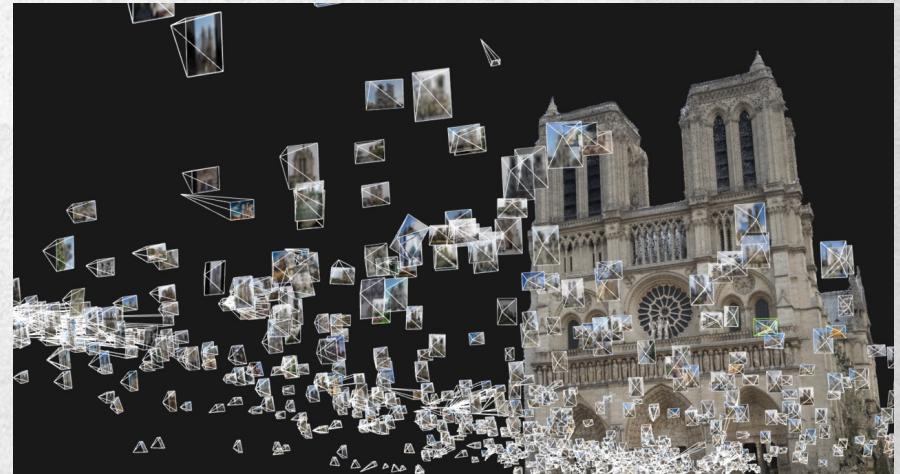
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# Common Use Cases

Drone surveying



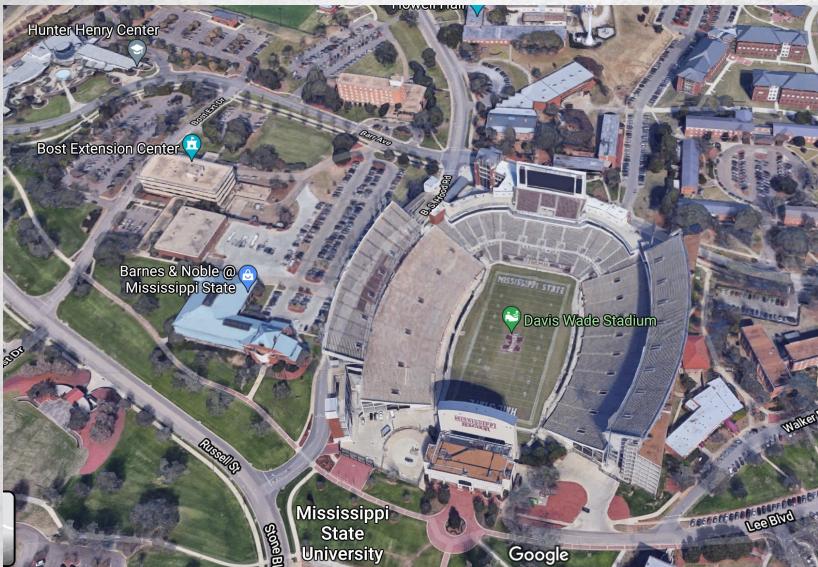
Building documentation



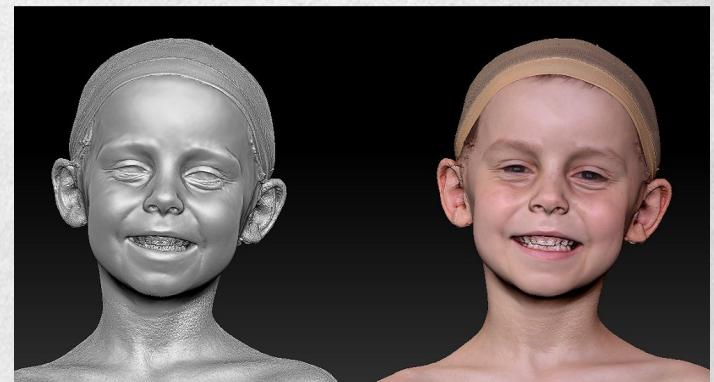
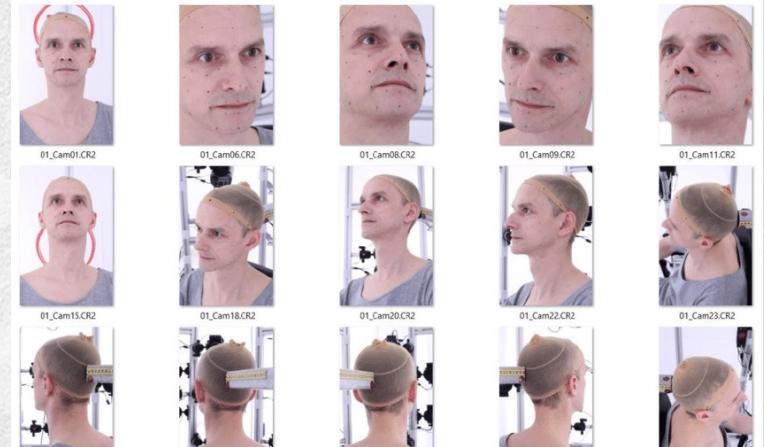
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# Common Use Cases

## Google Maps 3D

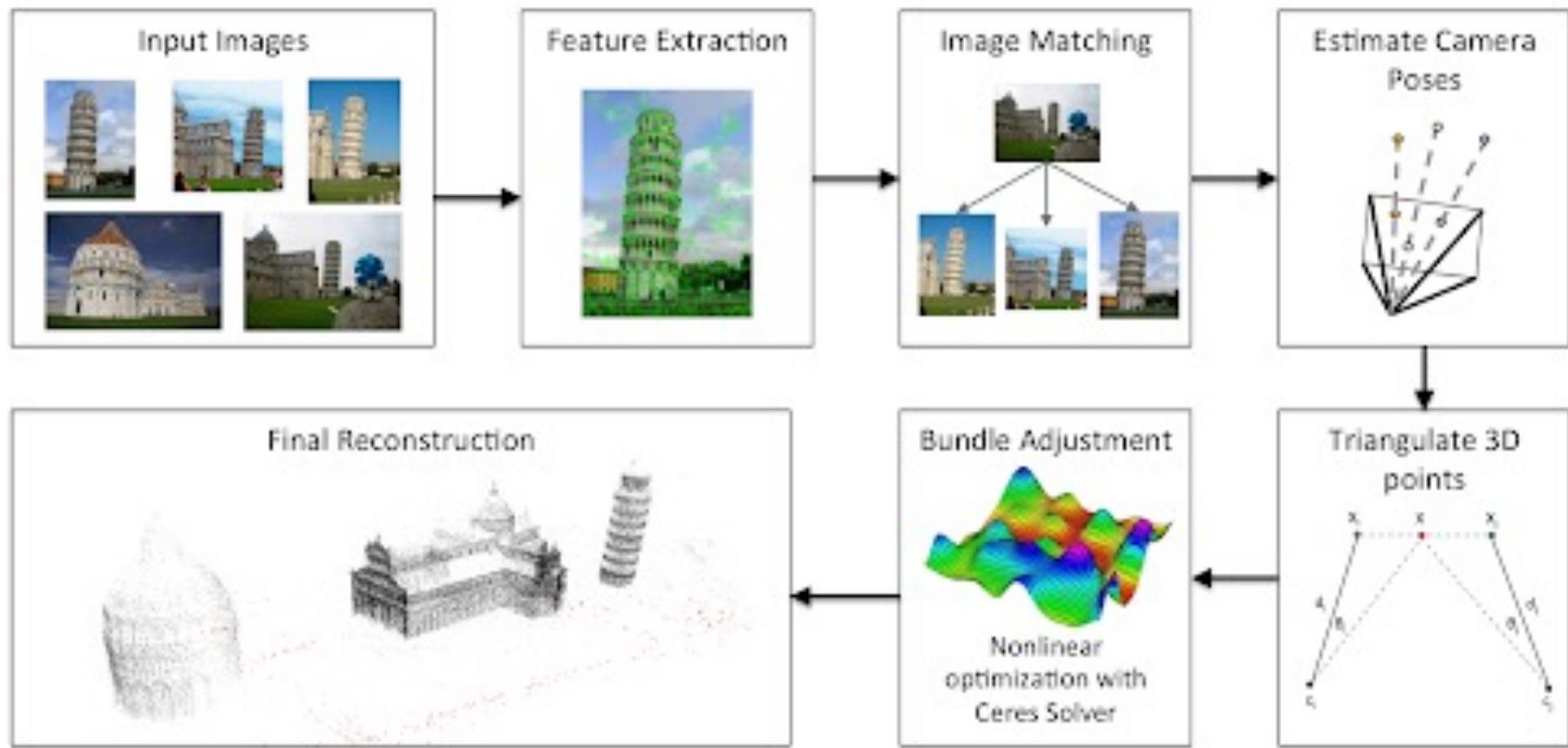


## Facial modeling



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# SfM Pipeline



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# SfM Software

Bundler + PMVS

<https://www.cs.cornell.edu/~snavely/bundler/>



COLMAP

<https://colmap.github.io/>



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# Drone Photogrammetry

Create 3D Models with Drones



dronegenuity



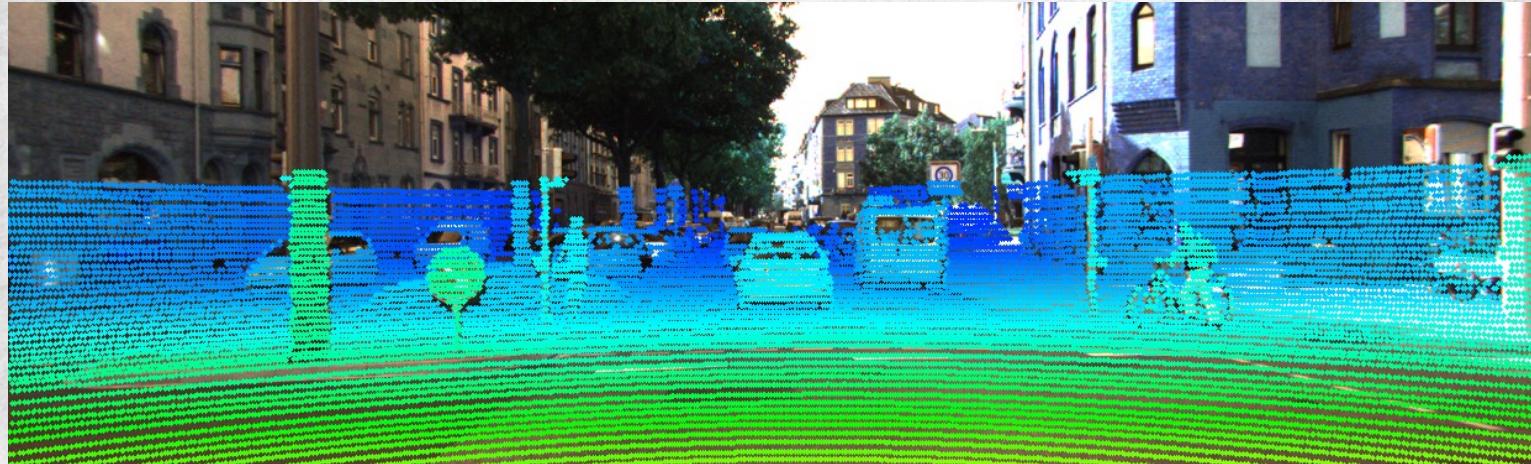
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# Multiple Sensors



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# Point Cloud Projection to Image



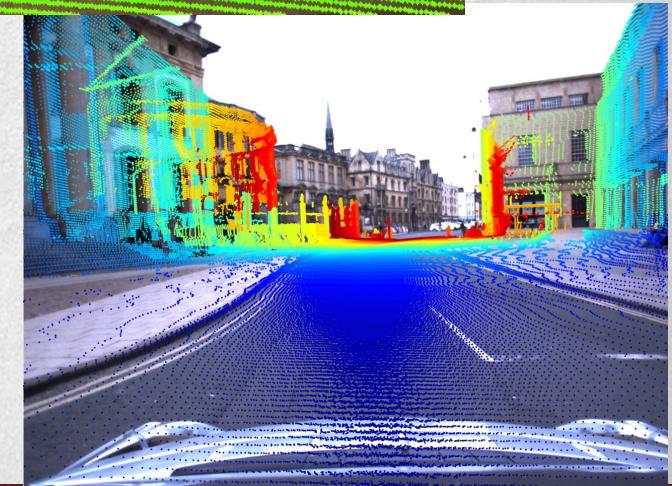
$$s \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

2D Image  
Coordinates

Intrinsic properties  
(Optical Centre, scaling)

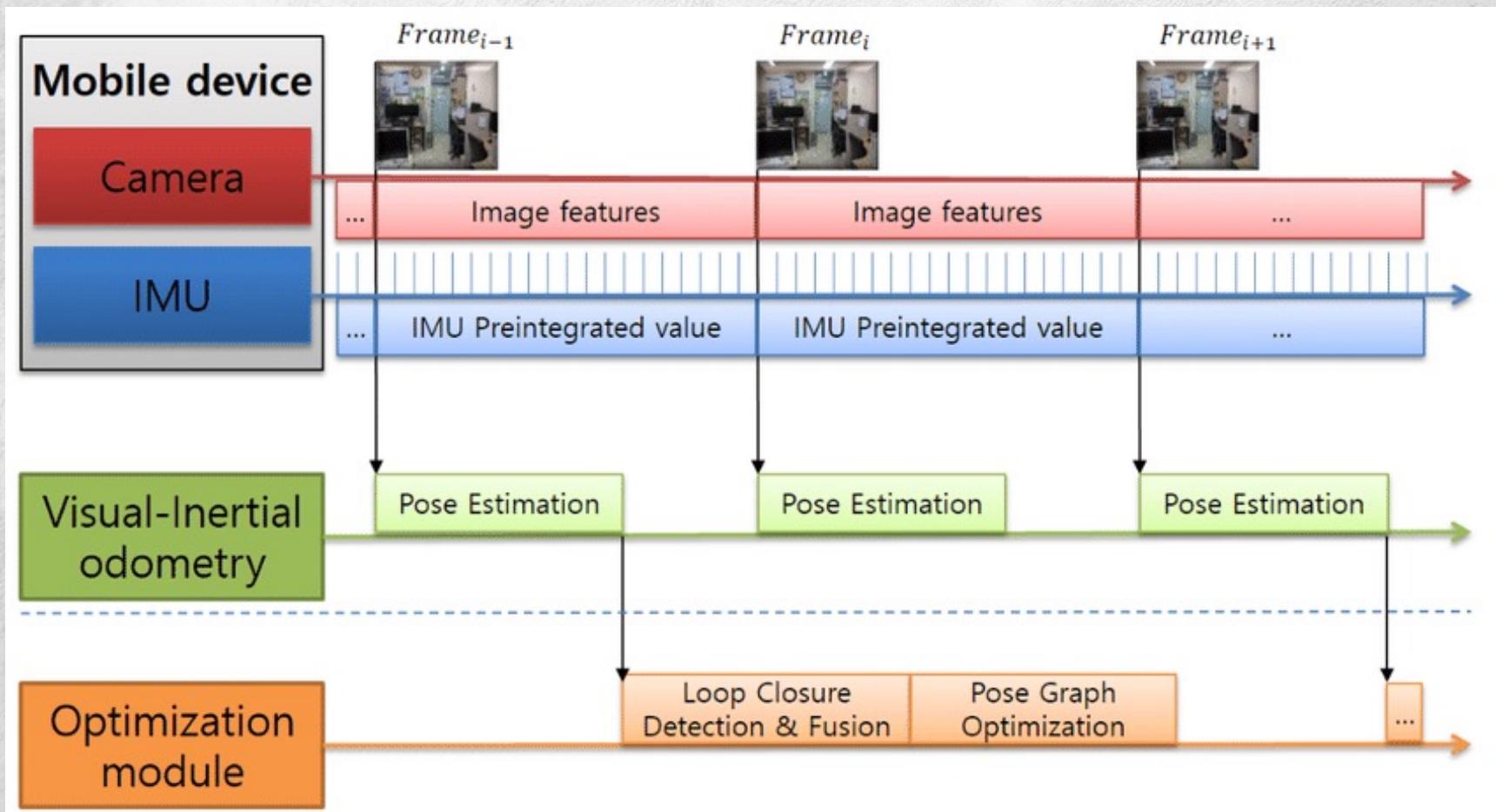
Extrinsic properties  
(Camera Rotation  
and translation)

3D World  
Coordinates



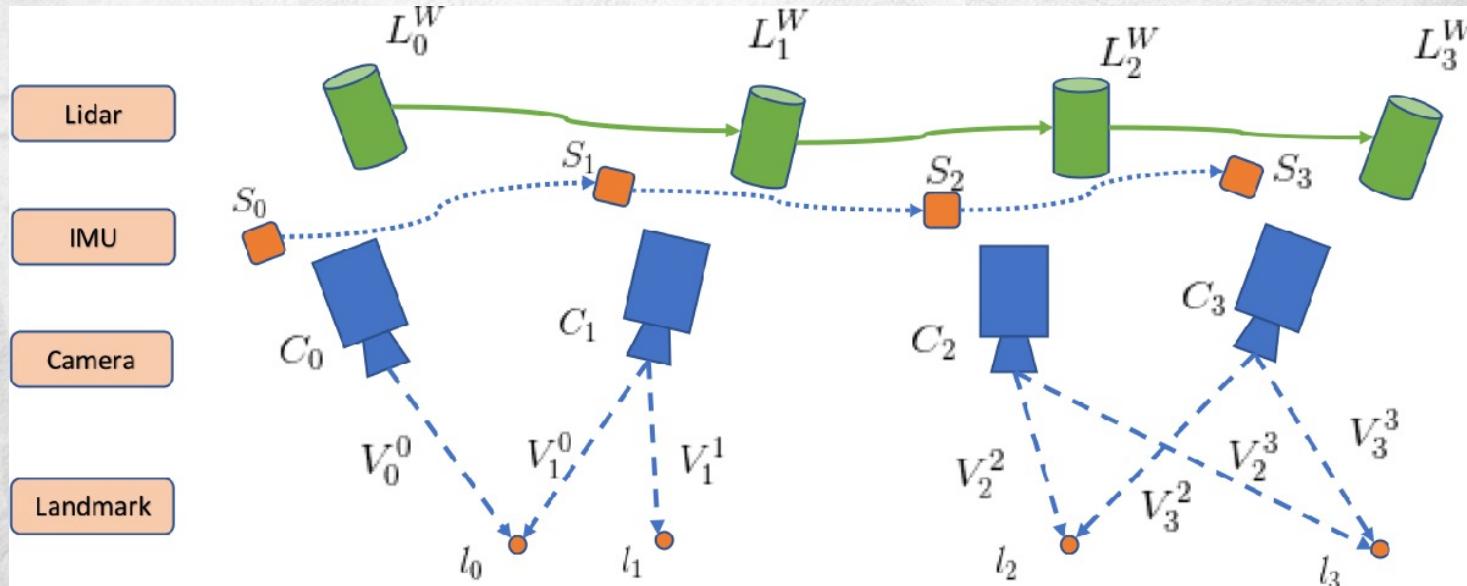
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# Visual – Inertial Odometry



# Advanced Sensor Fusion

- Data fusion from internal sensors + external sensors
- Need to consider error models of each sensor
- Will be covered in a later lecture on Simultaneous Localization and Mapping ...

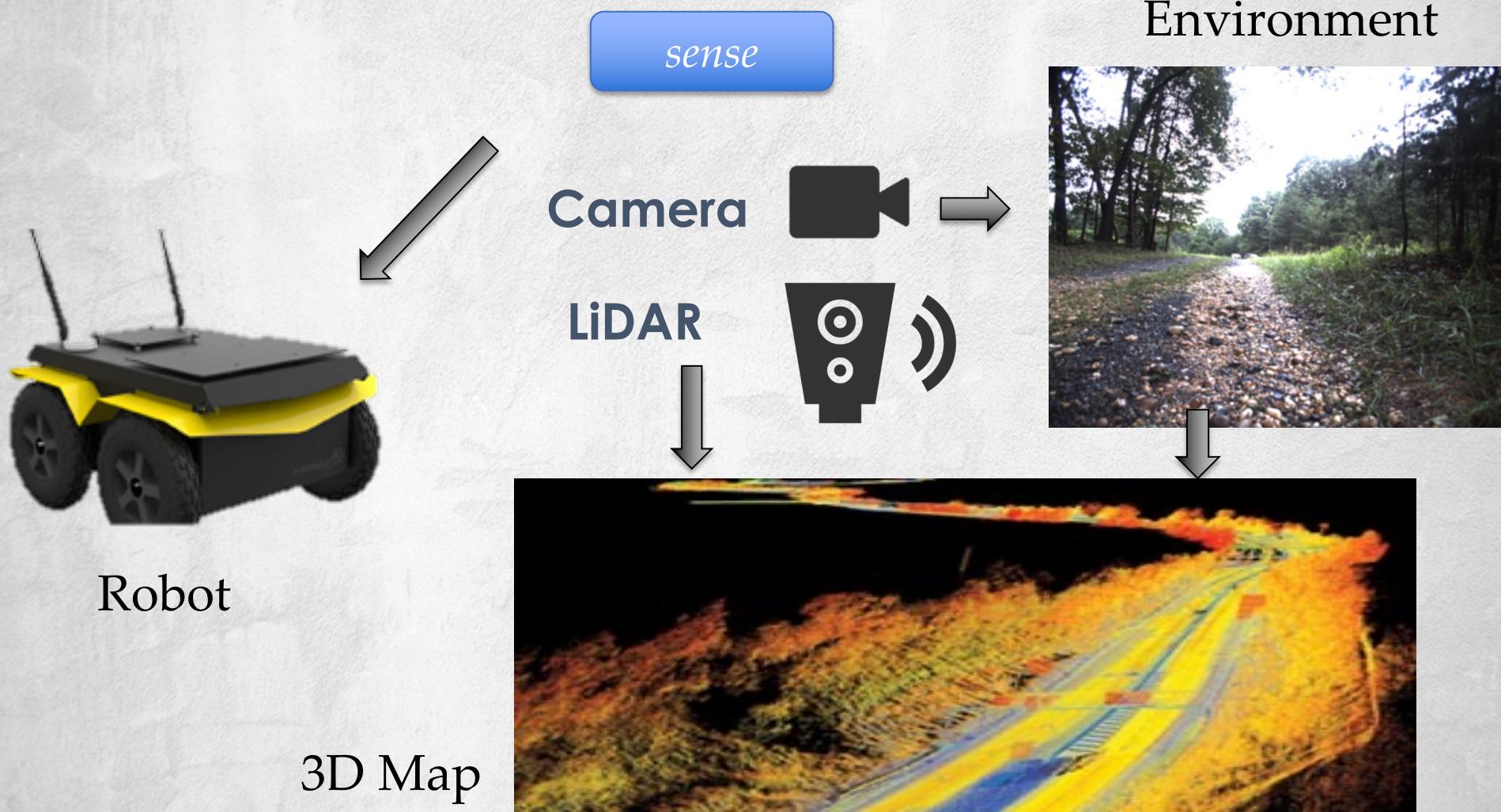


# Mapping



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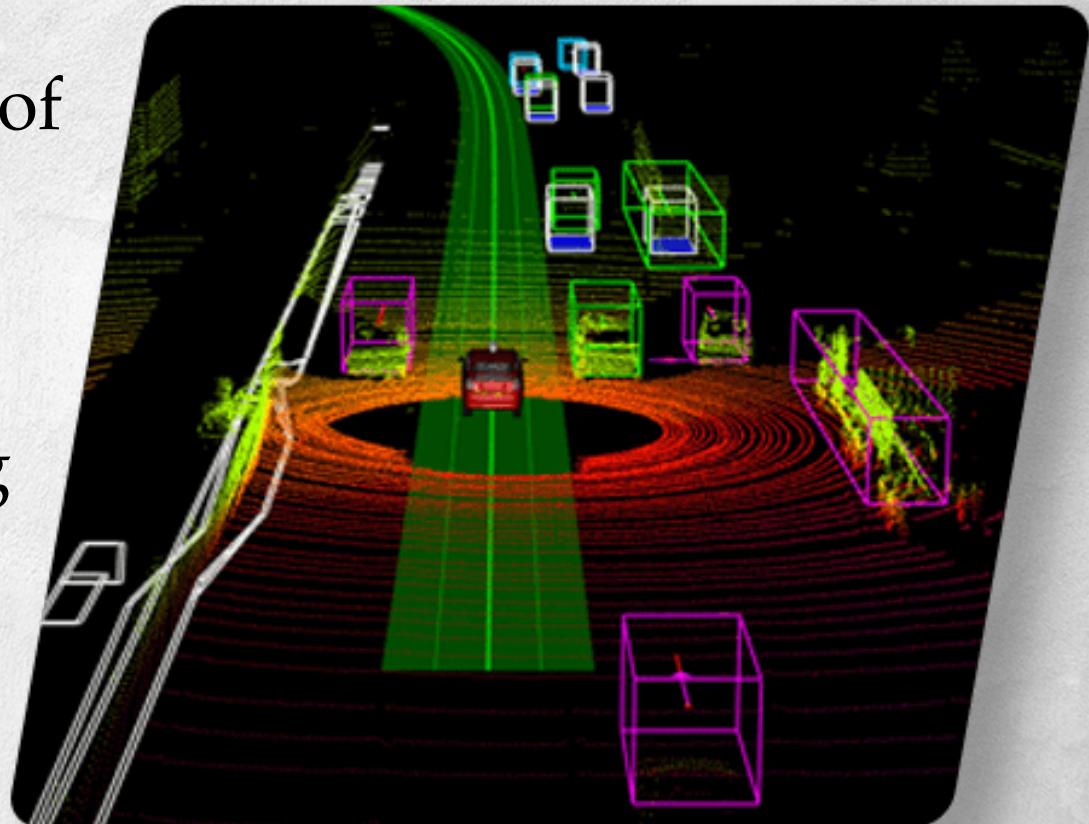
# Robot Model



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# 3D Mapping

- Get a complete map of the surrounding environment
- Navigation
- Scene understanding
- Obstacle avoidance



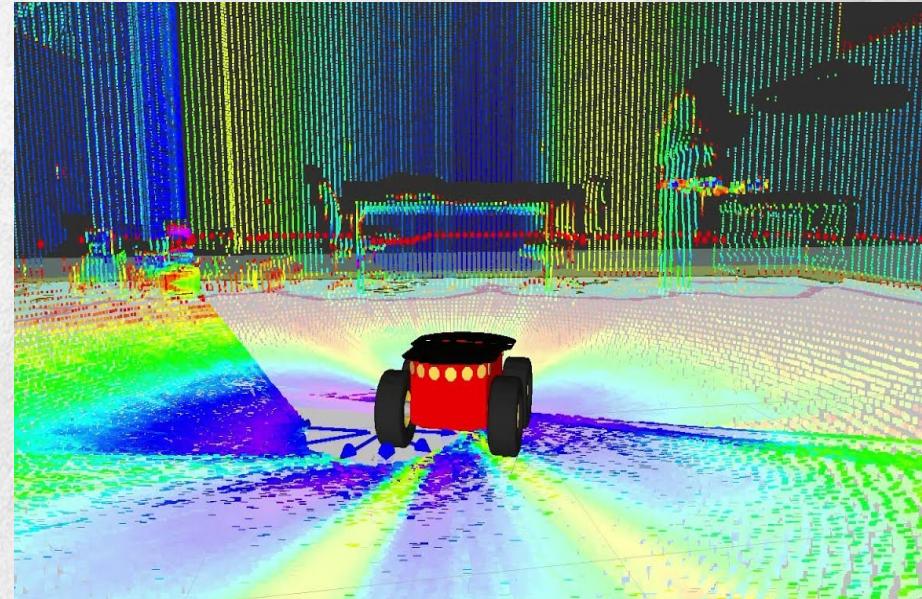
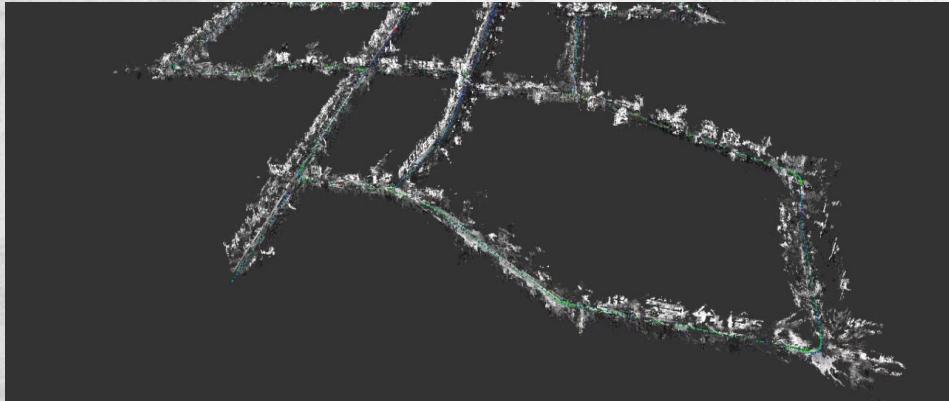
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# 3D Mapping

Camera



LiDAR



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# References

1. <https://www.picmonkey.com/blog/how-to-take-a-panorama-with-your-phone>
2. <https://www.semanticscholar.org/paper/Multi-Sensor-Fusion-for-Robust-Simultaneous-and-Li/523f6ac4cf0772fa4aeff35eaabf82e7e1fa36ca>



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