MULTI-MODAL MAPPING

Robotics Day, 31 Mar 2017

Frank Mascarich, Shehryar Khattak, Tung Dang

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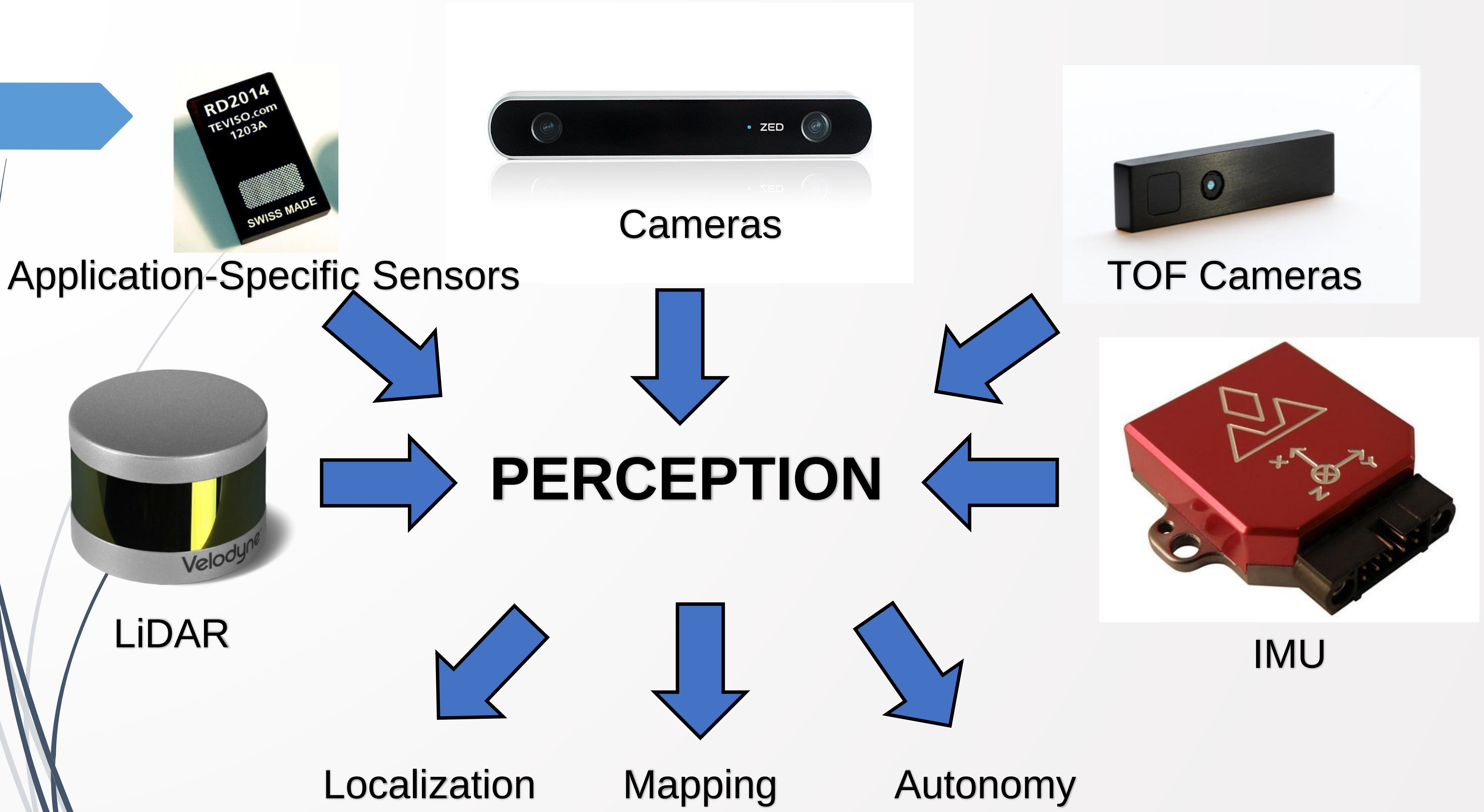
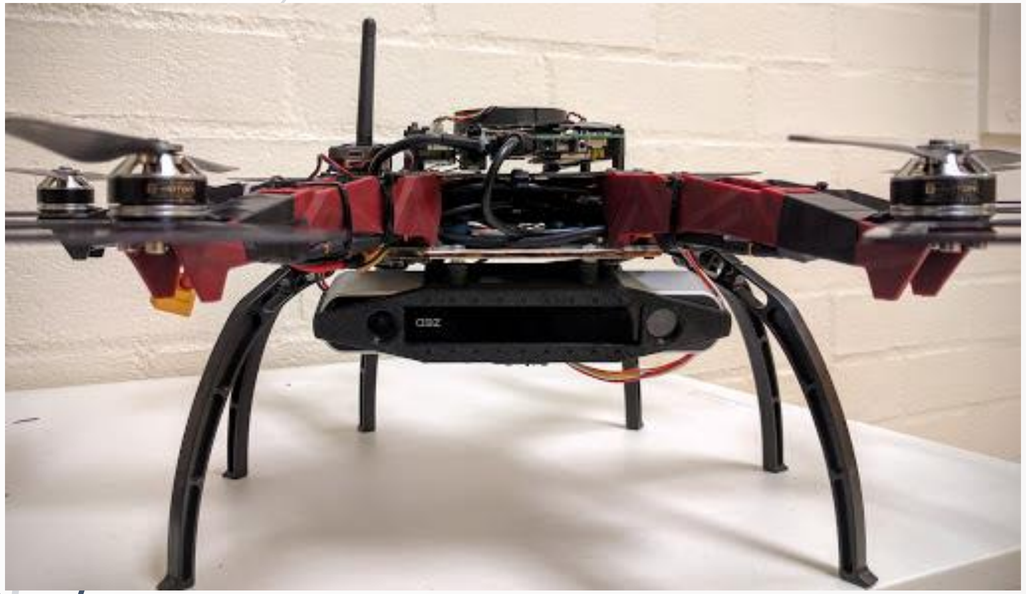
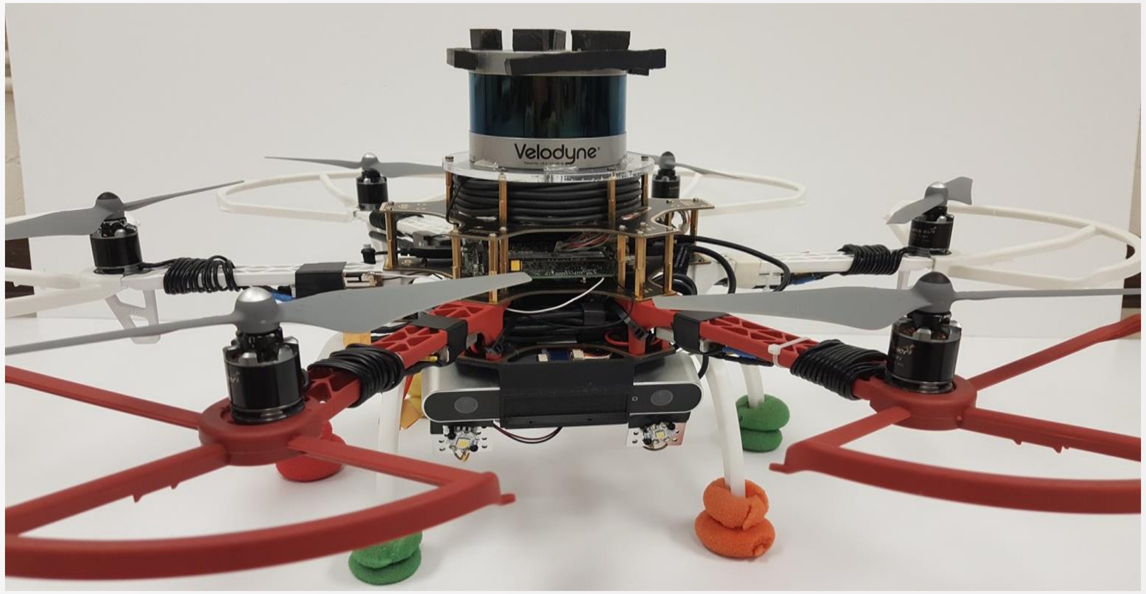

RD2014
TEVISO.com
1203A
SWISS MADE
Application-Specific Sensors
ZED
Cameras
TOF Cameras
Velodyne
LiDAR
PERCEPTION
IMU
Localization
Mapping
Autonomy

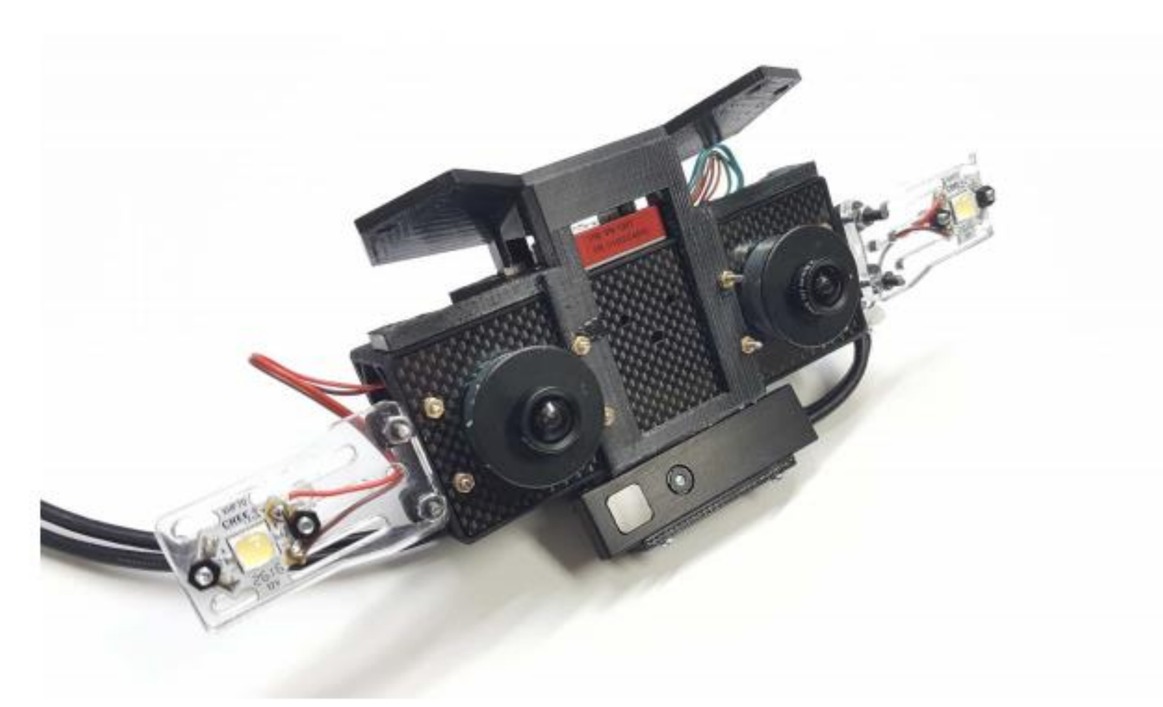
Robotic Perception

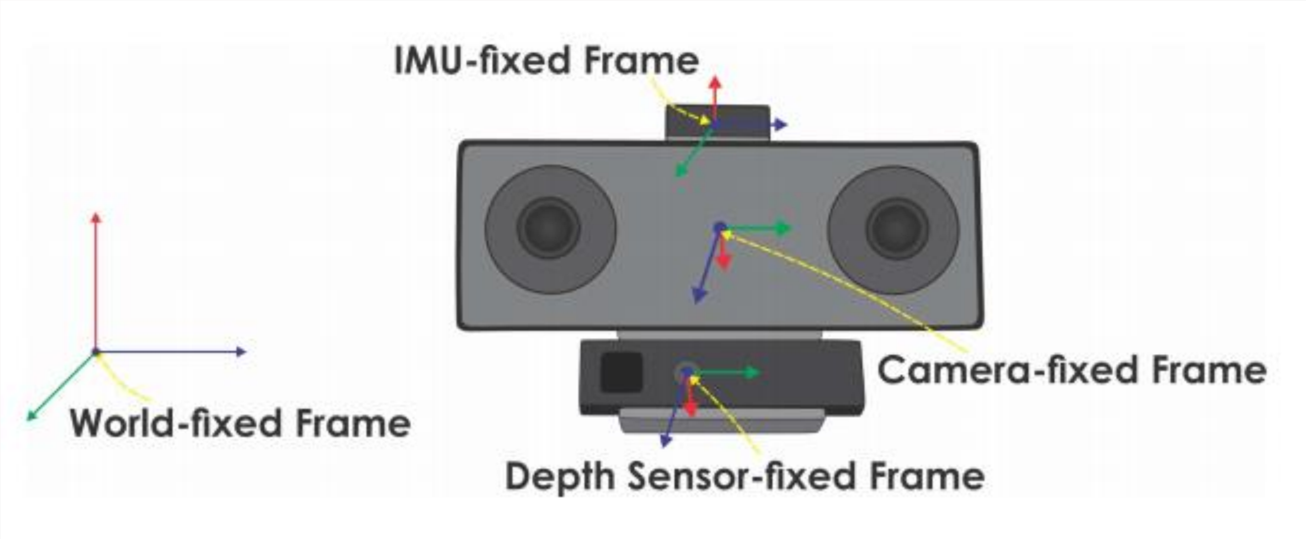




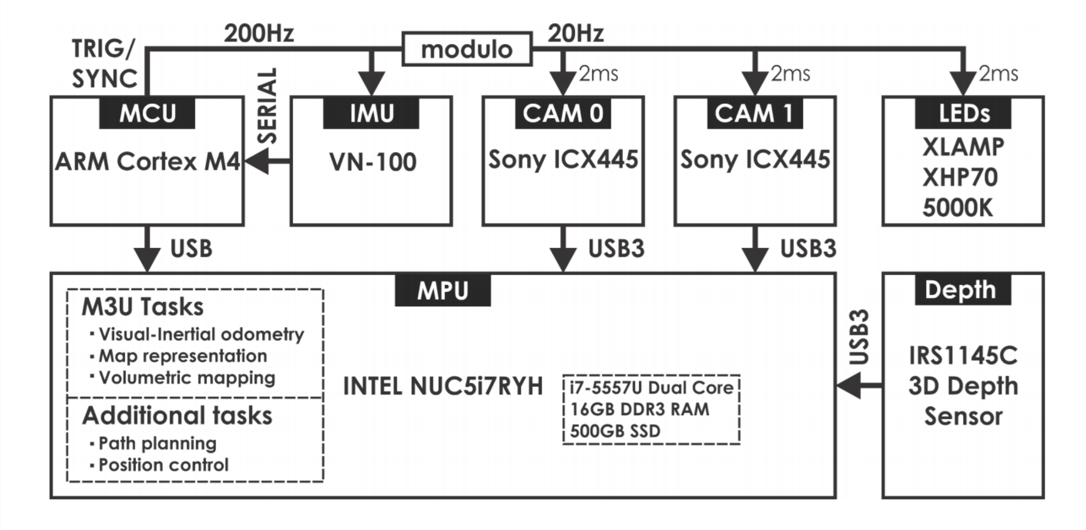
Robotic Perception

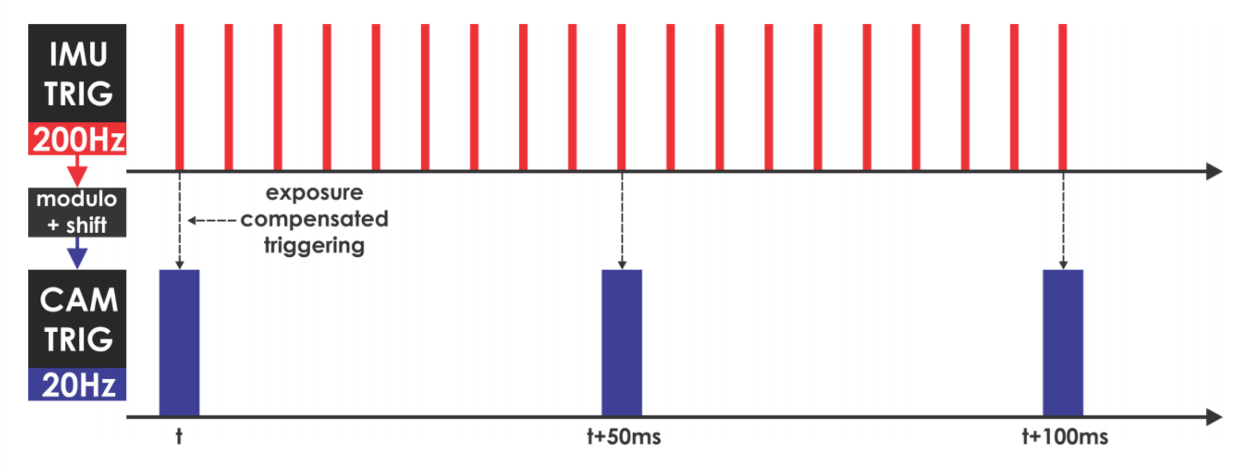
- M3U (Multi-Modal Mapping Unit)
  - Synchronization
  - Extendable
    - Multi-modal
    - Multi-camera
    - Application-specific sensing





M3U


TRIG/
SYNC
200Hz
modulo
20Hz
2ms
2ms
2ms
MCU
ARM Cortex M4
SERIAL
IMU
VN-100
CAM 0
Sony ICX445
CAM 1
Sony ICX445
LEDs
XLAMP
XHP70
5000K
USB
USB3
USB3
MPU
M3U Tasks
Visual-Inertial odometry
Map representation
Volumetric mapping
Additional tasks
Path planning
Position control
INTEL NUC5i7RYH
i7-5557U Dual Core
16GB DDR3 RAM
500GB SSD
USB3
Depth
IRS1145C
3D Depth
Sensor


IMU
TRIG
200Hz
modulo
+ shift
CAM
TRIG
20Hz
exposure
compensated
triggering
t
t+50ms
t+100ms

M3U


A Multi-Modal Mapping Unit for Autonomous Robotic Navigation and Exploration in Visually-degraded Environments
Frank Mascarich, Christos Papachristos, Kostas Alexis
This material is based upon work supported by the Department of Energy under Award Number [DE-EM0004478]
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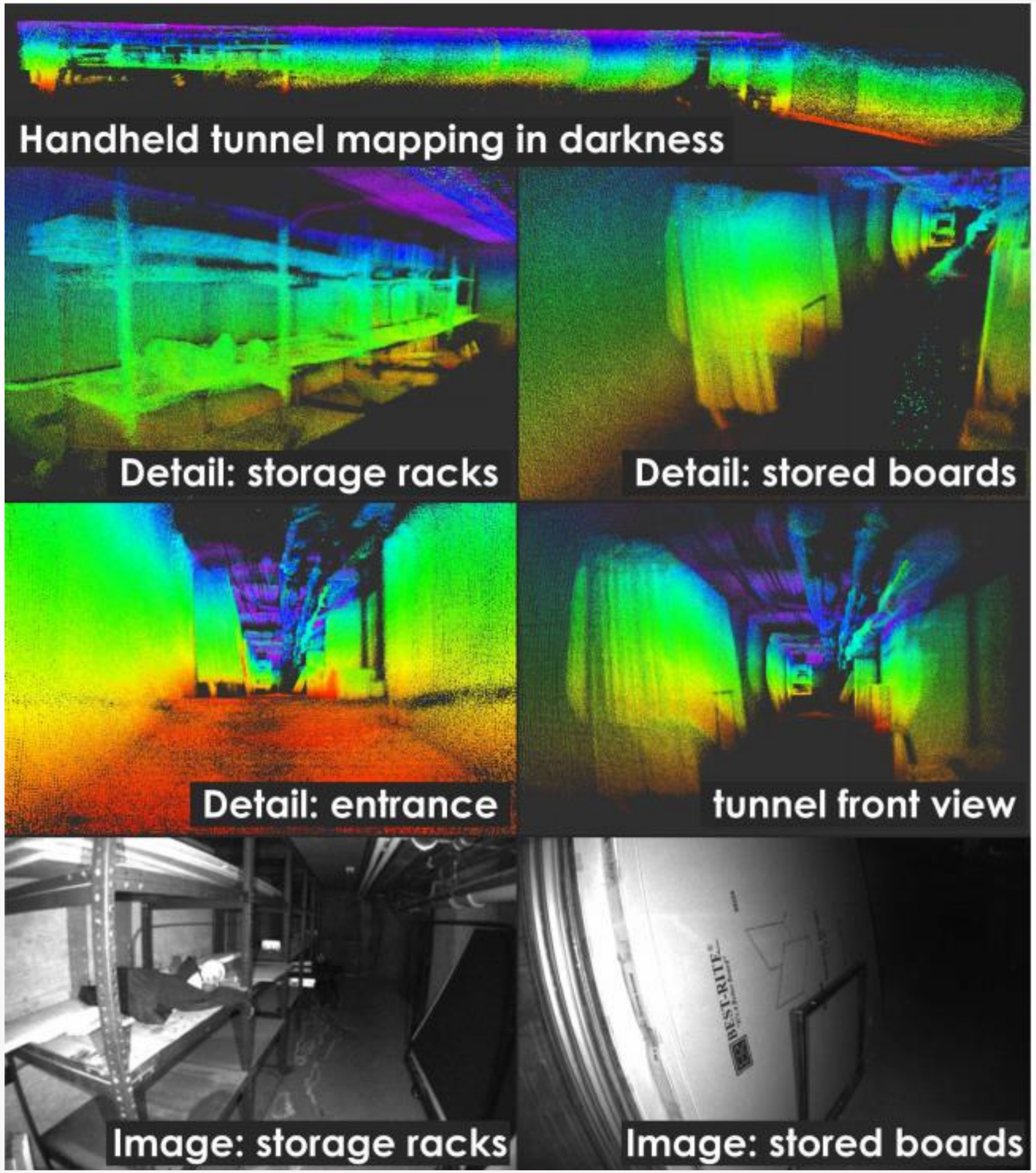
M3U

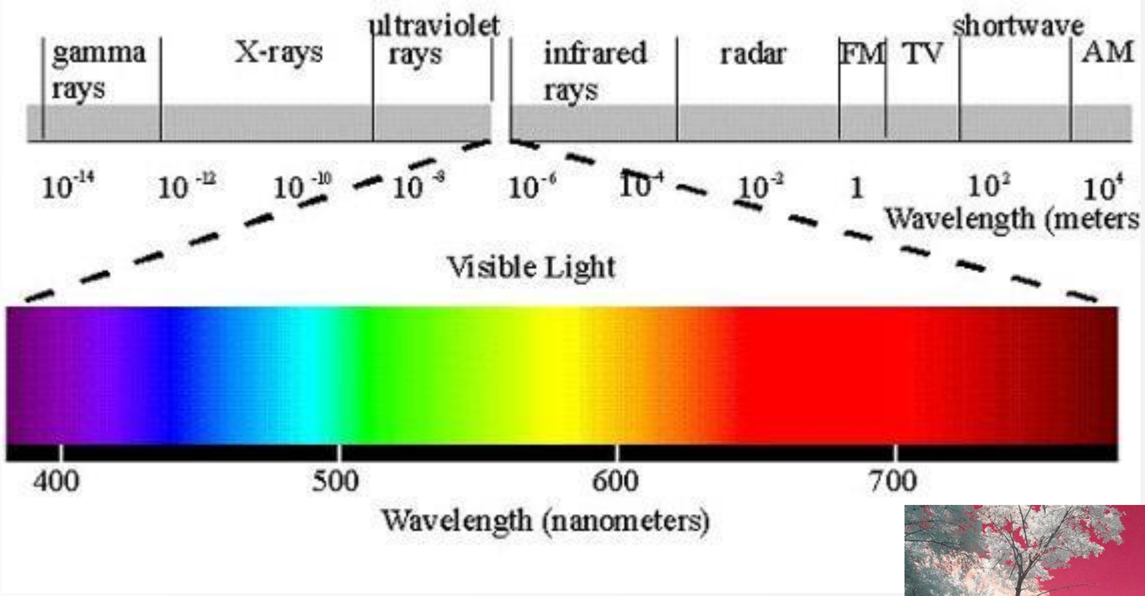


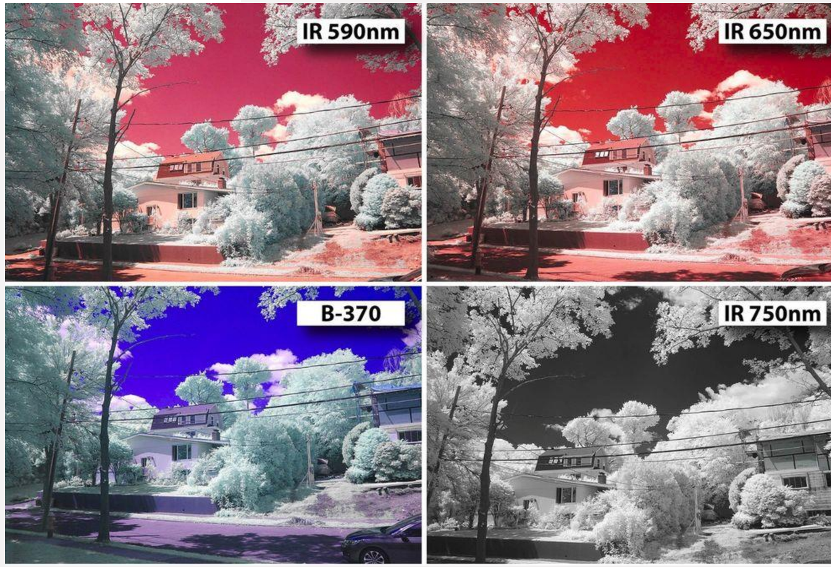
Handheld tunnel mapping in darkness
Detail: storage racks
Detail: stored boards
Detail: entrance
tunnel front view
Image: storage racks
Image: stored boards

Camera Systems

- Camera Systems
  - Monocular Camera Systems
  - Stereo Camera Systems
- Used to correlate position against static environment
- Require precise calibration
- Modalities
  - Visible Light
  - IR
  - UV

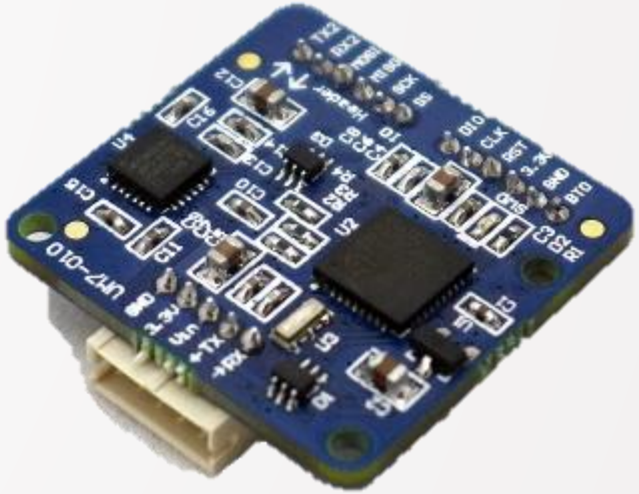
Alternative Spectra

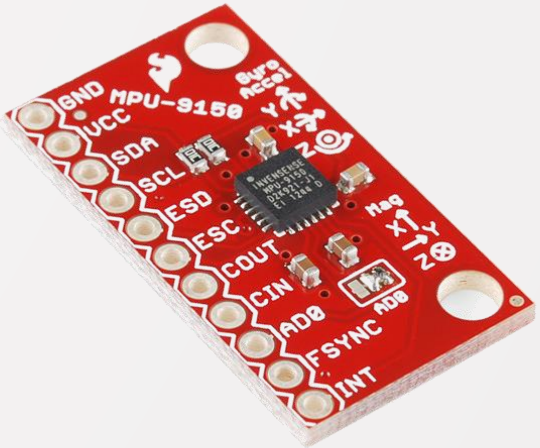




Navigation Sensors

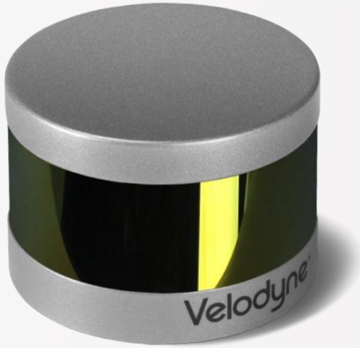
- Inertial Sensors:
    - Accelerometers
    - Gyroscopes
- Magnetometers (digital compass)
- Pressure Sensors
    - Barometric pressure for altitude sensing
    - Airspeed measurements

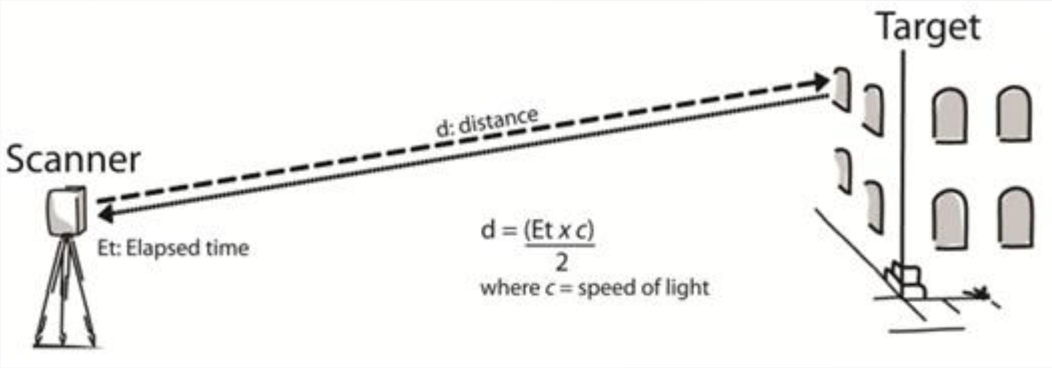




LiDAR

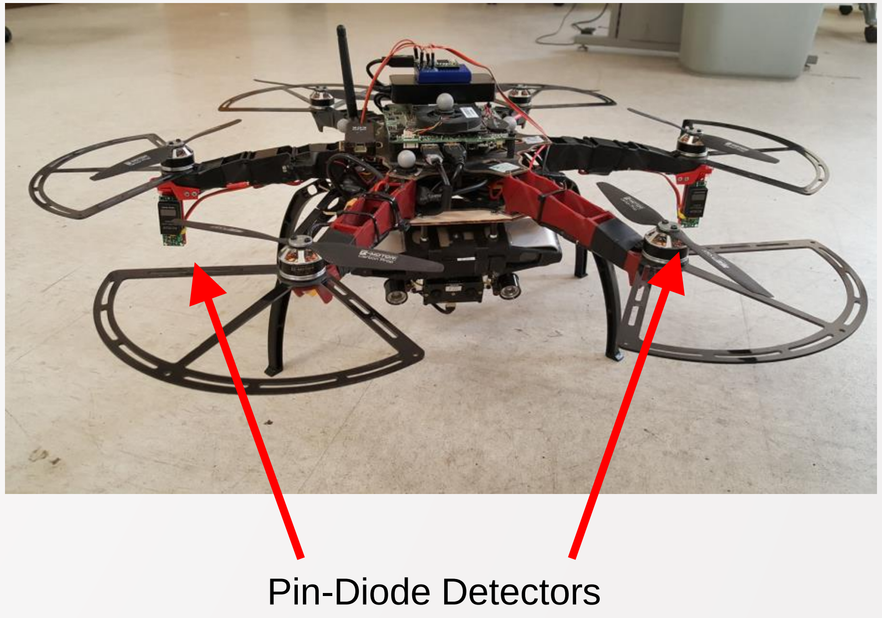
- Time of flight measurement
- Multiple beams
- Different fields of view



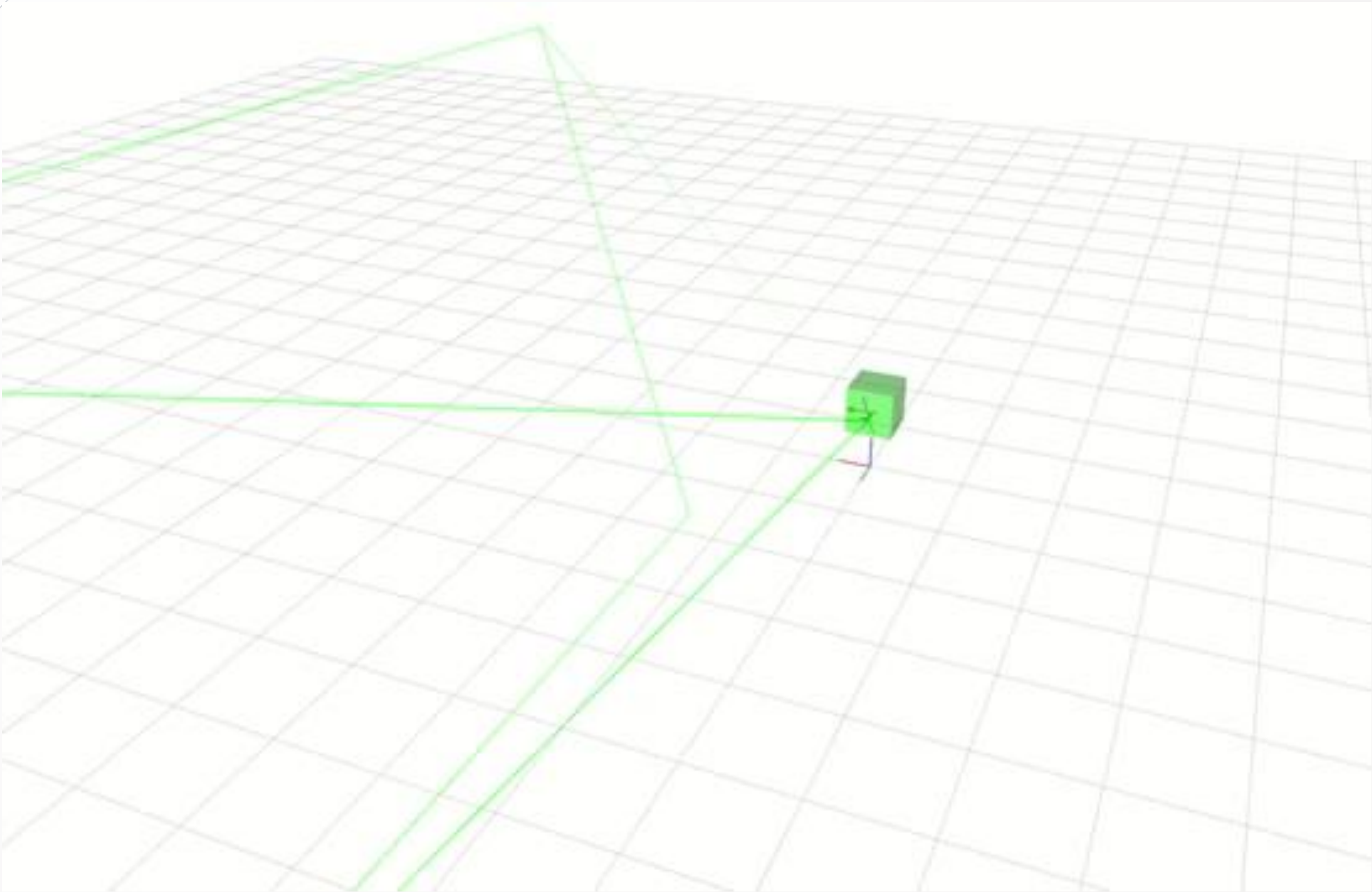


Application Specific Sensing

- Radiation Mapping
  - 2x pin-diode detectors
  - Mounted with a 45cm "stereo" baseline
  - MCU integrates radiation pulses over time and sends data to the MPU
  - Main processor tracks the position of the robot and annotates its map with the radiation data from the MCU
  - Utilize radiation data to localize sources in an unknown environment
  - Applications:
    - Security
    - Environmental disaster monitoring
    - Decommissioning nuclear facilities

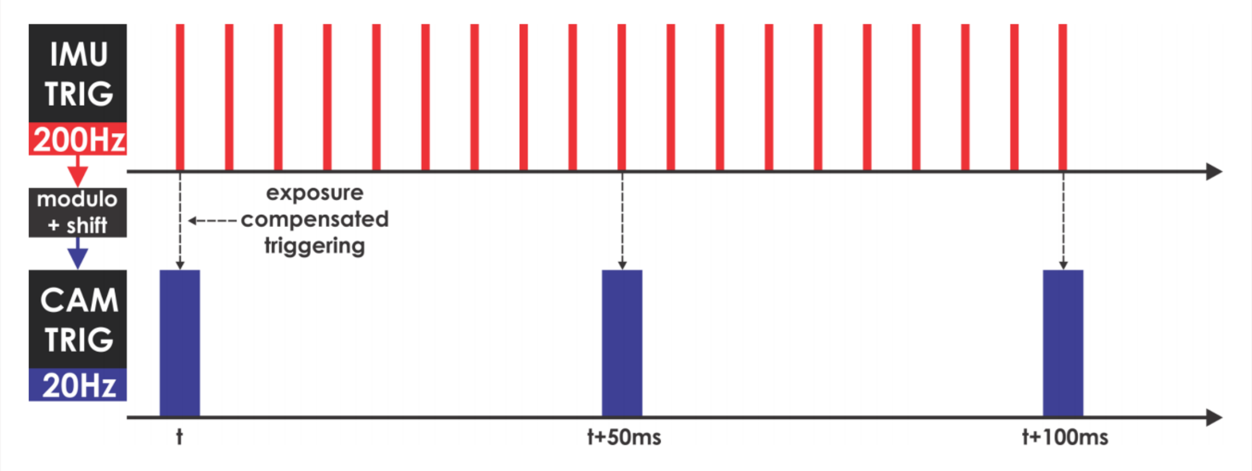


Radiation Detection and Mapping



Synchronization

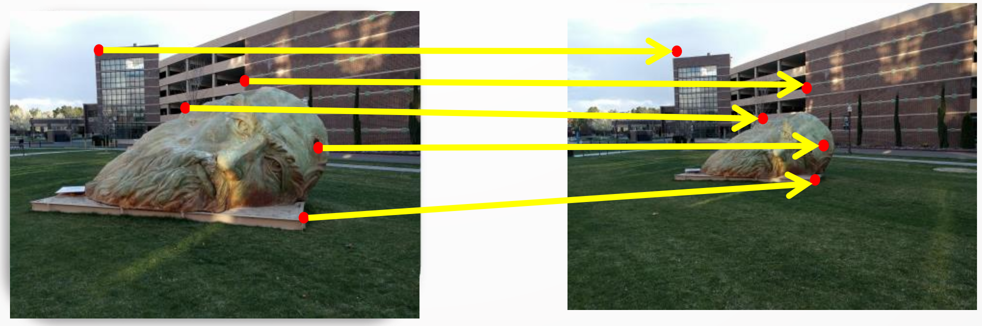
- IMU and Camera data is transmitted over USB
  - Unpredictable data arrival
  - Software Synchronization
  - Hardware Synchronization
    - Allows precise triggering



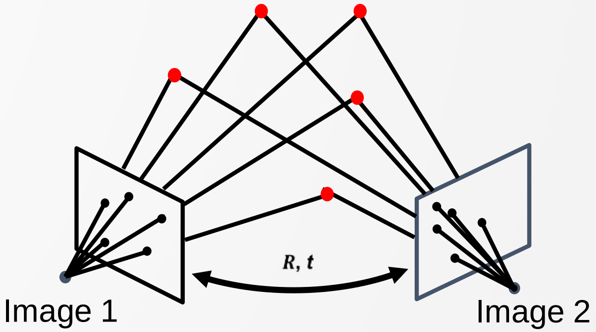
Visual Odometry

- Visual Odometry is the process of estimating the position and orientation of a camera by analyzing a sequence of camera images.

Acquire Images → Undistort → Detect Features → Track Features → Estimate Motion

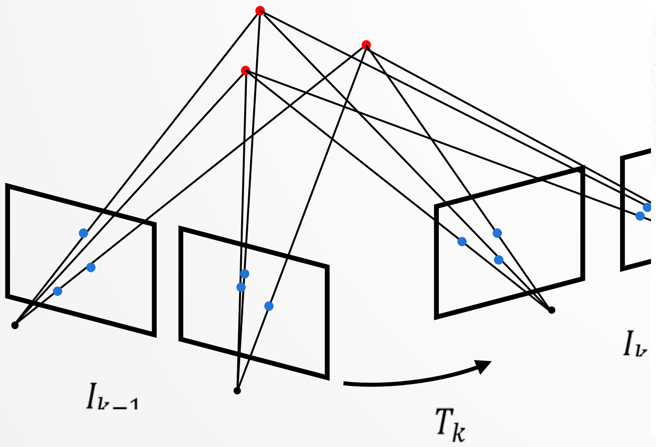


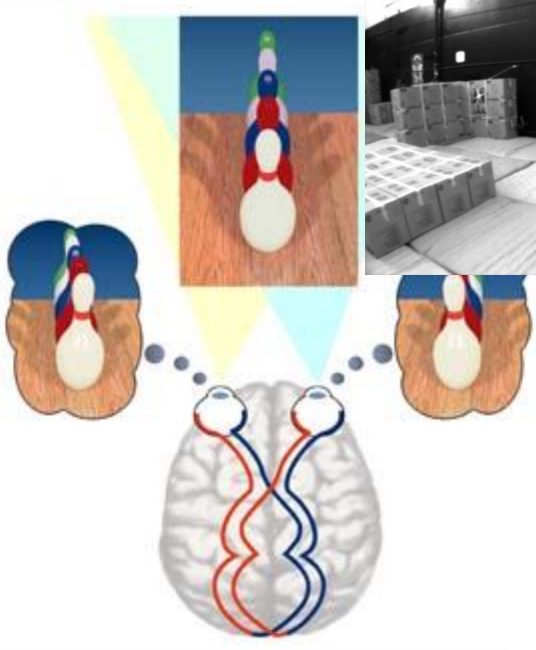
I_{k-1} I_k



Visual Odometry

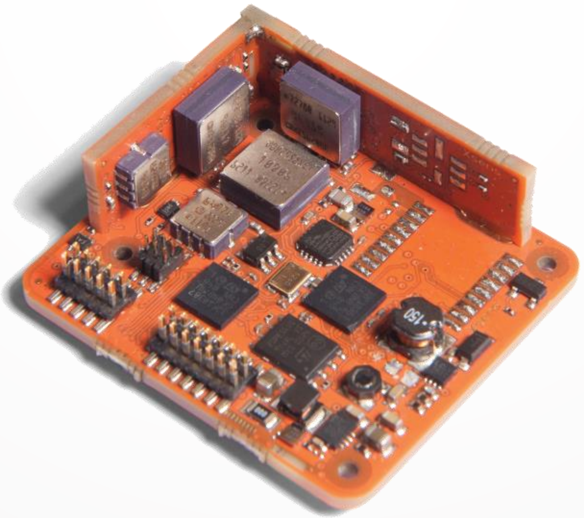
- Disparity is the distance by which objects shift from one image to another
- Disparity is greater for objects that are closer
- Allows stereo cameras to estimate depth without motion





Visual-Inertial Odometry

- Performance is dependent on the quality of the scene and computational capability of the system
- Inertial sensors provide acceleration and angular velocity at high speed
- Motion is estimated by doing integration
- Prone to drift, so not viable over longer period, but effective over short time frames



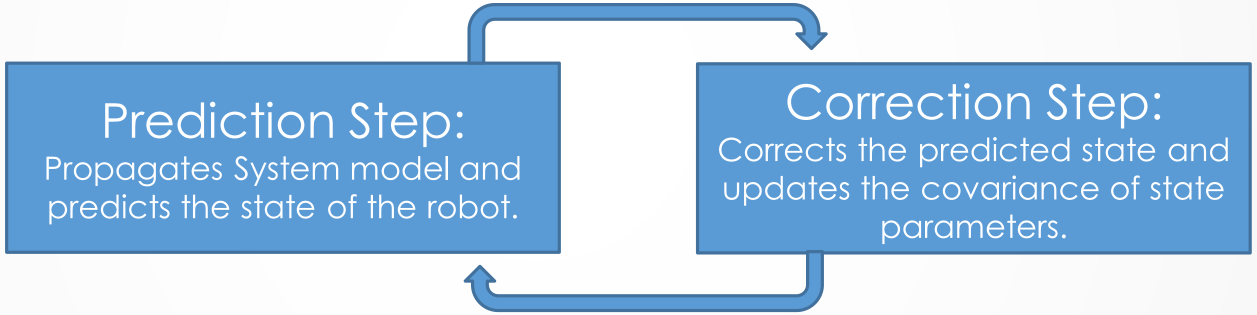
Visual-Inertial Odometry

- How to combine Visual and Inertial measurements in a mathematical and probabilistic way?

Take Weighted Average

Extended Kalman Filter (EKF)

- Works in a two-step manner:

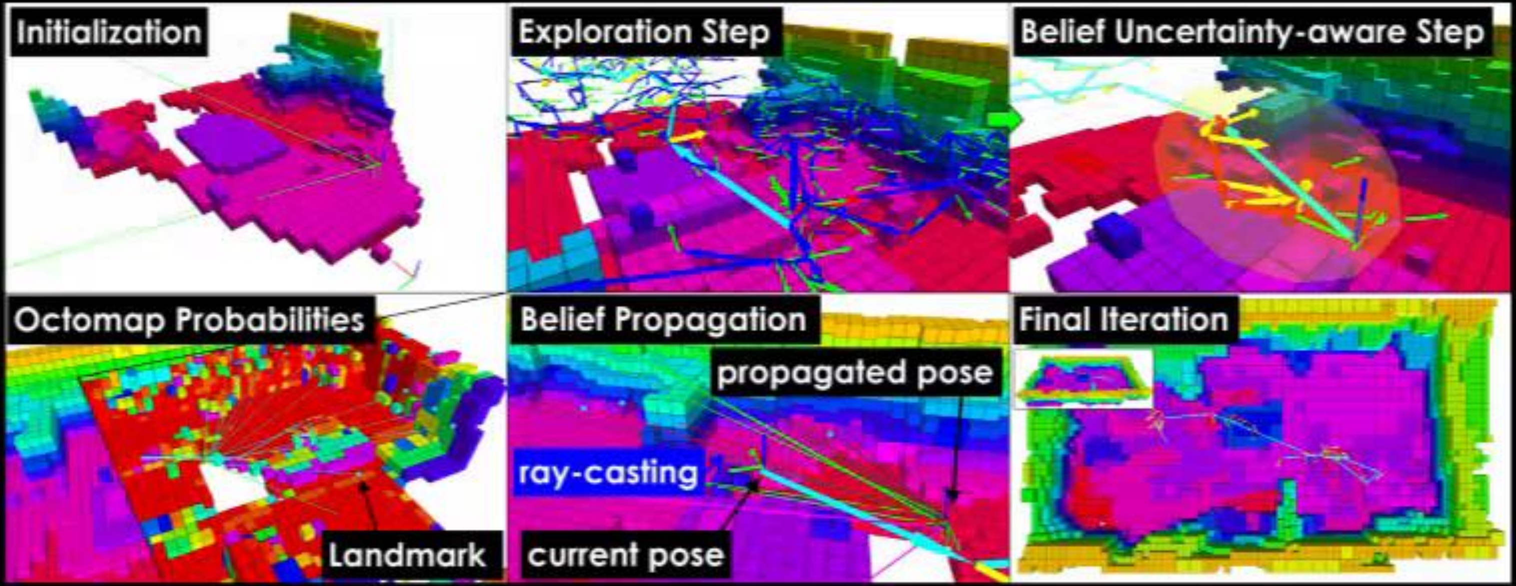


- Implemented EKF propagates a linearized model using IMU measurements as inputs and corrects prediction using vision measurements
- Estimates "State" of the robot:

X → Position, Velocity, Orientation

Uncertainty-aware Receding Horizon Exploration and Mapping using Aerial Robots

Christos Papachristos, Shehryar Khattak, Kostas Alexis



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Visual-Inertial Odometry

- What can we do with this VI pipeline?

Odometry → Localization

Feature depth information → Mapping

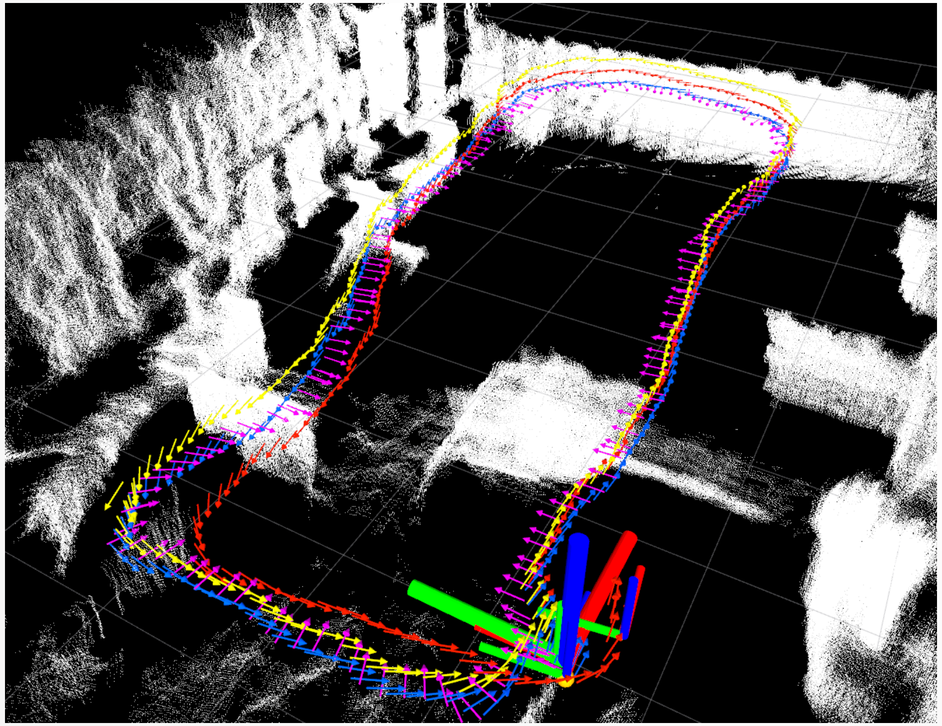
- Enables us to explore and map unknown environments
- Addresses the famous chicken and egg problem in robotics known as "Simultaneous Localization and Mapping" (SLAM)

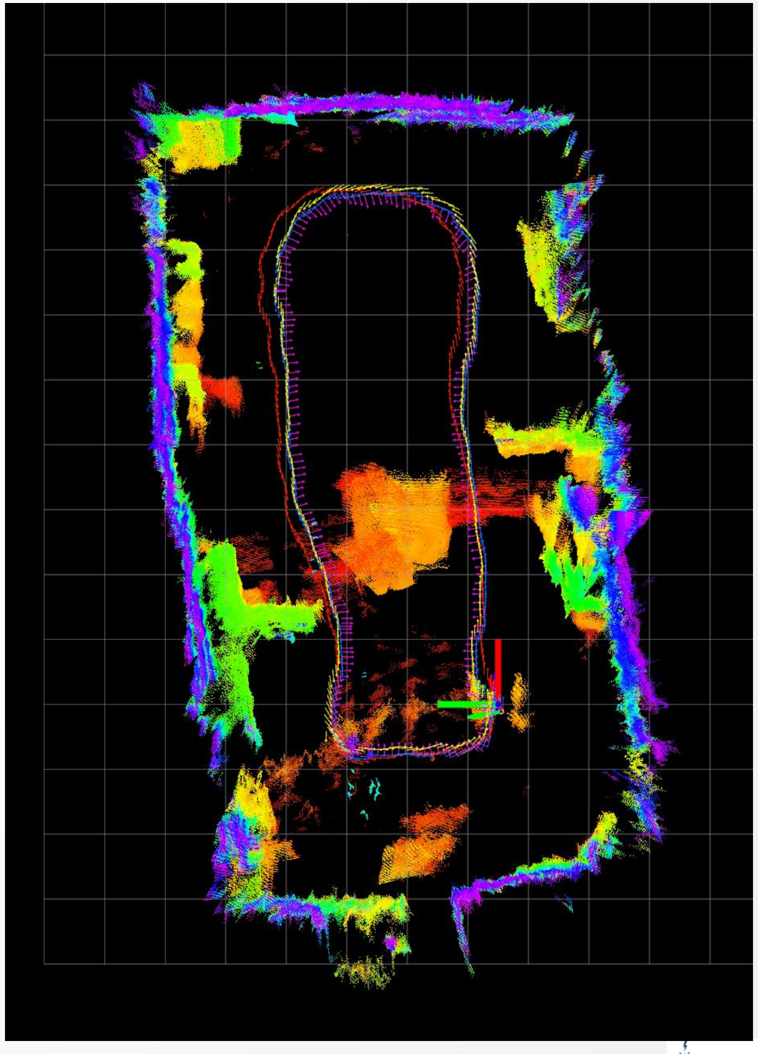
Where am I?

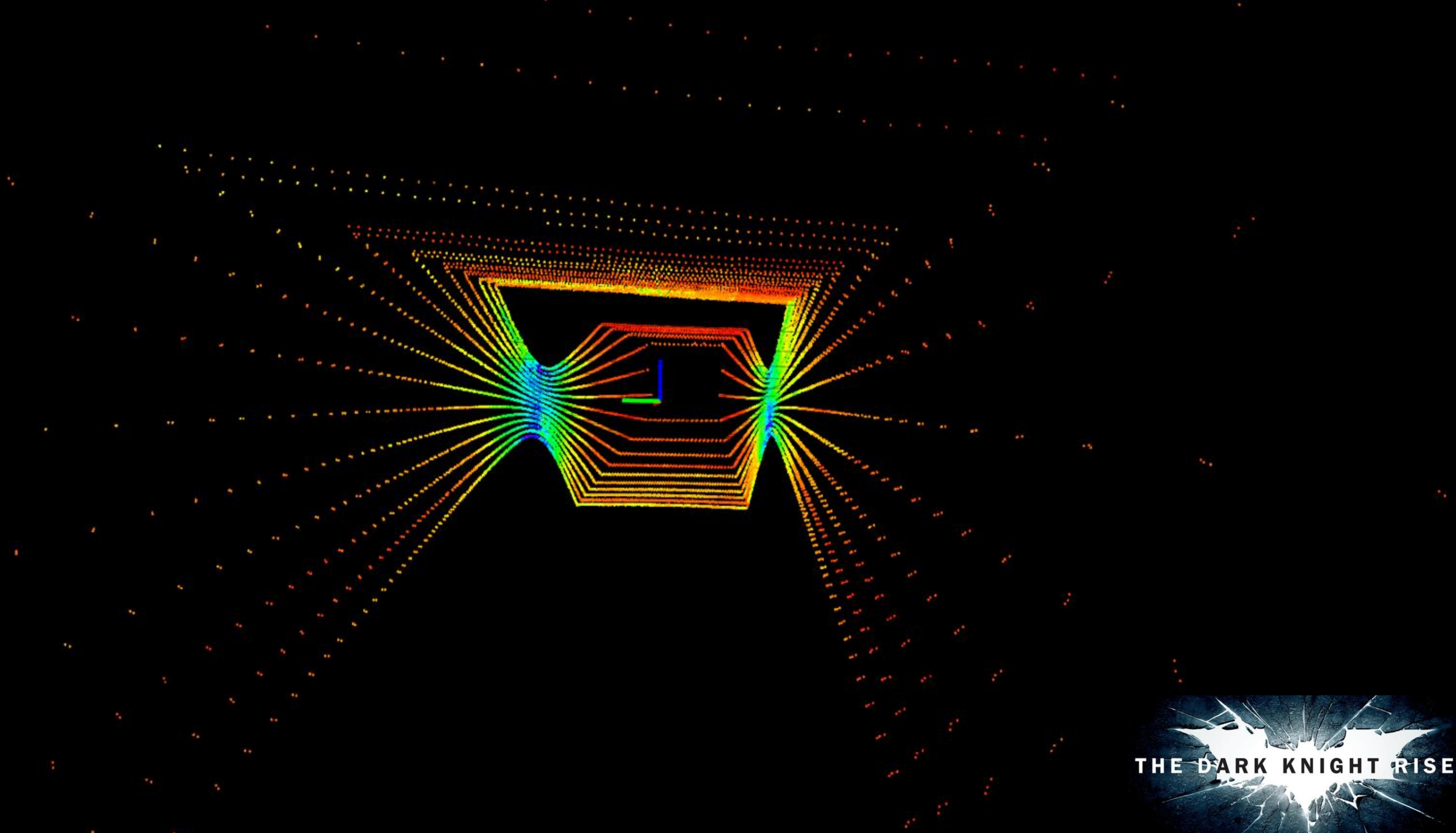
What's around me?

Visual-Inertial Odometry

- Odometry is prone to drift
- Cannot perform in visually degraded environments
- Mapping is limited by the camera's field of view



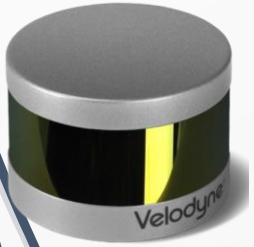




THE DARK KNIGHT RISES

Laser range sensors

Characteristics	Picoflexx, Realsense	Velodyne, Hokuyo
Size	-	+
Weight	-	+
FOV	-	+
Range	-	+
Dense point cloud	+	-

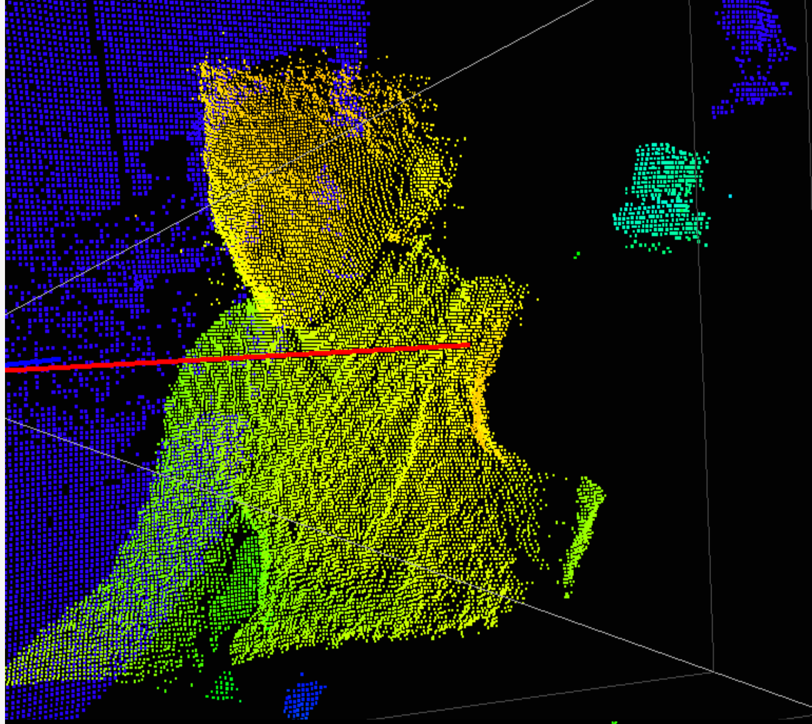


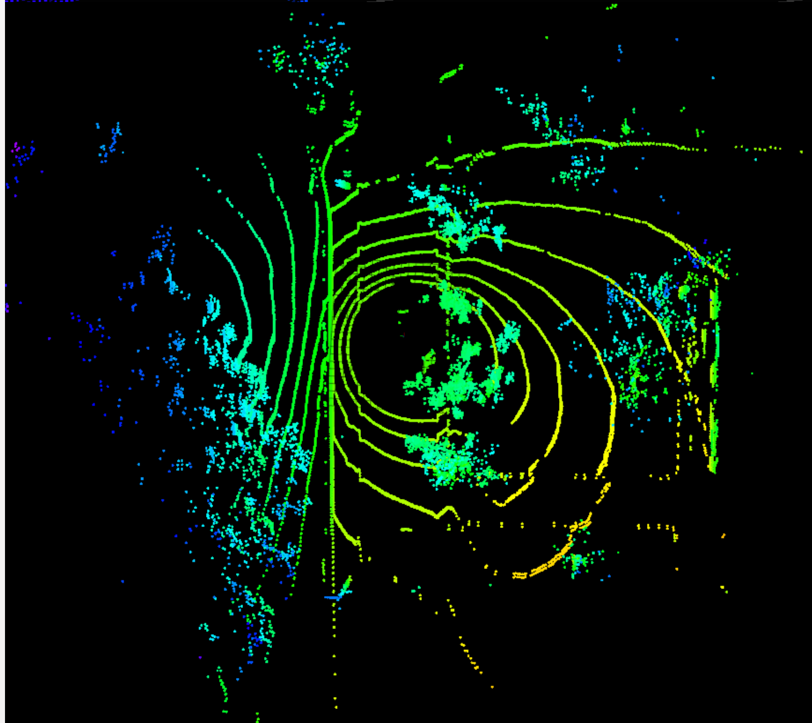
Velodyne

Hokuyo

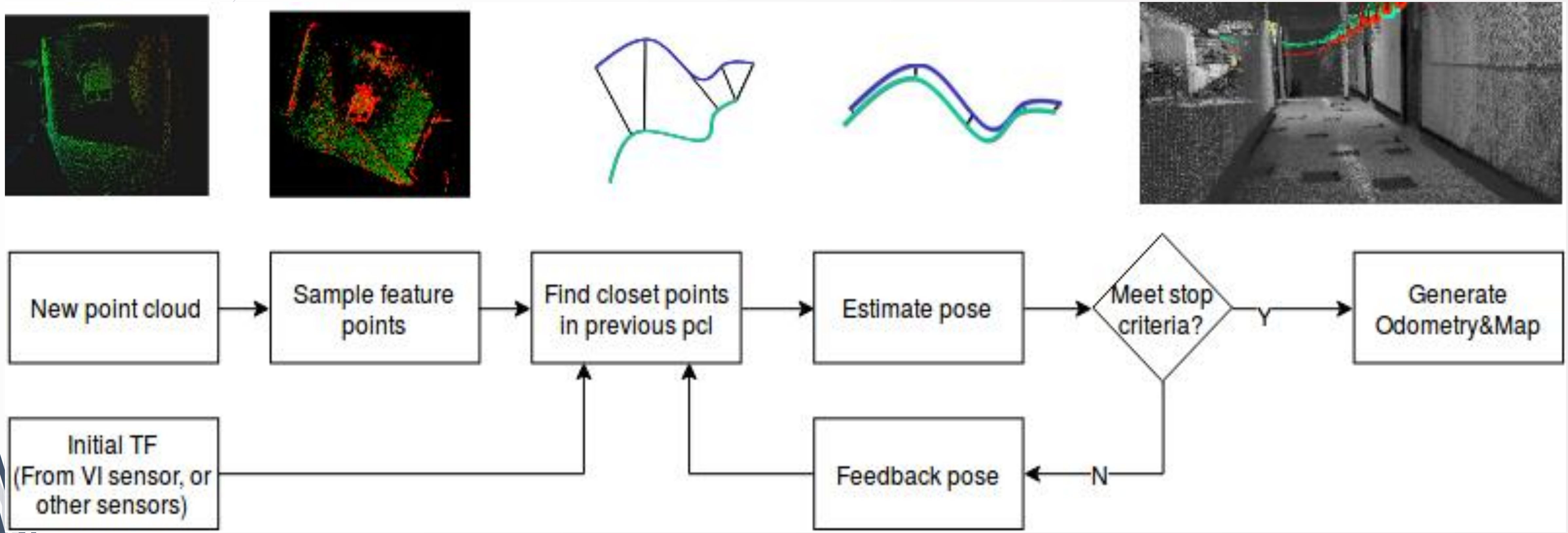
Realsense

Picoflexx

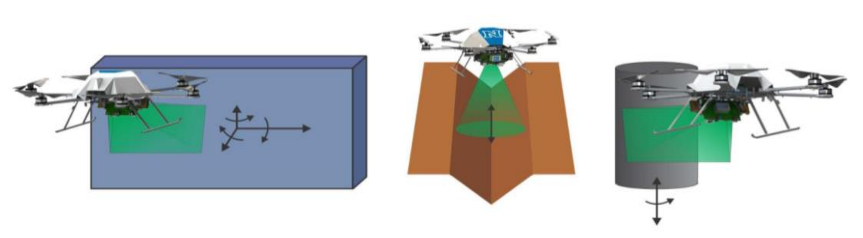


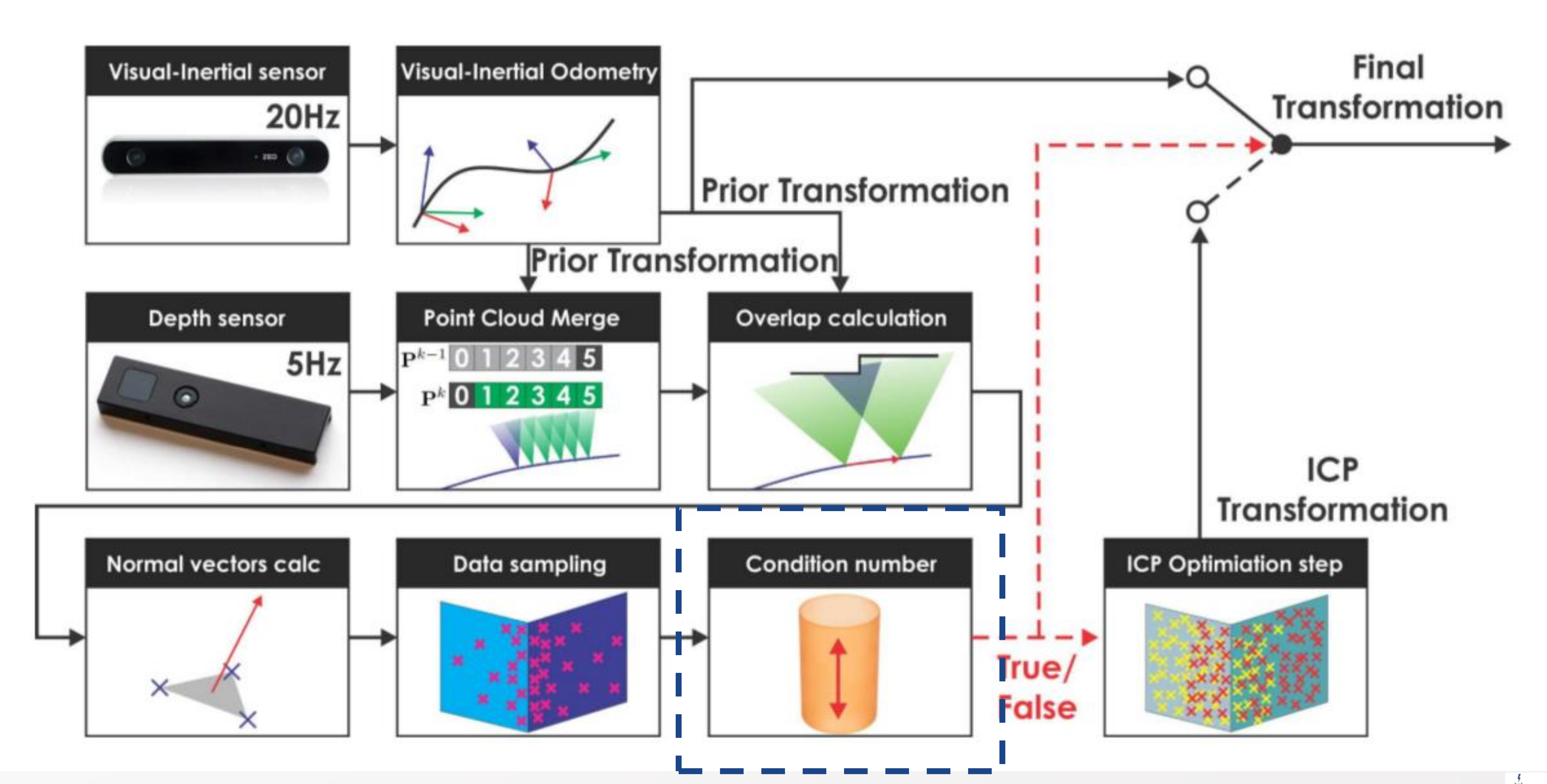


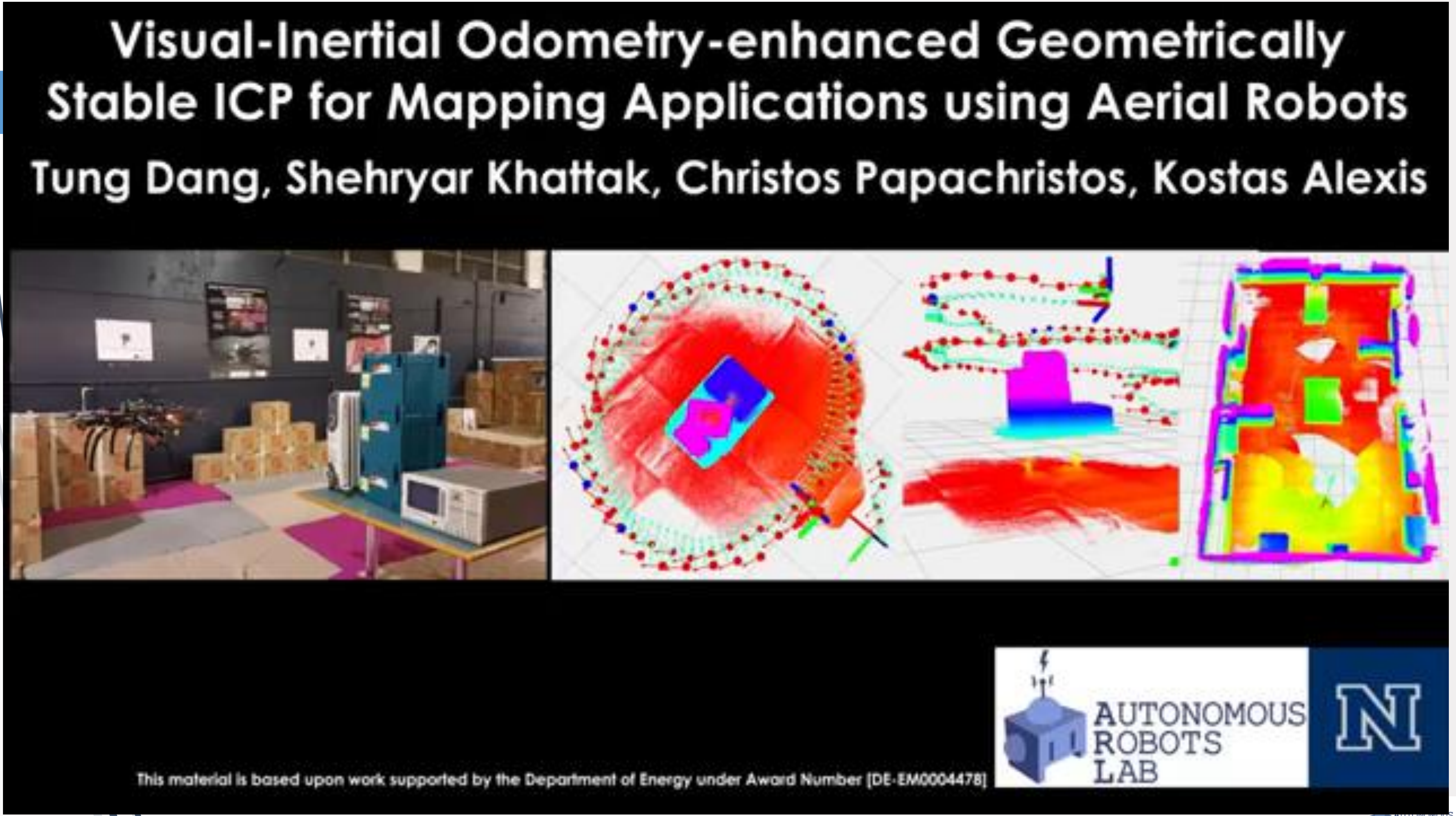
ICP (**I**terative **C**losest **P**oint)



Multi-modal approach



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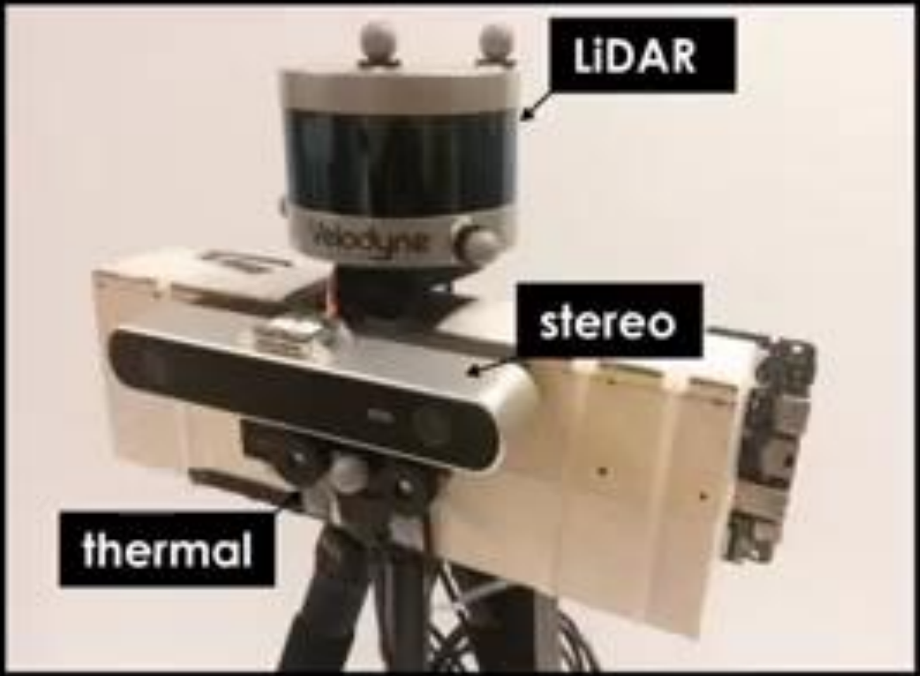
Preliminary Results on Multi-modal fusion for Autonomous Vehicle Localization - Garage Navigation / Fused Map



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Thank you!