Semantic Mapping and Navigation for Robotic Exploration

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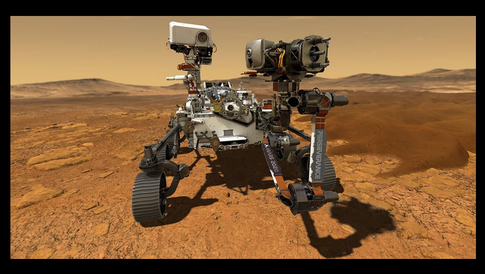
Context: Planetary exploration, Search and rescue



Objective: Developing a full robotic architecture for exploration of uncharted territory.

- New methods for 3D mapping with semantic knowledge of the environment
- Performing navigation while taking account of the nature of the robots surroundings :
  - ↳ Terrain, for safe and efficient path-planning
  - ↳ Specific instances for obstacle avoidance and observation of objects of interest.

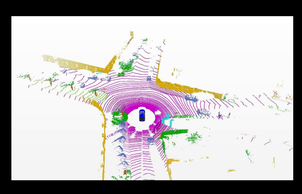
Data

Datasets

Semantic point clouds or couples of semantic images and depth maps with localisation and ground truth.

Examples :

Semantic Kitti [1]



SceneNN [2]

Sensors

Stereo Cam

RGB-D Cam

LiDAR & RGB Cam

+ Proprioceptive sensors *(IMU, encoders,...)*

+ GNSS positioning

Simulations

Robotic simulator with sensors, physics and segmentation simulation allowing control of the robot.

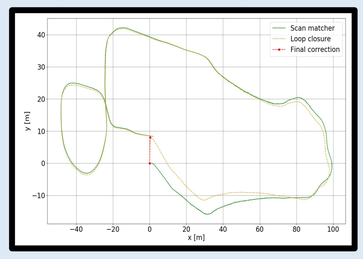
Examples :

DLR's OAISYS [3]

Ignition Gazebo

Localisation (SLAM)

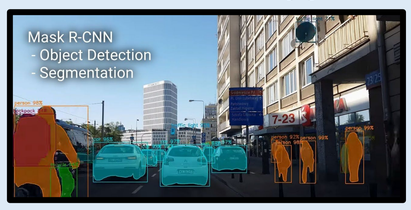
- **Front-end :**
  Frame-to-frame matching for fast and precise localisation
- **Back-end :**
  Slower process correcting the localisation drift induced over time. Based on loop-closure or absolute measurements



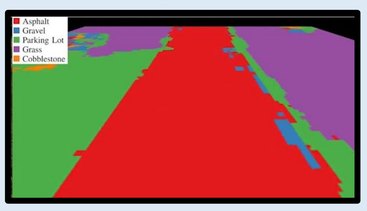
Semantic Segmentation

Pixel-level segmentation of camera images

Mask-RCNN [4]



Terrain segmentation [5]



Coupled to spatial segmentation for better consistency

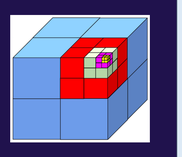
Semantic Mapping

Perspectives

Develop a new semantic map building method to best represent the static environment of the robot with low storage requirements and efficient communication with the navigation stack

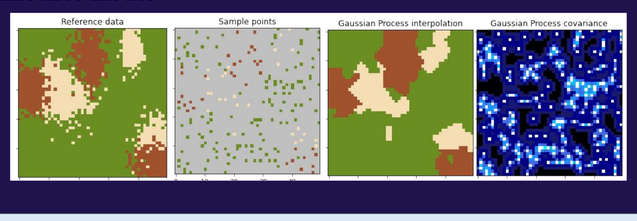
- Octree submaps storage

Represent the map as an octree graph of submaps to save space and allow faster access to the map data



- Continuous class interpolation [8]

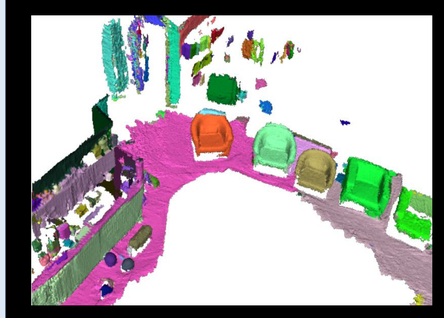
Interpolate semantics with Gaussian processes to store the map as a correlation matrix and allow continuous representation alongside a confidence metric

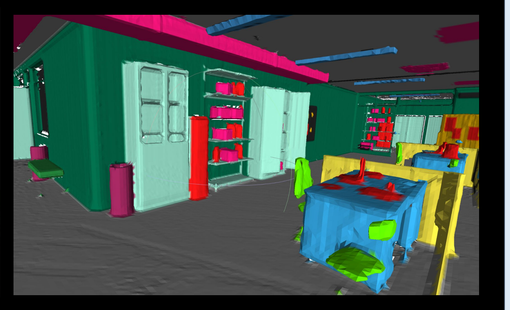


State of the art

Voxblox++ [7]
Instance segmentation and depth segmentation for semi-supervised classification.

Kimera Semantics [6]
Time consistent labeling through the use of best-certainty update. Part of a full semantic SLAM stack.



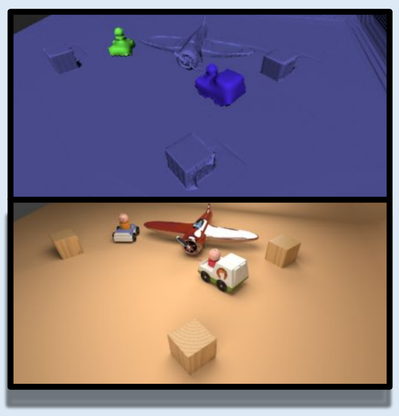


Both solutions use TSDF and marching cubes for map integration

Instances Detection & Tracking

Specific instances and dynamic objects must be separated from static surroundings and tracked in order for the robot to plan interaction or reactive obstacle avoidance.

Example : TSDF++ [9]



Semantic Navigation

Goal Definition

- Next-best-view [10]

Perform frontier exploration by identifying the robot's pose that will reveal the greatest part of the unexplored space

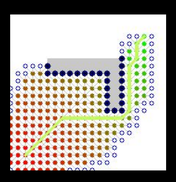
- Interest points exploration

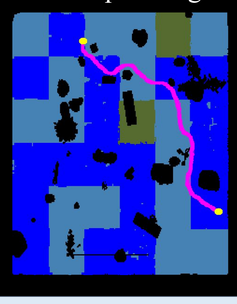
Drive the robot toward specific instances in order to precisely observe them or interact with them

Path-Finding

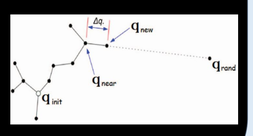
Perspectives: Adapting existing path finding algorithms (e.g. RRT, A*) to consider terrain traversability and mapping confidence when planning the robot's path to its current goal

A*





RRT



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