NRI: Collaborative Research: Autonomous Quadrotors for 3D Modeling and Inspection of Outdoor Infrastructure

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Motivation

- A lack of frequent and thorough inspection of the nation's civil and industrial infrastructure (e.g., bridges, power plants, refineries) increases likelihood and severity of accidents
- Human inspection is limited due to its safety concerns (for tall and narrow structures) and high cost (requires cranes and climbing utilities)
- Autonomous UAV assisted inspections with on-board sensing can provide highly accurate and up-to-date maps of the structure (due to more frequent inspections) while maintaining low cost

Objective

- Develop the sensing, estimation, and control technology necessary for enabling small-size quadrotors to assist humans in visual inspections

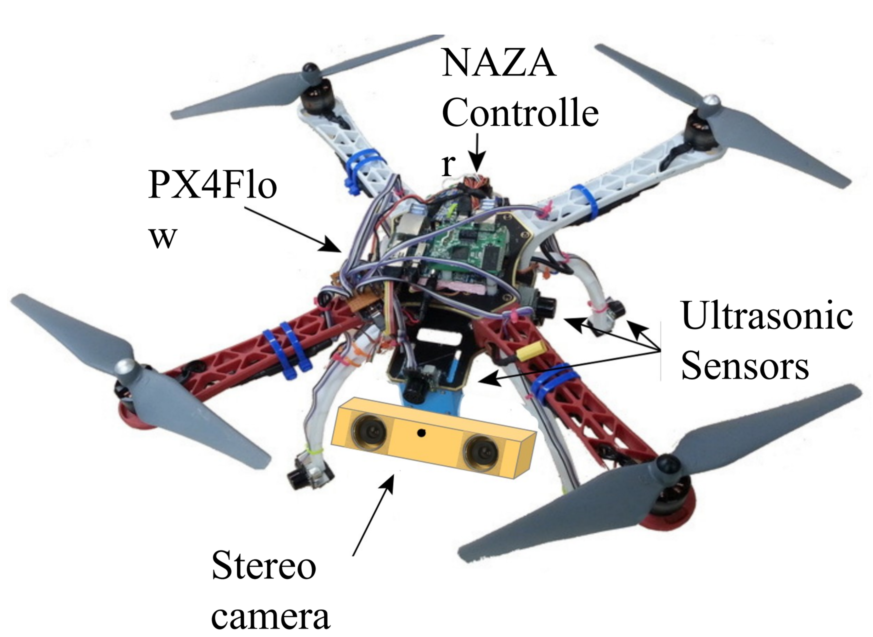
Research Thrusts

1. **Structure mapping:** Combine visual and inertial data to create sparse/dense 3D maps
2. **Representations:** Efficiently represent the map for different purposes (GUI, ODOA)
3. **Active sensing:** Find a minimum deviation path from the predetermined, obstacle-free trajectory which bounds the localization uncertainty and maximizes the information gain for mapping
4. **StereoVINS:** Employ measurement selection in VINS to efficiently perform consistent map-based localization and real-time map expansion
5. **Dense stereo:** Given pose estimates from StereoVINS, develop a dense stereo algorithm for obstacle avoidance and visualization
6. **Control:** Design a robust controller to reject outdoor wind disturbances and reliably avoid un-modeled obstacles

Research Platform

DJI quadrotor equipped with:

- NAZA attitude controller
- 8 MaxBotix ultrasonic range finder (obstacle detection)
- PX4Flow measuring height and velocity
- Stereo cameras & IMU
- NVIDIA TK1 GPU
- ARM processor



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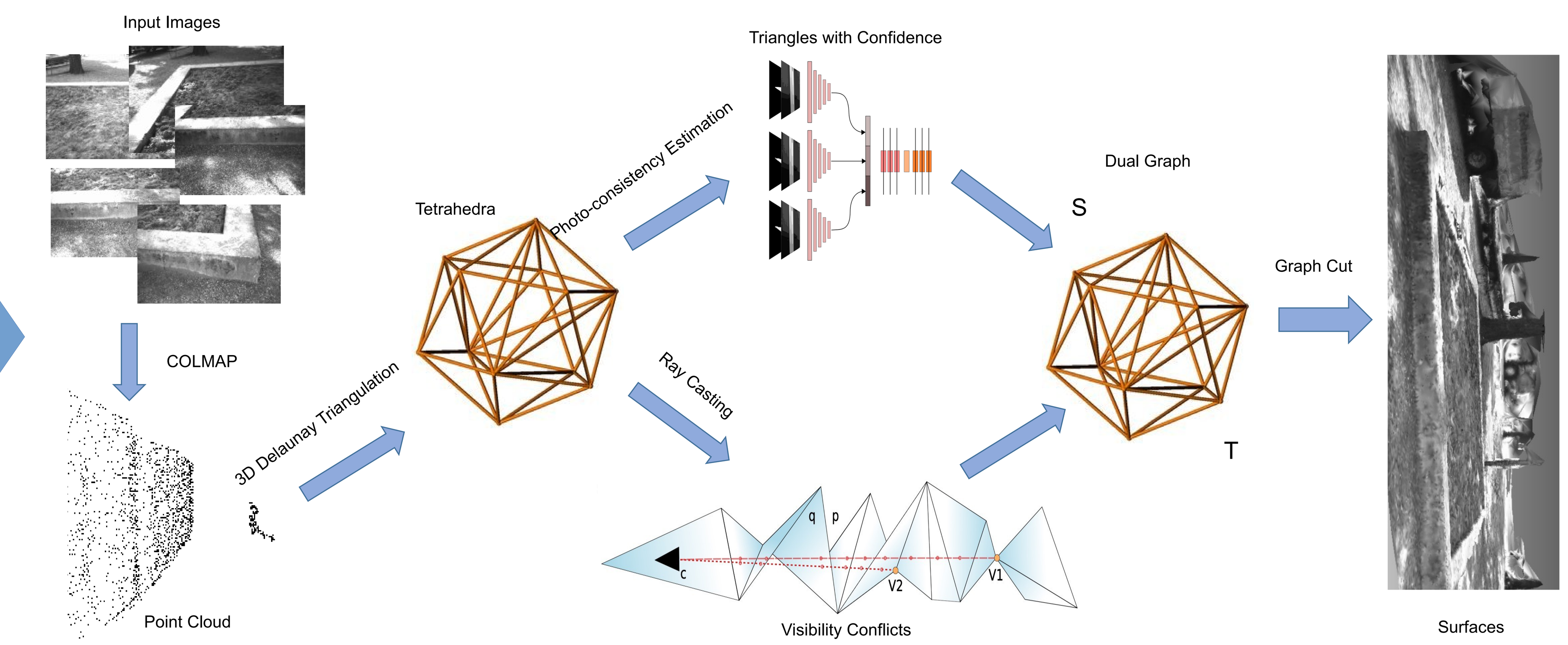
Research highlights and directions

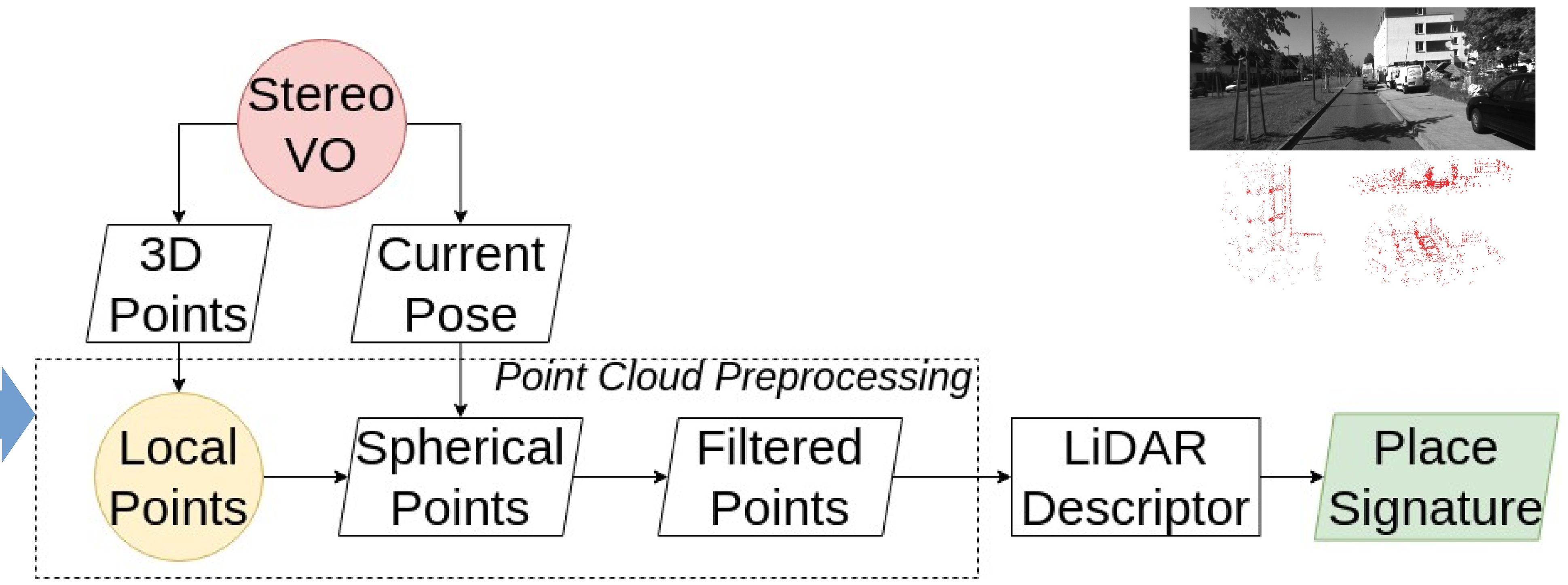
1. Multi-view, offline surface reconstruction

- *Key results:*
  - Inference of connected meshes from noisy point clouds based on global reasoning on tetrahedral graph generated by 3D Delaunay Triangulation
  - Deep network for estimating capacity of edges in dual graph, followed by graph cut to separate free space from occupied voxels
- *Ongoing work:*
  - Seek graph convolutional network formulation applicable to millions of nodes
  - Extensive qualitative and quantitative validation of current implementation



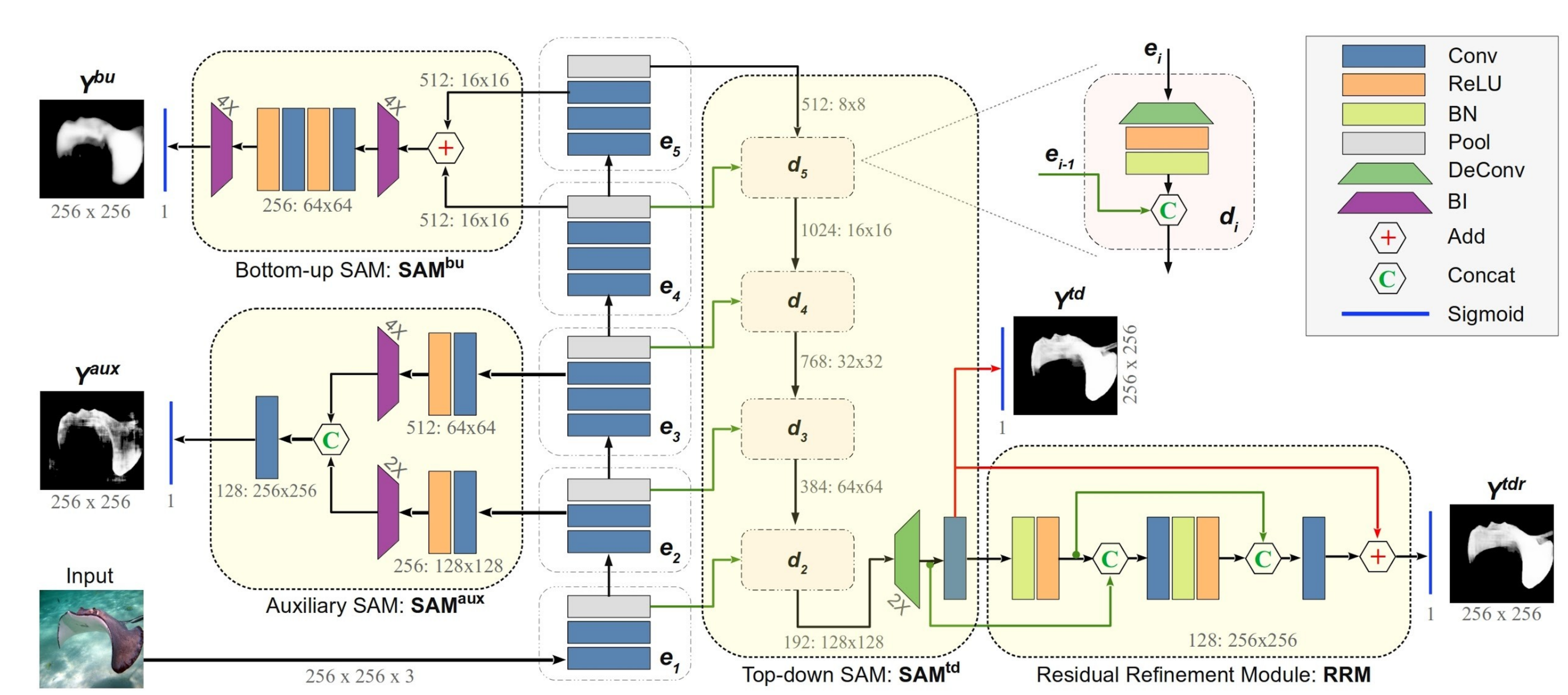
2. Scale-optimized Dual-Camera Mono-VO and Robust Place Recognition

- *Key results:*
  - A fast, robust direct monocular VO algorithm exploiting a secondary camera to optimize for scale and avoids computationally expensive stereo match process[2]
  - uses LiDAR-like representations augmented by scene 3D structures and grayscale intensity to recognize places[3]
- *Ongoing work*
  - Integrate inertial data and consider spline-based trajectories to further refine odometry estimates
  - Extensive implementation of the end-to-end VO+place recognition system



3. Saliency-guided Visual Attention modeling

- *Key results:*
  - Autonomously learn to extract salient point to guide visual attention to interesting artifacts in a scene under real-time performance
  - A novel deep visual model **SVAM-Net[5]** with SOTA performance on a single-board deployment
  - SVAM-Net model & USOD dataset releases
- *Ongoing work*
  - Combine simultaneous super-resolution and enhancement[6] with SVAM-Net to improve performance in poor visibility
  - Evaluate extensively on single-board platforms and physical robot



References

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