Simultaneous Localization and Mapping in 3D (3D SLAM)

Scott Robbins, Principal Investigator

robbins@mitre.org

Brigit Schroeder, Co-investigator

bschroeder@mitre.org

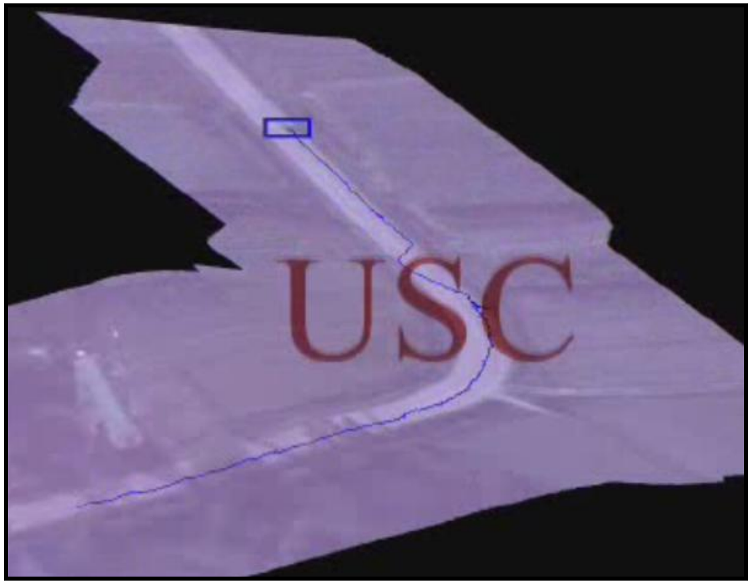
MSR

Problem

- **Improve situation awareness from small unmanned vehicles operating in urban and interior environments**
  - **Streets, alleyways, and building interiors**
  - **GPS denied or limited areas**
  - **Sensing in cluttered 3D environments**
- **Provide operators with 3D context**
  - **Relative position and path of the vehicle in the environment**
  - **Dynamic map of the environment as the vehicle moves**

Background

- **State of the practice:**
  - **Higher altitude UAVs use a video mosaic for situation awareness**
  - **Parallax from 3D environments of low altitudes or ground levels breaks 2D mosaic approach**
- **For 3D environments we need 3D mosaics. Simultaneous Localization and Mapping (SLAM) builds such mosaics**



Video mosaics are the state-of-the-practice in UAV situation awareness

University of Southern California, Isaac Cohen

Objectives

- Simultaneous Localization and Mapping (SLAM) to provide operators of small unmanned vehicles with a 3D mosaic to improve situational awareness
- Research Goals:
  - Localization: Where are we?
    - Track position and orientation in urban and indoor environments
    - Use on-board sensors to track the vehicle motion (visual odometry)
  - Mapping: Where is what I see?
    - Use COTS 3D sensors to produce dynamic 3D map (aka 3D mosaic)
    - Provide a stable, third person view of UAV/UGV video
  - Real time: Now, not later!
    - 3D map available to operators while on the move (not post-processed)
    - Produce position data in real time

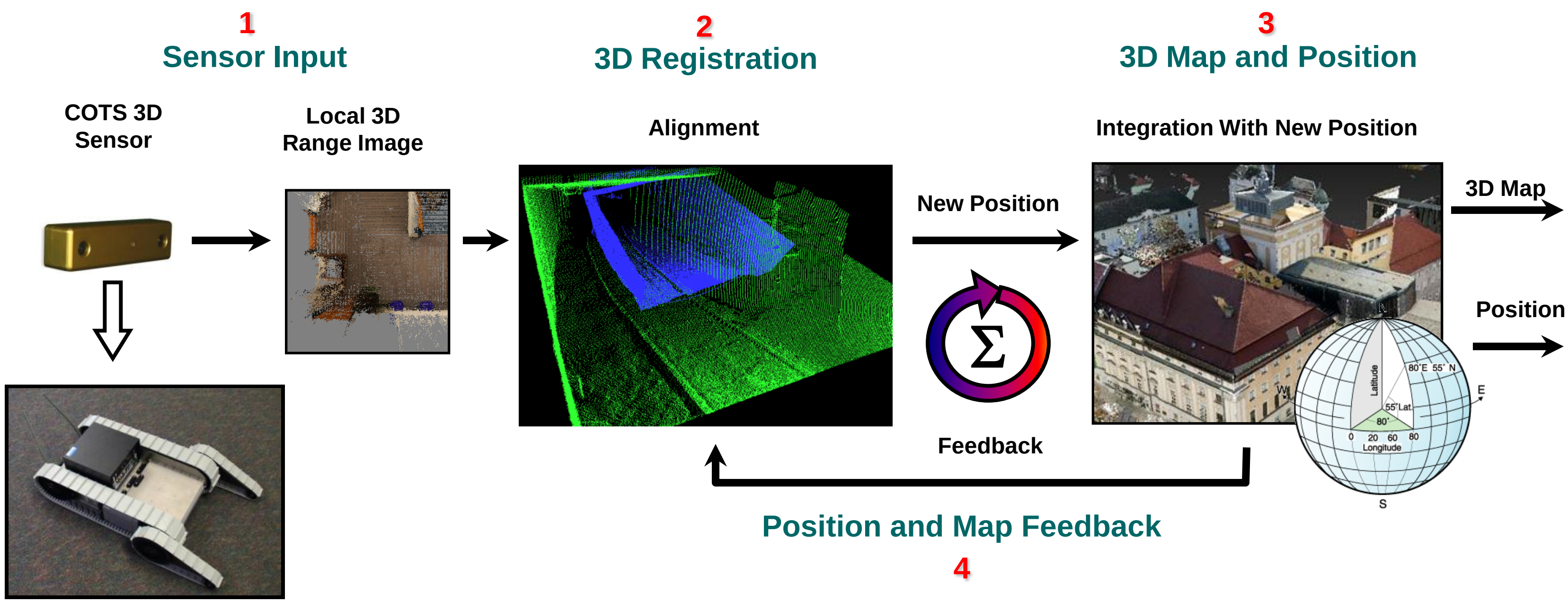
Activities

3D SLAM for Unmanned Ground Vehicles (UGVs)

- Localization with Visual Odometry (VO)
  - Track apparent motion of optical features
  - Invert tracks kinematics to recover vehicle motion (localization)
  - Use off-the-shelf software for detection, tracking, and localization
- 3D volumetric mapping
  - Use localized 3D sensor data (from VO) to produce a 3D map
  - Use volume-pixel (voxel) approach to manage data integration
  - Provide a stabilized “third person” perspective for operators
- Maintain operational context
- Realistic size, weight, power, and processing constraints
  - Building clearance mission conops:
    - Before entering an unknown building, robot maps out structure in 3D
    - Must operate in real time with sufficient accuracy and fidelity

Highlight

Simultaneous Localization and Mapping

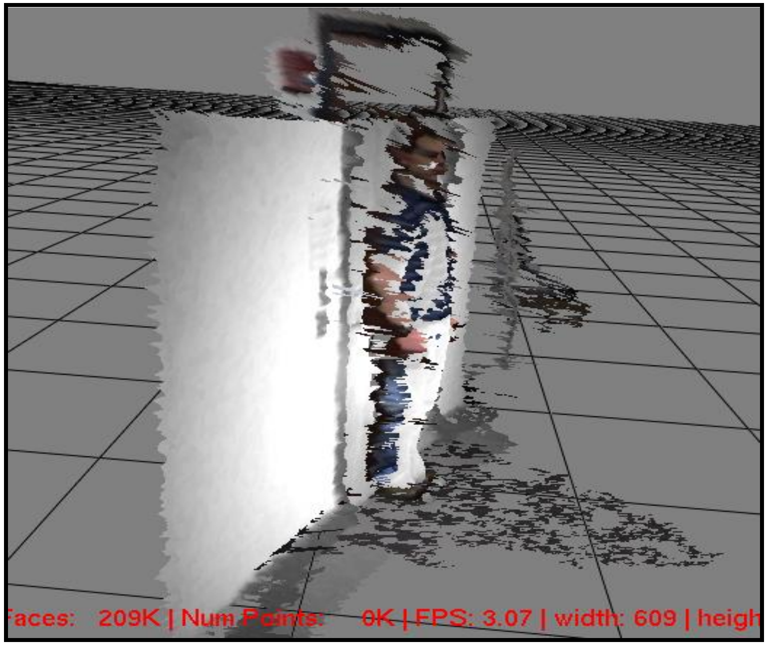


1. A new 3D image is acquired. Data is relative to the sensor's local position.
2. Local data is registered to the global map, based on the last known position.
3. This produces a new position (localization) and extends the map (mapping).
4. Newly calculated position and map are fed back into step 2, and the cycle repeats.

Demonstration

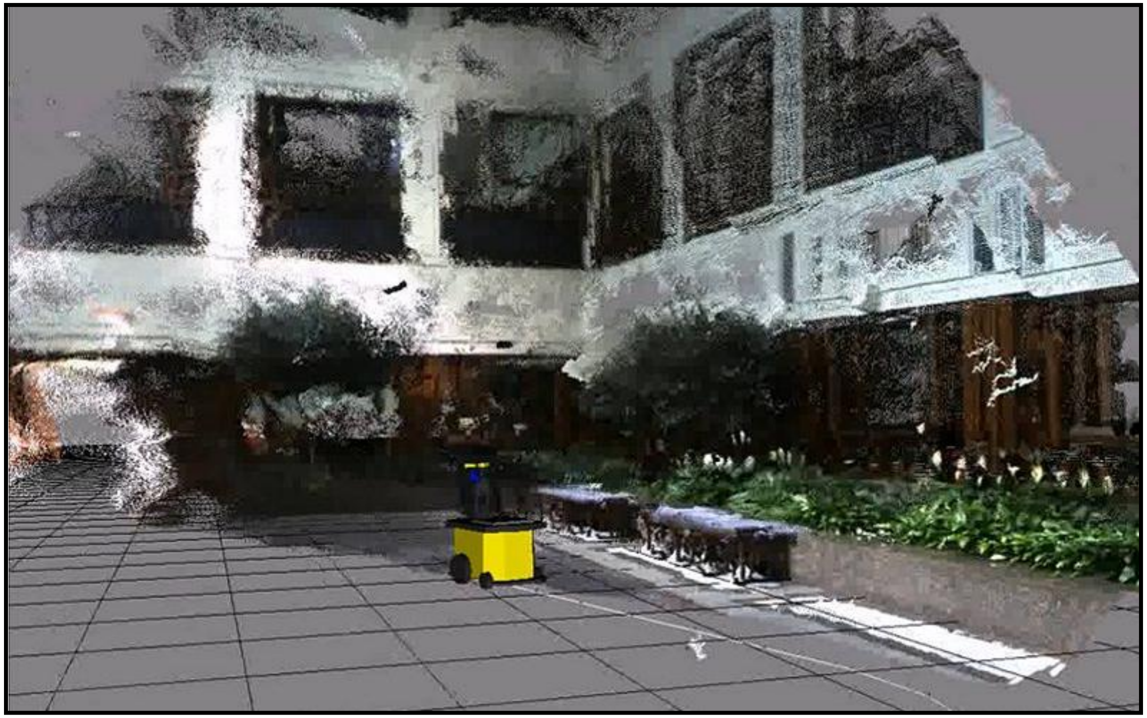
3D Sensing For UGVs:

- SwissRanger 3D Sensor combined with color camera
- Provides a color 3D view for UGVs



Demonstration (cont.)

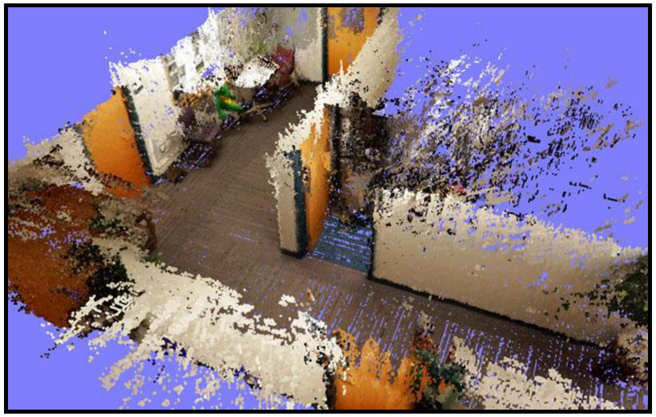
- **3D Mapping from an unmanned ground vehicle**



Impacts

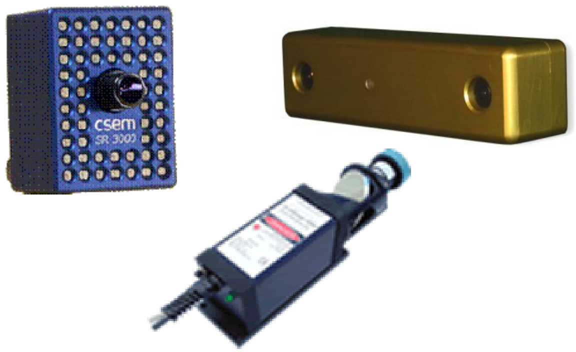
- **Localization for GPS-denied ISR**
  - **Enable UGVs and UAVs to transition from outside to inside without loss of positioning**
  - **Location of target objects relative to unmanned vehicle**
- **Situational awareness in urban settings**
  - **Real-time 3D mosaics for unmanned low-altitude and ground vehicles (where 2D mosaics are infeasible)**
  - **Build 3D virtual models of urban areas prior to operations for planning and training**

Future Plans



3D evidence grid to integrate and refine sensor data

Moravec, et al 2002



Multiple sensor modalities

Clockwise from top left, phased light, stereo vision, and laser range scanning.

UAV Implementation

Rotomtion SR200