UAVs in Urban Environments

Honeywell Aerospace Advanced Technology

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Agenda

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- Multi-vehicle operations
- Organic Air Vehicle - 2
- Small UAVs in urban environments
- Obstacle Avoidance Flight Tests

Heterogeneous Urban RSTA Team (HURT)

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Multi-year program run out of DARPA/IXO with Northrop Grumman as prime

Program purpose:

To provide tactical information services to the dismounted war-fighter

Specific program goals:

- **To deliver real-time, three-dimensional RSTA information** *directly to the war-fighters* **in a MOUT environment.**
- **To achieve** *unlimited* **and** *unrestricted interoperability* **among heterogeneous collections of unmanned platforms.**
- **To demonstrate** *collective autonomy that never goes obsolete*.

Honeywell role:

Developed integrated planning & control scheme for entire HURT system

HURT Operation

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HURT makes it possible to issue high-level commands to a team of RSTA vehicles.

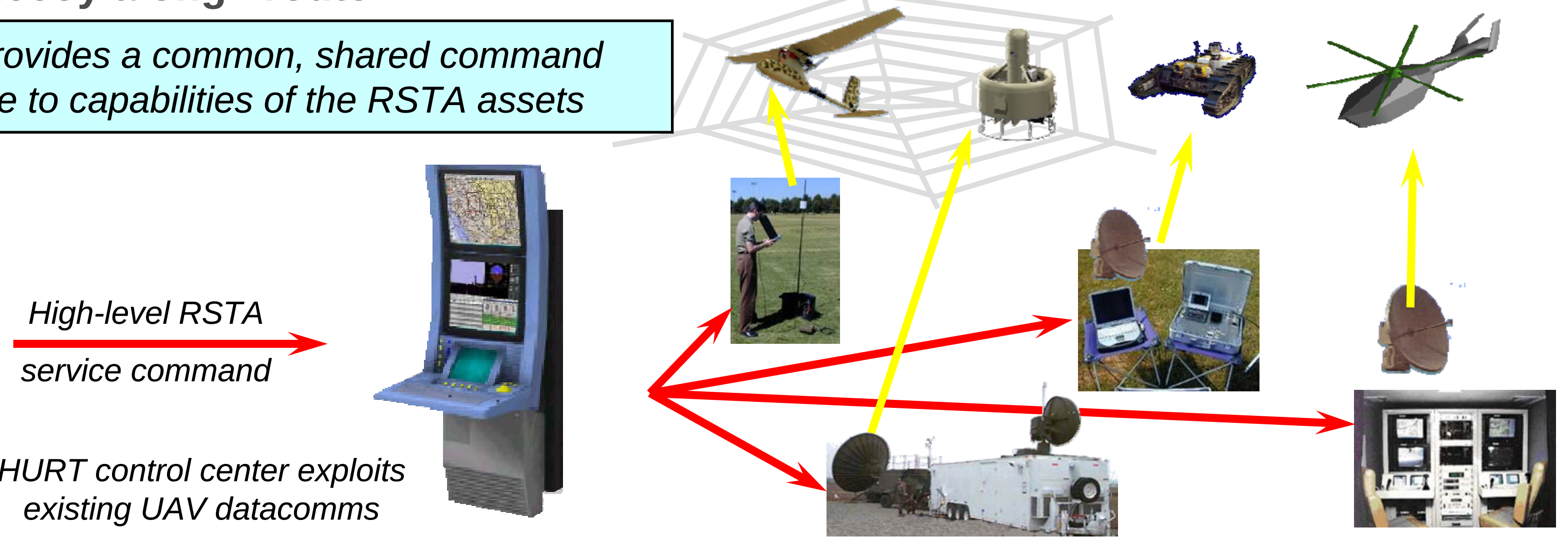
- **“Monitor <designated area>”**
- **“View <Coordinate> from <perspective>”**
- **“Search <feature> for <pattern>”**
- **“Map area defined by <bounds>”**
- **“Establish comms net among <nodes>”**
- **“Deliver <payload> to <coordinate>”**
- **“Fly as decoy along <route>”**

HURT provides a common, shared command interface to capabilities of the RSTA assets

High-level tasking interface

Heterogeneous, networked unmanned systems

HURT user(s)



HURT control center exploits existing UAV datacomms

Program Status

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Year 1 demo (Sept. 2005)

- **Successful flight demo of 4 UAVs (RMax, 2 ravens and 1 Pointer) flying RSTA missions autonomous at MOUT site**
- **Demonstrated persistent full-area surveillance, eyes-on-to-target, moving ground target tracking**
- **Honeywell led the planning & control component of the HURT program**
  - **Provided core planning software & integrated algorithmic modules for autonomous moving target tracking, eyes-on-to target and coordinated multi-UAV area surveillance**

Year 2 Objectives

- **Algorithms substantially developed for**
  - **3D routing & coverage planning with airspace de-confliction constraints**
  - **Moving target tracking from fixed-wing minimally-capable small UAVs**
  - **Dynamic platform and payload arrival and/or departure**
  - **Arbitrary set of platforms and payloads**
  - **Any number of RSTA service requests**
  - **Airspace de-confliction without altitude separation**

Small UAVs in Urban Environment

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- Organic Air Vehicle – 2 program
- Obstacle Avoidance
  - Dynamic mapping
  - Path Planning
- GPS-denied operations
- Extend to DARPA Urban Challenge

Organic Air Vehicle II (OAV II)

- Vertical Take-off and Landing ducted fan-vehicle
- 112 pounds dry weight
- Heavy fuel engine
- Perch and Stare capability
- Carries a 15+ pound Mission Equipment Package (MEP)
- Active collision avoidance system
    - Autonomously detect and avoid obstacles as small as a 6 mm wire
    - Integrated GPS/INS system with active sensor for
        - collision avoidance and
        - GPS denied navigation in urban environments

Dynamic Mapping and Path Planning

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- Organic Air Vehicle – 2 program
- Obstacle Avoidance
  - Use knowledge of environment
  - Find Obstacles
  - Plan a Path
  - Get to Goal
- GPS-denied operations
- Extend to DARPA Urban Challenge

Probabalistic Evidence Grid

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•Sensor Independent

•Probabalistic

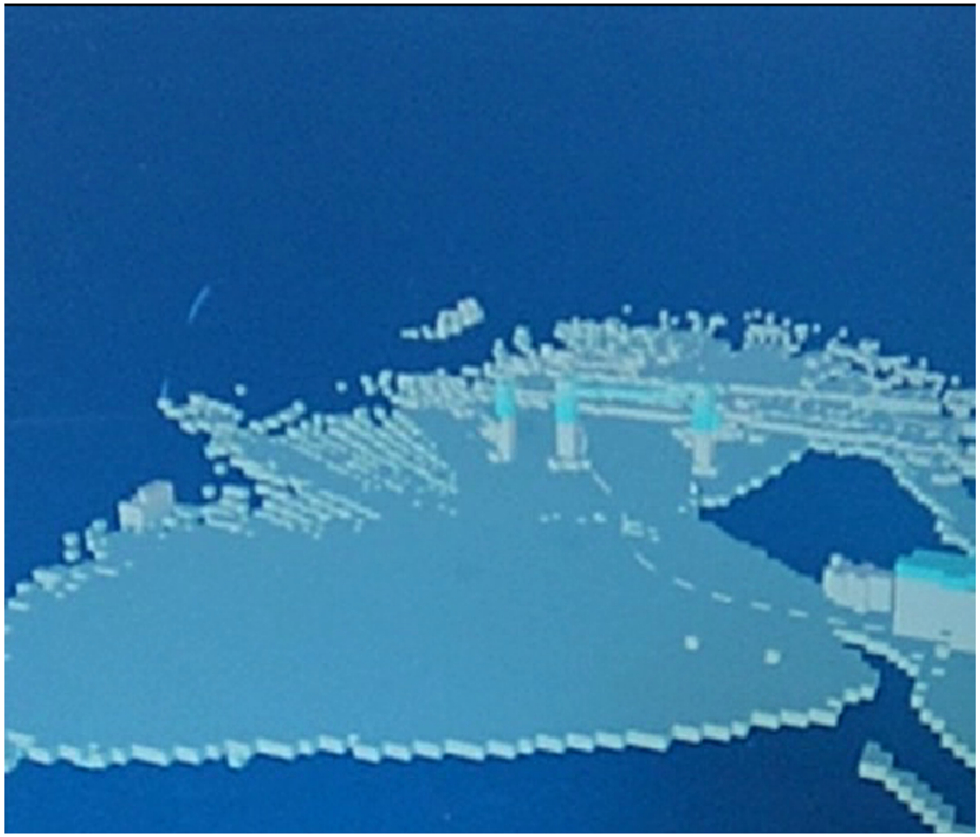
✓Probability increases with each detection to a saturation level

✓Probability decreases with each lack of detection allowing objects to be deleted appropriately

✓Includes sensor field of view and vehicle motion & perspective to improve resolution

•Allows multi-sensor fusion

Evidence Grid showing bushes, containers and wire on poles



Path Planning and Obstacle Avoidance

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- **Objectives:**
  - **Want algorithm that always finds paths when paths exist**
  - **Want smooth paths, so vehicle can follow the path without slowing too much**
  - **Want fairly optimal (short) paths**
  - **Want fast runtime (eg, less than 1 second, when implemented in C)**

- **Laplacian algorithm, with Multigrid solver, satisfies these objectives**

Laplacian Algorithm (no local minima)
Like air escaping from hole in enclosed container

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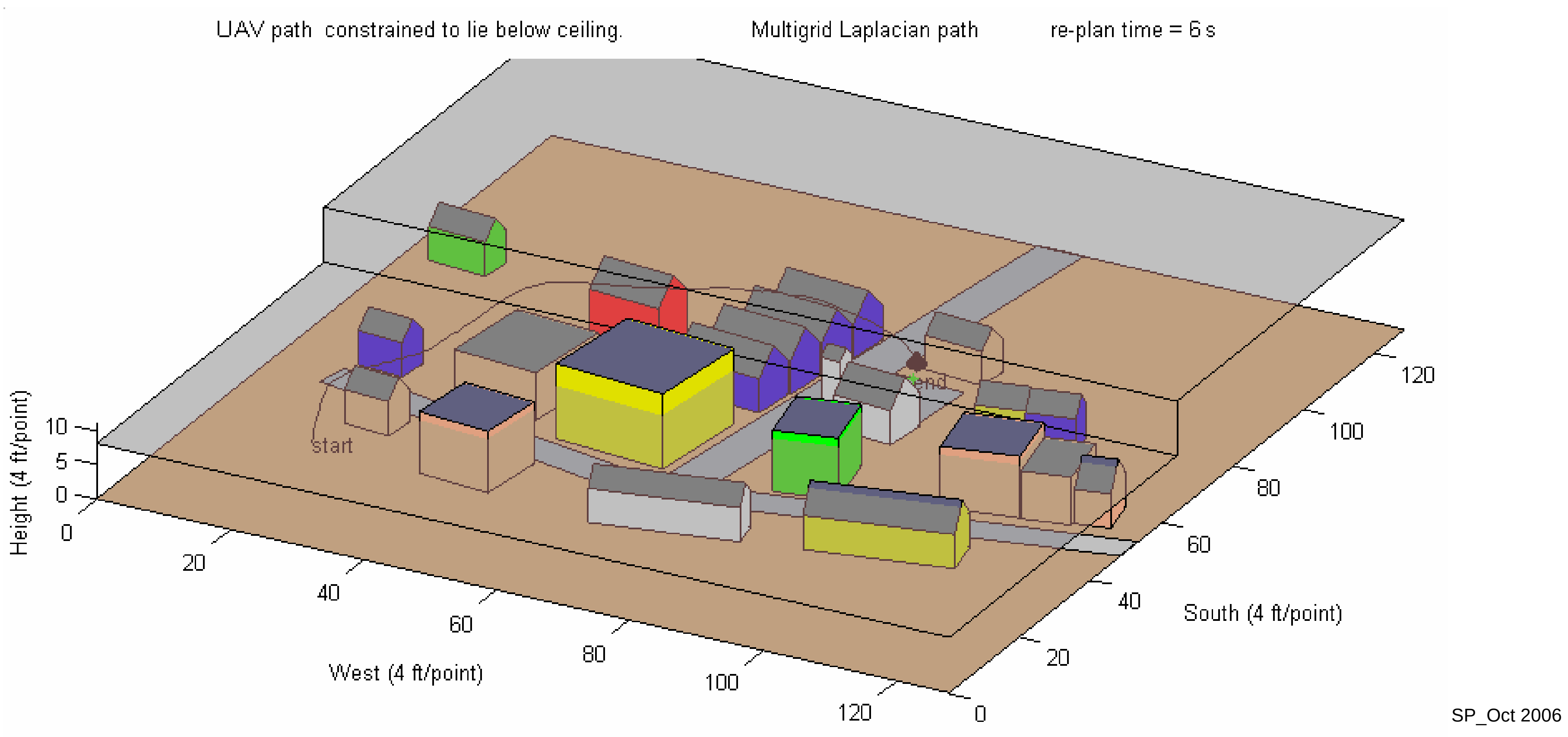
- **Boundary Conditions: potential=0 on obstacles & outer walls, potential = -1 at end point.**
- **Interior: Iterate   potential = average of potentials of neighboring points**
- **Interior has -1 < potential < 0   No local min in interior, since average of neighbors**
- **All max & min points lie on boundary where potential = 0 or -1, so only min is at end point**
- **Solve for potential using multigrid, then follow gradient of potential**



Guaranteed solution when path exists

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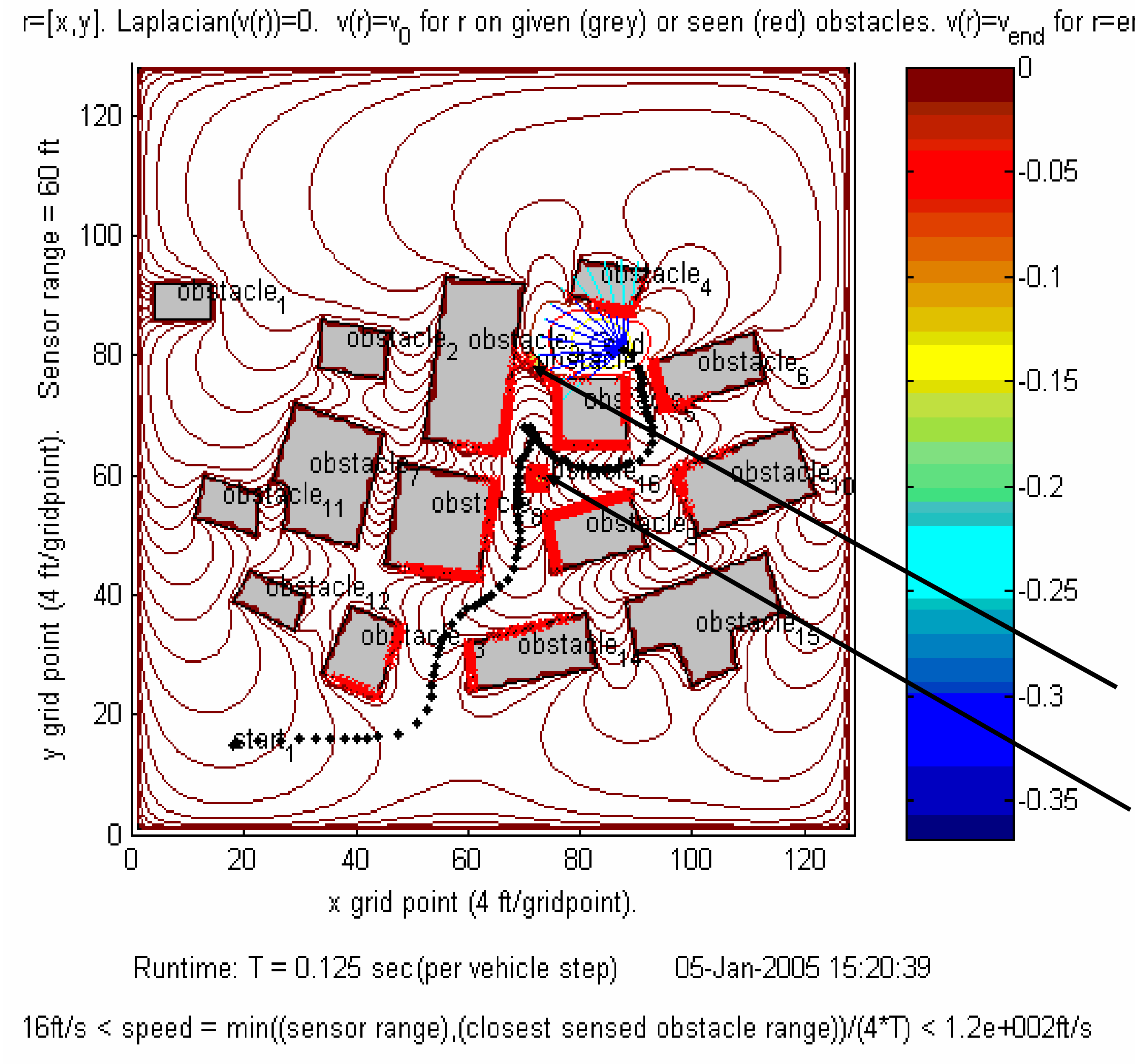

Ft. Benning McKenna Urban site buildings

When sensor sees this uncharted obstacle, vehicle turns around.

When sensor sees this small uncharted obstacle, vehicle maneuvers past it.

Further Speedup: Grid obstacles finely, crude grids elsewhere

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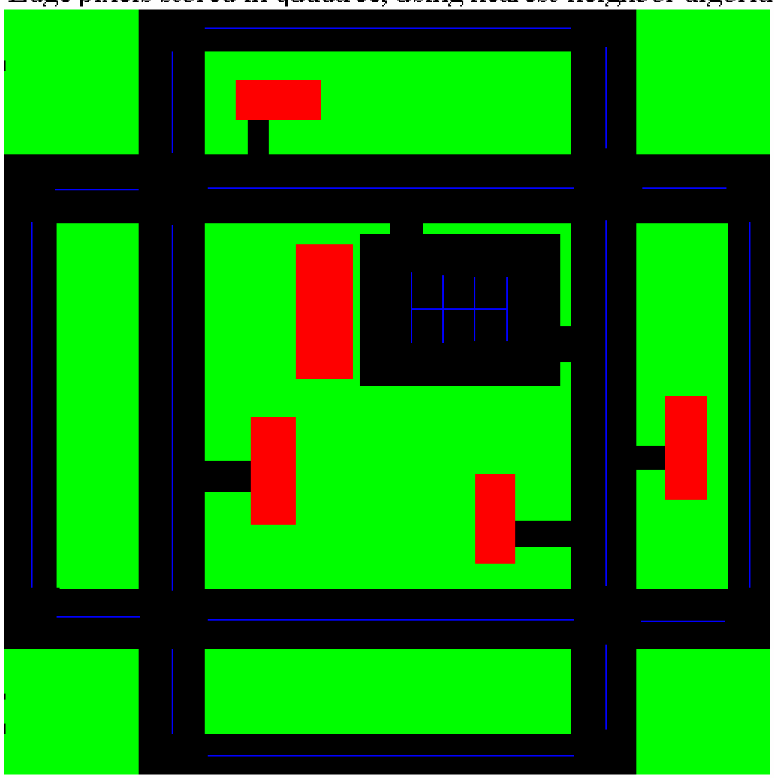
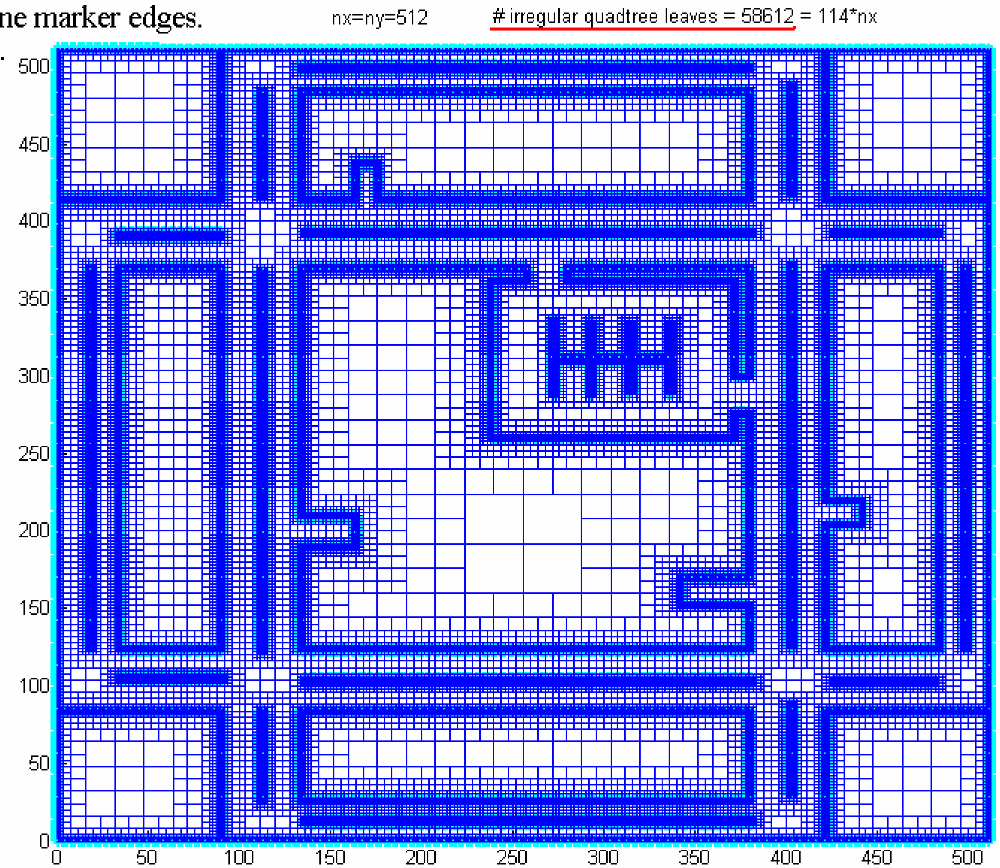
Sensor scans road and records black/green road edge, and blue lane marker edges.
Edge pixels stored in quadtree, using nearest-neighbor algorithm.



(512 foot) by (512 foot) region. Several square city blocks.
Black roads and parking lot, blue lane markers, red buildings, green grass.



(512 ft)^2 region Finest pixels at obstacle edges are (1 ft)^2

Movie of helicopter avoiding obstacles

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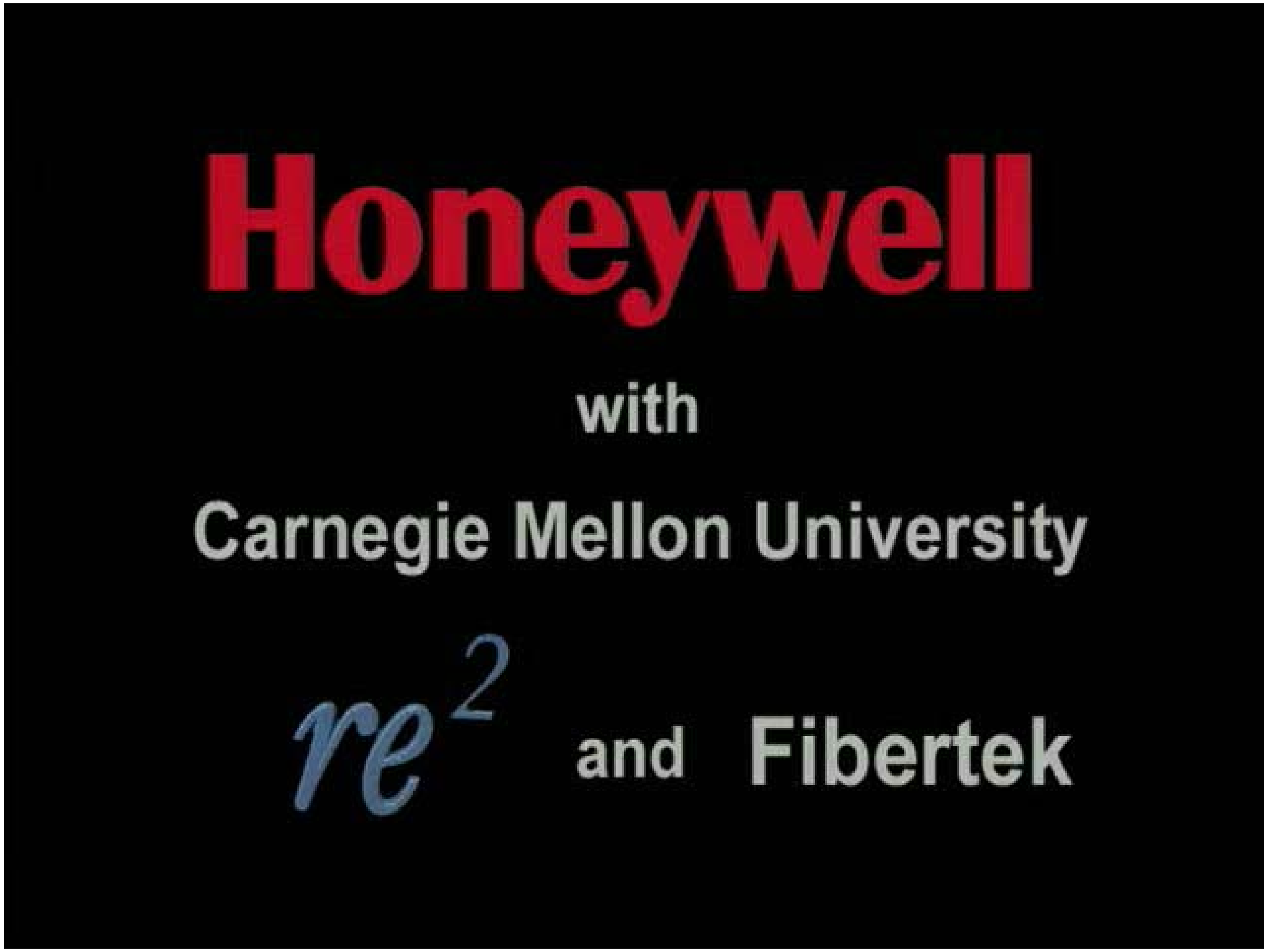
- Laplacian Algorithm updating at 1 Hz
- Inner-loop reactive obstacle avoidance updating at 5 Hz



Summary

- Laplacian Algorithm, with Multigrid Solver, Satisfies Objectives:
  - Always finds paths when paths exist
  - Gives smooth paths, so vehicle can follow the path without slowing too much
  - Gives fairly optimal (short) paths
  - Has fast runtime (eg, less than 1 second, when implemented in C)
  - Flops = 5*(path_length/space_between_obstacles)*(number of grid points)

- Extend Obstacle Avoidance to Collision Avoidance and GPS-Denied navigation

- Algorithm independent of sensor modality, can be applied to Ground and aerial vehicles