Agenda

• Multi-vehicle operations

• Organic Air Vehicle - 2

• Small UAVs in urban environments

• Obstacle Avoidance Flight Tests
Heterogeneous Urban RSTA Team (HURT)

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

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

“Provide me with cellular coverage as I move”

“Show me what’s in that window”

Heterogeneous, networked unmanned systems

HURT user(s)

High-level RSTA service command

HURT control center exploits existing UAV datacomms
Program Status

Year 1 demo (Sept. 2005)

• Successful flight demo of 4 UAVs (RMx, 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

• 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

- 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

• 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

- 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 (e.g., 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

- 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

UAV path constrained to lie below ceiling. Multigrid Laplacian path re-plan time = 6 s
Guaranteed solution when path exists

When sensor sees this uncharted obstacle, vehicle turns around.

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

Ft. Benning McKenna
Urban site buildings

Runtime: $T = 0.125$ sec (per vehicle step) 05-Jan-2005 15:20:39

$16\text{ft}/\text{s} < \text{speed} = \min((\text{sensor range}), (\text{closest sensed obstacle range}))/4^*T < 1.2e+002\text{ft}/\text{s}
Further Speedup: Grid obstacles finely, crude grids elsewhere

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

- 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