Intelligent Autonomous Surveillance of Many Targets with Few UAVs

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UAV Based Surveillance

Homeland Security Applications

- Harbor monitoring
- Land border / littoral patrol
- Infrastructure monitoring
- Situation awareness during operations

State of Practice

- Human remote operation

Advantages of autonomous operation

- Reduce or eliminate human fatigue effects
- Maximize use of observational assets humans poor at complex optimization
- Better integration with operational act's and systems
- Enable shift to sensor web model

UAV Development trends

- Access 5: FAA led effort to increase UAV use of National Airspace System
- AI technologies to increase operational efficiency
- Increased UAV reliability, availability and affordability

Army/NASA Autonomous Rotorcraft Project

Project Lead: Matt Whalley (Army) Autonomy Lead: Michael Freed (NASA)

Hardware

Yamaha RMAX
- 184 lb GW, 65 lb payload
- 3 m rotor diameter
- One hour endurance
- $86,000

Avionics Payload
- Crossbow IMU
- Radio modem
- PC104+ flight computer
- PC3 video computer
- Sonar
- Differential GPS
- Vibration Sensors
- Weight-on-wheels sensors

Sensor payload
- Stereo pair mono cams
- Actuated color camera
- Actuated video camera
- SICK scanning laser

Facilities

Hangar, facilities for fabrication, maintenance, inspection

Self contained transport, workstations, comn/telemetry

Instrumentation trailer supports development and test activities

Passive Obstacle Sensing and Mapping

Software implementation gives 160 x 120 disparity map once every 5 seconds

Active Obstacle Sensing and Mapping

- SICK PLS scanning laser
  - Weight: 3.8 lb
  - Field-of-view: 180 degree
  - Range: 0-75 m
  - Resolution:
    - 1.0 deg @ 75 Hz
    - 0.5 deg @ 37.5 Hz
  - Accuracy: 1 cm @ 81 m range
  - Mount: reposition-able

Obstacle Field Route Planner

- OFRP creates 2D solution
  - Voronoi graph creation
  - Graph culling
  - Path culling using Dijkstra's method while checking path boundaries
  - Path subdivision
  - Repeat path culling
- Integrated with Apex and flight control laws
- Details in 2003 AHS paper

Stereo Ranging for Safe Landing Area Determination

- JPL Safe Landing Area Determination (SLAD)
  - PALACE landing
  - Evaluates surface roughness, slope, available area
  - GPS denied
- Ames Stereo Pipeline
  - Point cloud for obstacle avoidance

Change Detection Using Scanning Laser

SICK laser used to build 3-D model of site and detect changes Thrun, et al, "A Non-Rigid Approach to Scan Alignment and Change Detection Using Range Sensor Data", to be presented at FRC 05, Australia, July 2005.

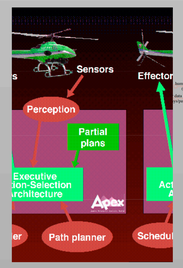
Mission-Level Autonomy

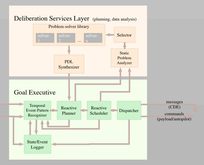
Surveillance Planning

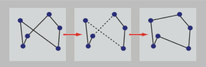
- Plan path to maximize situation awareness
- Minimize expected cost of ignorance
- Human performance inferior in most cases [Freed, Harris & Shafto, 2004]

ARP Autonomy framework: Apex

- Plan generation
- Plan execution
- Procedure interleaving







"Two Opt Exchange" Route Planning

Automatically Generated Monitor Diagram

Environment	Executive
Failures Interruptions Opportunities Side Effects Serendipity Instability Synergies Glitches Slack Deterioration	Closed-loop Control Contingency Handling Procedural Reasoning Fast Replanning Smart Monitoring Multitask Management Resource Projection Synchronization Tactical Plan Repair Auto-Calibration

Autonomy Requirements