Challenges UAV operators face in maintaining spatial orientation

Lee Gugerty
Clemson University
Overview

• Task analysis of Predator UAV operations
  – UAV synthetic task
  – Spatial orientation challenges

• Data on spatial orientation challenges
  – From experiments and protocol studies

• Applications
  – Training
  – Interface design
Cognitive Task Analysis
Predator UAV reconnaissance operations

- Structured interviews
- Air Force UAV trainers and UAV trainees
  - 7 pilots
  - 12 sensor operators / mission planners
Efficiency Goal: visit many targets

Repeated missions

Efficient, effective Predator missions

Main Recon Goal: effective, efficient imagery over an extended time

Safety Goal: return to base

Efficiency Goal: visit many targets

Effectiveness Goal: satisfy EEI

BRUTE SIM: GOAL STRUCTURE

Avoid stalls & spins

Handle malfunctions

Avoid terrain

Avoid enemy airspace

Avoid conflict with friendlies

Avoid icing & rain

Maintain control of UAV

Avoid dangerous situations

more

more
Efficiency Goal: visit many targets

Main Recon Goal: effective, efficient imagery over an extended time

Repeated missions

Efficient, effective Predator missions

Safety Goal: return to base

Efficiency Goal: visit many targets

Efficient travel to next ROZ

Efficiently visit targets in ROZ

Visit max # of high priority targets

Visit low priority targets on way

Visit low priority targets if time left

Effectiveness Goal: satisfy EEI

Choose sensor

Image target effectively

Set order and path for visiting targets within a ROZ

Set ROZ entries & exits

Sensor(s) set

Position UAV for effective imagery

Operate sensor

Set duration for imaging

Set imaging altitude

Set ground distance

Set UAV path

Good depression angle

Good slant range

Put sun behind

Position to see EEI

Position for quality image
Goal Constraints

Constraints on Mission Planning (within restricted zones)

- Wind speed and direction
- Clouds occluding targets
- Clouds and storms in UAV’s path
- Ad hoc targets
- Target layout
- ROZ entry and exit points
- Imaging altitude for individual targets
- Terrain height
- Shape of ROZ box
- Sensors needed for individual targets
- Target priority
- Time for occupying ROZ box
- Time for imaging individual targets
- UAV speed
Synthetic Task - BRUTE
Basic Research UAV Task Environment

Pilot Station
- Joystick controls camera
- Joystick flies aircraft

Camera Operator Station
- Joystick controls camera
- Joystick flies aircraft

ESC
F1 - Referee Hold/On
F2 - Waypoint Hold/On
F3 - Altitude Hold/On
F4 - Video Camera
F5 - Follows Target
F6 - Follows Following
F7 - Follows Explicit
F8 - Following
F9 - Follows Mode
F10 - Follows Camera
F11 - Follows Target

Clearing Range: Z=33.23.91
Wind: Externally 30°, velocity: 10
Cognitive Task Analysis: 
UAV Spatial-Orientation Challenges

• Directing the aircraft and camera
• Using cardinal directions to locate targets
Should camera operator point camera right or left to view target 7?
At target 6, how many vehicles on the east side of the building?
Cognitive Task Analysis: UAV Spatial-Orientation Challenges

• Challenging spatial tasks:
  – Directing the aircraft and camera
  – Using cardinal directions to locate targets
• Little training
• Exacerbated by UAV characteristics:
  – Smaller visual field of view
  – Lessened vestibular & kinesthetic feedback
Overview

• Task analysis of Predator UAV operations
  – UAV synthetic tasks
  – Spatial orientation challenges
• Data on spatial orientation challenges
  – From experiments and protocol studies
  – Focusing on cardinal direction task
• Applications
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  – Interface design
Data on UAV spatial orientation tasks

- Cardinal direction task - static

Is the parking lot with cars North, South, East, or West of the building?
Cardinal direction task: Histograms of accuracy for AF recruits

very poor performance for half the subjects
Effect of aircraft/camera heading

- EASY
Effect of aircraft/camera heading

- HARD

Is the parking lot with cars North, South, East, or West of the building?
Cardinal direction task:
Accuracy by heading expertise

Experts
Better novices
Poorer novices
Cardinal direction task:
Misalignment effects

![Graph showing the percent correct for different aircraft headings for different groups.](image)
Cardinal direction task: South reversal

[Graph showing percent correct for different aircraft headings for pilots, better novices, and poorer novices]
Cardinal direction task: Accuracy by heading expertise

- Pilots: better novices show poorer performance due to misalignment, cutting accuracy by 10% to 70%.
- Effects decrease with expertise.

Diagram: Percent Correct vs Aircraft Heading (degrees) for pilots, better novices, and poorer novices.
Misalignment effects with BRUTE UAV synthetic task

Task:
- plan route, visit targets, answer target questions
- some questions required cardinal direction judgments
At target 6, how many vehicles on the east side of the building?
Effect of misalignment on cardinal direction accuracy with BRUTE

![Graph showing the effect of misalignment on cardinal direction accuracy with BRUTE. The graph plots percent correct against aircraft heading (degrees) for both static and dynamic tasks with target A and target B.]
Data on UAV spatial orientation tasks

• Quantified effects of UAV spatial tasks
  – Direction of turn task
    • Misalignment $\Rightarrow$ slowing (1 s)
  – Cardinal direction task
    • Misalignment markedly decreases accuracy
      – up to a 70% decrease
      – also slows (e.g., doubles) RTs
  • Overall difficult task
    – Many novices close to chance
Data on UAV spatial orientation tasks

- Quantified effects of UAV spatial tasks
  - Direction of turn task
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  - Overall difficult task
    - Many novices close to chance

*Need for training or interface aids, especially re misalignment*
Mental strategies used on spatial orientation tasks

• Direction of turn task
  – Mental rotation (MR)

• Cardinal direction task
  – Specialized strategies
    • South reversal
  – General strategies
    • Mental rotation
    • Heading referencing
Is the parking lot with cars North, South, East, or West of the building?
Is the parking lot with cars North, South, East, or West of the building?
Is the parking lot with cars North, South, East, or West of the building?
### Strategies from verbal protocols

<table>
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<th>6 novices</th>
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<td>0</td>
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<tr>
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Data on UAV spatial orientation tasks

• Quantified effects of UAV spatial tasks and identified strategies
  – Direction of turn task
    • Strategy: Mental rotation

  – Cardinal direction task
    • Strategies: Heading referencing & some MR
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Training cardinal direction judgments

• Heading referencing a good candidate for training
  – Used by experts and better novices
  – amenable to part-task training
    • Step-by-step strategy

*Understanding strategies guides training and interface development*
Heading referencing step 1: map reading
Heading referencing step 3: from reference direction to nearby bearings
Heading referencing step 4: from known bearings to other bearings
Training cardinal direction judgments

• Part-task training of heading referencing
  – Then integrate part tasks
Training cardinal direction judgments

- Part-task training of heading referencing
  - Then integrate part tasks
- Use of eye-tracking to monitor strategies
  - Then provide real-time feedback
- Use of structural alignment theory
Structural alignment theory:

- Analogy, metaphor ... & cardinal direction judgments involve:
  - Comparing, matching elements, aligning elements in disparate representations
- Eg, comparing 2 models helps find objects in 1 model
Training cardinal direction judgments

- Part-task training of heading referencing
  - Then integrate part tasks
- Use of eye-tracking to monitor strategies
  - Then provide real-time feedback
- Use of structural alignment theory
  - Training in matching & comparing displays (e.g., maps, 3D views)
Interface aids for direction of turn task

- Rotating (track-up) map
  - But lack of global (survey) knowledge

- Aretz’ wedge
  - Provides local (egocentric) and global knowledge
  - In use in Predator
Interface aids for cardinal direction task

• Aretz’ wedge
  – In use in Predator;
  – but doesn’t help cardinal direction judgments, so

• Integrate egocentric info into map view
  – Consider “egocentric” labels
Interface aids for cardinal direction task
Interface aids for cardinal direction task

- Integrate exocentric refer direction in 3D view as in heading referencing
  - E.g., VCS Video display with compass rose overlay and aircraft direction arrow
Questions?
Predator Operations
Pilot and Sensor-Operator Stations
Data on UAV spatial orientation tasks

- Direction of turn task
  - Egocentric forward ALIGNED with top of map
  - Egocentric forward MISALIGNED with top of map
Direction of turn task
Effect of ref. frame misalignment

1 s slowing

slight accuracy decrease

[Graph showing response time and percentage correct against plane heading]
Map-first mental rotation

Is the parking lot with cars North, South, East, or West of the building?
Map-first mental rotation

Is the parking lot with cars North, South, East, or West of the building?
3D-first mental rotation

Is the parking lot with cars North, South, East, or West of the building?
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