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INTRODUCTION & MOTIVATION

Growing orbit population
Congested and contested
Limited number of sensors
Out-dated tasking techniques
Human-intensive
Varied hypotheses of interest
E.g., collision, mode of operation, maneuver status, anomaly resolution
Sensor tasking goal: gather evidence to answer specific SSA questions
Hypothesis resolution
Cognitive Systems Engineering (CSE):
Provides designer with realistic model of how human functions cognitively
Dimensions of Complexity in SSA:
Large problem space, Dynamic, High-risk, Social, Distributed, Uncertainty, Disturbances, Automation

COGNITIVE WORK ANALYSIS APPLIED TO SSA

Work Domain Analysis (WDA)
Purpose: analyze operator goals, work domain affordances and constraints
Abstraction hierarchy: linkages between purposes, priorities, functions, and resources of domain
Structural means-ends relationships
Varying levels of detail
Two hierarchies: SSA work domain (below)
SSA environment (see paper)

WDA Insights
1) Data aggregation should account for the fusion of disparate sensor resources and various signal characteristics, including considerations of uncertainty, ambiguity, and unobservability
2) Sensor allocation approaches should be able to directly address varied decision-maker objectives or hypotheses
3) Fused data should be reflected through updated hypothesis knowledge

Control Task Analysis (ConTA)
Purpose: model task-required cognitive processes
Decision ladder: maps information processing and states of knowledge
Encourages flexibility/expertise
Cognitive work & information relationship requirements
CWR-3: Translate observational data into evidence
CWR-6: Track hypothesis resolution, compare to thresholds
CWR-9: Capability to adjust hypothesis priorities
CWR-10: Assess expected hypothesis resolution
CWR-13: Generate actions/requests to reach target hypothesis resolution

HUMAN-IN-THE-LOOP DATA COLLECTION

Sensor Network Scheduling Approaches
Purpose: Translate operator-assigned priorities into sensor network actions
Schedules observations to gather evidence to help answer decision-making questions
Evaluated two different scheduling objective functions:
Covariance-Based: reduce uncertainty in space object state
Position & velocity covariance
Hypothesis-Based: reduce uncertainty in hypothesis resolution
Entropy (conflict and non-specificity)

Experimental Design
Scenarios: 7 minutes long, 1-minute action intervals
3 electro-optical sensors (i.e., telescopes)
6-7 space objects distributed in LEO, MEO, and GEO
5-6 hypotheses (see table to right for types)
Perform each scenario once with each scheduler

HUMAN-IN-THE-LOOP TEST RESULTS

Objective measurement of effectiveness in assigned task of hypothesis resolution
Low entropy means low conflict and ambiguity from gathered evidence
Result: Statistically significant improvement in entropy using hypothesis-based approach
- Improved resolution quality
- Consistent across all scenarios (low interaction)

Situation awareness global assessment technique (SAGAT)
Score: $F_{1,8} = 0.42, p = 0.520$ | Confidence: $F_{1,8} = 0.47, p = 0.494$

Situation awareness global assessment technique (SAGAT)

CONCLUSIONS

Cognitive Work Analysis:
Affordances/constraints of SSA work domain & environment
Decision support system design
Information fusion & sensor allocation

Prototype Decision Support System Development & Evaluation:
Addressed design requirements derived from CWA
Performance: improved with hypothesis-based approach
Situation awareness & confidence: similar for both schedulers

Full study includes cognitive support objectives & workload
Journal of Cognitive Engineering and Decision Making

Future work:
Improved scenario realism, increased complexity
Address additional cognitive work requirements