Supporting Adaptive C2 Structures in Time-critical Environments

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“Recent military experiences with AVs [Autonomous Vehicles] have consistently demonstrated their value in a wide range of missions, and anticipated developments of AVs hold promise for increasingly significant roles in future naval operations.”

- NRC Committee on Autonomous Vehicles in Support of Naval Operations 2005

How do we support teams of AV operators, each controlling a team of AVs?

- Can we balance workload across the team of operators?
  - Initial Planning
  - Dynamic Re-planning
- Can we adjust quickly if one operator suddenly goes offline?
Develop integrated human interface and automation technologies to enable small co-located or distributed groups of operators to manage multiple air, undersea, & surface vehicle systems

- User environment design
- Tools to support collaborative decision making
- Automated mission planning and re-planning
- Integration with local AV planning systems
Our Approach

- Integration of multi-disciplinary contributions
  - Cognitive Work Analysis (CWA) for information requirements definition and understanding
  - Team design optimization for planning and replanning
  - Innovative UI concepts to support information and collaboration needs

- Flexible consideration of evolving operator needs as AV technology capabilities and requirements evolve
Objective: Extend CWA products to collaborative work domain and rich organizational structure

Apply CWA techniques to capture:
- Information requirements by role
- Information tasking and handoff procedures
Extending the Abstraction Hierarchy

- CWA identifies information and constraints that govern all actors and actions in the domain
- Use of information across roles must be mapped to drive design

<table>
<thead>
<tr>
<th>Macros (Abstract)</th>
<th>Whole</th>
<th>Subsystem</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td></td>
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- Use of information across roles must be mapped to drive design

<table>
<thead>
<tr>
<th>Roles</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV Control and Navigation</td>
<td>Planning, mission monitoring</td>
</tr>
<tr>
<td>Mission Operator</td>
<td></td>
</tr>
<tr>
<td>AV Manager</td>
<td>Objective completion</td>
</tr>
<tr>
<td>Knowledge Manager</td>
<td>Information management</td>
</tr>
<tr>
<td>Sea Combat Commander</td>
<td>Strategic objectives</td>
</tr>
</tbody>
</table>
Abstraction Hierarchy

Abstraction decomposition representation mapped to key roles and technologies
- Developed DL to represent control handoffs, information tasking
- Initiated when operator can no longer control an asset or complete task with their current resources
Use Case

- General Domain: Littoral Combat Ship
- Setting: Strait bordering Hostile Nation
- Missions:
  - Intercept Suspicious Vessels with likely Contraband; Disable
  - Clear Strait of Threats so Carrier can enter
- Players:
  - LCSs (4) – Each with Mission Manager (UV Manager)
    - LCS1 & LCS3: Marine Interception Ops Pkg – VTUAV (2); USV (2)
    - LCS2 & LCS4: Surface Warfare/Area Clearing Pkg – RMV; BPAUV; USV
  - Carrier – Overall Command = Sea Combat Commander - UCAV
- Events:
  - Two Targets of Interest (TOI) enter strait
  - One turns out to be hostile, one neutral
  - Hostile TOI destroys nearby VTUAV; disables LCS1
  - Assets reallocated by Team Planner so can complete two primary missions
Socio-technical system design and analysis at Aptima

- **Tasks**
  - must be accomplished during mission (mission tasks, processes, actions, targets)

- **Resources**
  - needed to accomplish those tasks (e.g., information, raw materials, equipment, physical assets & weapons)

- **Decision-makers (DM)**
  - human decision makers who will constitute the team
Team design challenges
- AV team operations are still to be realized; capacity for flexibility of parameters and assumptions is important
- Adaptive, mid-mission planning requires consideration of the disruption caused by proposed plan changes
- Decision maker with high-level view should be able to interact with the planner

Major function requirements:
- Initial Mission Planning:
  UV allocation, C2 planning
- Mission Re-Planning:
  Change Plan with new missions, Unexpected events

Initial areas of focus
- Asset-Task Allocation
- Decision maker – Asset Assignment
Asset – Task Allocation and Scheduling

– Minimize Mission Completion Time subject to capability and precedence constraints
– Multidimensional Dynamic List Scheduling (MDLS) heuristic algorithm to solve the IP in two steps:
  ▪ Prioritize tasks according to precedence constraints and deadlines using the Critical Path Method (future opportunity to add inter-task information flow requirements here)
  ▪ Assign assets to the tasks so as to
    – Minimize task completion time and
    – Minimize inefficiency in asset-capability assignments

Decision maker – Asset Assignment

– Minimize the Maximum Workload Disparity (workload imbalance) across the decision makers
  ▪ Considers the burden of managing assets as well as executing tasks
– Penalty function added to constrain the disruption caused by the new plan
  ▪ Enabled by maintaining a “previous assignment” at all times so the CTP knows the current state when planning the future
– Current implementation is a heuristic evolutionary algorithm
Integration: What we learned

- Guidance from the CWA to the team planner
  - Granularity of information required as output from the planner
  - Sea Combat Commander holds the high-level functional purposes:
    - Asset preservation
    - Secrecy of assets
    - Intelligence gathering
    - Minimal interference

- Guidance from the CWA to the User Interface
- Alignment of team planning functionality with information and communication requirements analysis