Adjustable autonomy in swarms of UAV

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Project context

- SMAART project ("Systèmes multi-agents adaptés à la reconnaissance de théâtre et l’auto-organisation des drones")
- Keywords: self-organized UAV swarms + authority sharing
- Functional demonstrator
Operational context
Self-organizing UAV swarms
Operational Context

- Surveillance and intrusion management (tracking)
- Fixed and rotary wing UAVs + sensors network
- ~3-5 FW-UAV, ~12 RW-UAV
Strategic Air-Base
UAV self-organisation

- Applying stigmergy principle ("ant-based" behaviors)
- 2 different kinds of pheromone: surveillance and pursuit
- UAV guidance: direct objective or pheromone gradient
- Repelling effects for obstacles
Pheromone Grids

- Visit Pheromone
  - Produced by UAVs, evaporates
  - Repels patrolling UAVs

- Alarm Pheromone
  - Produced by contacts, diffuses
  - Attracts tracking UAVs, consumed
## Modes & States

<table>
<thead>
<tr>
<th>Mode</th>
<th>State/Symbol</th>
<th>Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patrol</td>
<td></td>
<td>Visit Pher.</td>
</tr>
<tr>
<td>Pursuit</td>
<td></td>
<td>Alarm Pher.</td>
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<tr>
<td>Auto</td>
<td></td>
<td>Visit/Alarm Pher.</td>
</tr>
<tr>
<td>Rally</td>
<td></td>
<td>Command</td>
</tr>
<tr>
<td>Hover</td>
<td></td>
<td>Command</td>
</tr>
<tr>
<td>Stopped</td>
<td></td>
<td>Command</td>
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</tbody>
</table>
Strategic Air-Base
Authority sharing
Autonomy levels
Main questions

• Which modes of control?
• How to adapt levels of automation?
• Which interfaces?
<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>The computer offers no assistance, human must do it all.</td>
</tr>
<tr>
<td>2</td>
<td>The computer offers a complete set of action alternatives, and</td>
</tr>
<tr>
<td>3</td>
<td>Narrows the selection down to a few, or</td>
</tr>
<tr>
<td>4</td>
<td>Suggests one, and</td>
</tr>
<tr>
<td>5</td>
<td>Executes that suggestion if the human approves, or</td>
</tr>
<tr>
<td>6</td>
<td>Allows the human a restricted time to veto before automatic execution, or</td>
</tr>
<tr>
<td>7</td>
<td>Executes automatically, then necessarily informs the human, or</td>
</tr>
<tr>
<td>8</td>
<td>Informs him after execution only if he asks, or</td>
</tr>
<tr>
<td>9</td>
<td>Informs him after execution if it, the computer, decides to.</td>
</tr>
<tr>
<td>10</td>
<td>The computer decides everything and acts autonomously, ignoring the human.</td>
</tr>
</tbody>
</table>

[Parasuraman, Sheridan & Wickens, 2000]
UAV: Decision Modes

- Surveillance only
- Pursuit only
- Autonomous

If \( \text{pheroAlarm} \neq 0 \) then Pursuit.
Else Surveillance.
Surveillance

Full Pheromone Grid
Pheromone Grid (Threshold)
No Grid-Zone Info only

Coverage  Phero. adjust.  UAV Deploy.  Locomotion
Acquisition  Analysis  Decision  Implementation
Displaying times of visit

level 6

level 10
Corresponding HCI element

Coverage

Level 10

Level 1

Level 6

Grille

seuil 3 min

max 8 min
Surveillance

Adjust Priority by increments

Position assigned manually by Operator

Pheromone-based decision

Coverage Phero. adjust. UAV Deploy. Locomotion

N UAVs...
Corresponding HCI elements

Priority links to UAV & contact

Zone info/control
Pursuit: contacts

- Alarms are automatically aggregated into Contacts (time & space threshold)

- Contacts are organized into Intrusions (contacts generated by same intruders)
  - Possibilities (new intrusion, affect to previous intrusion, etc.) sorted by likelihood by the system
Intrusion
Pursuit

Automatic Aggregation of Alarms

Contacts  Intrusions  UAV Deploy.  Locomotion

Acquisition  Analysis  Decision  Implementation
Pursuit

Choices Sorted by Likelihood

Time before auto.

Auto. Most Likely

Contacts  Intrusions  UAV Deploy.  Locomotion

Acquisition  Analysis  Decision  Implementation
Pursuit

Position assigned manually by Operator

Deployment of UAVs via an Intrusion

Pheromone-based decision

Contacts Intrusions UAV Deploy. Locomotion

Acquisition Analysis Decision Implementation
Pursuit

HCI elements

Intrusion Panel

Contact menu

Select nearby UAVs & dispatch them
Conclusion

• Relying on a self-organized swarm of UAV

• Offering different levels of “autonomy” for control
  ‣ in information display
  ‣ in (individual) UAV mode selection
  ‣ in UAV deployment

• Allowing to manage higher levels “semantic” patterns (intrusions)
Future work

- Prototype demonstration on air base scenarios
- Experimental comparison of performances in adaptive, fully automatic or fully manual configuration
- Connect tool to existing management framework
- Experimentation in real size
Thanks for attention !

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