A System for Single Human Supervision of Multiple Robots in Urban Search and Rescue

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Relevance to BTC research

• Single human supervision of multiple social robots

Shopping and Retail

Education
Desire for Single-Human Multiple-Robot System (SHMRS)

• Multiple robots:
  – Efficiency, Reliability
  – Some tasks require multiple robots

• Need for human supervision:
  – Errors bound to occur
  – Experience, greater awareness, flexibility, problem solving
  – Supervision possibly by only a single human, maximize robot to human ratio for safety, manpower savings

5 Murphy, R., Blitch, J., & Casper, J. (2002). AAAI/RoboCup-2001 Urban search and rescue events: Reality and competitions. AI Magazine Volume 23, Number 1, 37 - 42
Single-Human Multiple-Robot System (SHMRS)

3 major components:
• Robot group
• Human supervisor
• Control station/interface
Cognitive Concerns: Workload

- Robot supervision is challenging
- Increased cognitive workload with each added robot

Failure to perform critical tasks
  - Failure to spot target / victim

Errors
  - Collisions

(Wickens & Hollands, 2012)
Cognitive Concerns: Situation Awareness (SA)

- Awareness and understanding of what is happening presently with each robot.
- Awareness of what will soon happen.
Cognitive Concerns: Situation Awareness (SA)

- SA is needed for
  - Making informed decisions
  - Error prevention
  - Timely intervention

Occasionally the children's behavior escalates and becomes violent.
Solution: Applying Automation

Intelligent autonomous behaviours

• To address workload
  – Supervisor mentally relieved of processing tasks handled by automation
  – Fewer physical actions

• To address lack of SA
Applying Automation in SHMRS

- Individual robot level
  - Obstacle avoidance
  - Standard responses
- Robot-group level (coordination)
  - Inter-robot coordination
Concerns with Multiple-Robot Coordination

- Communication resources
  - Bandwidth
  - Influences volume and rate of communication \(^1\)

- Computation resources
  - Processing power and storage

- Affects maximum level of autonomy or sophistication in robot behaviours \(^1, 2\)

- When demand exceeds supply,
  - Robots may perform slowly \(^3\) or grind to a halt
  - Can affect entire robot group


Problem Statement

Autonomous coordination should be designed to alleviate workload and prevent situation awareness degradation

BUT

Coordination must consume as little communication and computation resources as possible
Approach to Problem

**Centralized Robot Group (CRG)**

- Apex Robot
- Subordinate Robot 1
- Subordinate Robot 2

- Hierarchical framework
- Communication only between Apex and Subordinate

**Distributed Robot Group (DRG)**

- Robot 1
- Robot 2
- Robot 3

- Robots are peers
- Each robot communicates with all other robots
Benefits and Drawbacks (of CRGs)

• Prone to Single-Point-Failure (SPF)\textsuperscript{1,2,3}
• Subordinates can be smaller, simpler and less expensive\textsuperscript{4}, using microprocessors
• Allows coordination even with such robots\textsuperscript{4,5}
• Communicating with fewer group members can reduce communication costs\textsuperscript{6}

Model of Proposed Solution

Single-Human Multiple-Robot System with a Centralized Robot Group

Defining attributes
1. SHMRS is equipped with a robot group that is:
   a) Strongly centralized
   b) Explicitly communicating
   c) With a co-located apex robot

2. Communication channel incorporated between supervisor and each robot
Model of Control Solution

Defining attributes

1. SHMRS is equipped with a robot group that is:
   a) Distributed
   b) Explicitly communicating
   c) Able to deploy all members within mission environment

2. Communication channel incorporated between supervisor and each robot
Implemented SHMRS

- Capable of deploying groups of two and three robots
- Capable of deploying robot group using centralized and distributed organization structures
Autonomous Coordination
EXPERIMENTATION
Design of Experiment

- Two factors in the experiment
  - Organization structure
    - Centralized
    - Distributed
  - Group size
    - 2 robots
    - 3 robots
- 8 unpaid participants
  - Each performed 4 USAR missions
Scenario in Experiment

- Background
  - Indoor USAR scenario
- Objectives of mission
  - Locate all simulated victims as quickly as possible
Mission Area

Entrance to mission area

Control station

11.80m

13.16m
Simulated Victims
Simulated Hazards

- Simulated hole
- Simulated debris pile
## Performance Measures

<table>
<thead>
<tr>
<th>Measures for system performance</th>
<th>Measures for supervisor cognition</th>
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<tbody>
<tr>
<td>• Number of victims located</td>
<td>• Participant workload</td>
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<tr>
<td>• Number of robots incapacitated</td>
<td>• Participant situation awareness</td>
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- **Workload**
  - Determined with NASA-TLX (Task Load Index)$^1$

- **Situation Awareness**
  - Determined with SAGAT (Situation Awareness Global Assessment Technique)$^2$

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RESULTS
Mean NASA-TLX score VS Group size

Workload

Centralized robot group (Proposed solution)  Distributed robot group (Control solution)
System Performance

Mean number of robots incapacitated VS Group size

Mean number of victims found VS Group size

Legend
- Centralized robot group (Proposed solution)
- Distributed robot group (Control solution)
Findings

• Supervising CRG consistently resulted in greater workload
• Participants were highly focused on ensuring safety of Apex robot
• As a result, performance towards finding victims declined
Conclusions

• Robot-group organization does affect human supervisor
• Where possible, DRG supervision may be preferable
THANK YOU