Cooperating Robots for Search & Rescue

Jijun Wang
Michael Lewis
University of Pittsburgh

Paul Scerri
Carnegie Mellon University
USAR Challenge

Urban Search and Rescue (USAR) refers to rescue activities in collapsed buildings and structures.

- **Application Goals**
  - Explore a structure, map significant features
  - Locate, assess, and map victims
  - Deliver emergency kits (radio, water, first aid...)
  - Transmit a human readable map

- **Hazardous task**
  - Lives saved by assisting human rescuers
  - Explore compromised structures, limited access areas
  - Robots are ultimately expendable

- **Time critical**
  - Great benefit from quickly locating victims
  - Requires careful path planning and strategy

- **Highly unstructured/unpredictable**
  - Requires adaptability, decision-making
  - Negotiation = Navigation + Influence

Courtesy Adam Jacoff NIST
Operator controls:

- Multiple teleoperated robots
  - Limited by number of hands, etc.
- Multiple semi-autonomous robots
  - Typically using waypoints
  - Describable using neglect-tolerance/span of control measures (Goodrich 2005)
- Multiple cooperating robots
  - Automates coordination as well individual behavior
  - Necessary as number of robots increases
Autonomous Coordination with Machinetta

- Team member represented in team by a \textit{proxy}
  - E.g., TEAMCORE, GRATE and COLLAGEN
- Proxies encapsulate generic teamwork algorithms
  - Autonomously generate and allocate new waypoints to search
Experiment Setup

Teams of 3 Robots were controlled by:

- Teleoperation
- Waypoint selection
- Self generated non-conflicting waypoints
  - Auto-cooperation mode

14 Operators

- Controlled robots
- Searched for victims using pan/tilt camera
- Identified victim locations on map
Pioneer P2-DX in USARSim
Mirrored Arenas

Auto & manual modes were counterbalanced as participants searched arenas containing rearrangements of the same elements.
Display
North up Map
Thumbnails

[Image of a computer screen showing a software interface labeled "Robots List" with three sections: "[Bot1]: Goto START", "[Bot2]: Goto START", and "[Bot3]: Goto START." Each section has a thumbnail image of a screen shot, a box for name, and a box for state.]

- Background Color
- Screen Shot
- Name
- State
In-focus Camera
Controls
Mission Panel (camera facing map)
Operator Subjective Opinion

Outcome of autonomy

- Significant Help: 36%
- Minor Help: 43%
- No Difference: 7%
- Worse: 14%
Victims found by participants

more victims were found in auto mode
Switches between robots

Operators switched focus between robots more often in auto mode
Exploration Coverage
Robots explored more of the arenas as measured by area mapped using laser when allowing auto mode.
Switching between robots

More victims were found when operators shifted focus between robots more often

Switches vs. Victims

Victims found in both arenas

Switching times in both arenas

Victims

Linear (Victims)
Waypoints before switching
Operators maintained longer focus on robots traversing waypoints when in manual mode
Teleoperation duration/switch

Operators were less likely to teleoperate an in-focus robot when in auto mode.

![Graph showing comparison between teleoperations in one switching in auto mode and teleoperations in one switching in manual mode. Error bars indicate 95.00% CI.](image)
Conclusions

- Coordinated autonomy helped operators explore more area & find more victims
- Coordinated autonomy led operators to switch focus more readily and observe more of the environment
- Users spent same time interacting with robots but spent it more usefully with autonomously coordinated team
  - E.g., panning and tilting cameras more
Time controlling & Victims found

Too little or too much controlled movement reduced the number of victims found

![Graph showing Operation vs. Victims](image-url)