Autonomous Multi-Robot Exploration in Communication-Limited Environments

Stephen Cameron, Julian de Hoog and Arnoud Visser

University of Oxford
University of Amsterdam
Mobile Robots Today

- reconnaissance, surveillance
- mapping, exploration
- search and rescue
- using the RoboCup Rescue scenario as inspiration
Typical Challenges

- Engineering
- Localisation and Mapping
- Team Coordination
- Communication
The Exploration Problem

- Team of robots exploring unknown environment
- Assume reasonable SLAM (particle filters / scan matching)
- Central base station
- Possibly communication drop-out or failure

**How to:**

- explore as quickly as possible
- relay as often and as efficiently as possible

*currently assuming paths are easily found and stay found!*
Existing Approaches

- Line of sight
- Frontiers / Utilities
- Robot packs
Role-based Exploration

Relays
Ferry information back and forth between teammates

Explorers
Explore far reaches of the environment
Hierarchy

- control commands
- new information

Both centralised and distributed
Demo
Where to Rendezvous?

- open space
- junctions
- large comm range
Path Edges and Nodes
More Examples
Dynamic Environments
A problem
Swap roles?
Another Common Scenario: Loops
The “Role Swap” Rule

- Two robots, A and B
- A wants to go to $D_A$, B to $D_B$
- Let $\gamma(u,v)$ be path cost from $u$ to $v$
- If $\max\{\gamma(A,D_A),\gamma(B,D_B)\} > \max\{\gamma(A,D_B),\gamma(B,D_A)\}$...
- ...then let A and B swap (role, state, location in hierarchy, everything)
The “Role Swap” Rule
Demo
Which is better?

Opportunistic exploration

Dynamic role-based exploration
Knowledge at BaseStation

Opportunistic exploration

Dynamic role-based exploration
Control over team

Opportunistic exploration

Dynamic role-based exploration
Dynamic Role-based Exploration

- Simple, easy to implement
- Not dependent on communication
- Speed of exploration is equivalent to opportunistic frontier / utility based exploration
- Information is returned to the BaseStation much faster and more frequently
- Greater control over the team
Another Example
(showing hierarchy and role changes)
The Same Example
(showing comm links)
Dynamic Role-based Exploration

- Simple, easy to implement
- Not dependent on communication
- Speed of exploration is equivalent to opportunistic frontier / utility based exploration
- Information is returned to the BaseStation much faster and more frequently
- Greater control over the team
- Dynamic adjustment to various environment types
Realistic?
Future Work

• Theoretical Description of the Role Swap Rule
• Extensive testing of emergent behaviour
• Additional roles: static relays?
• Testing on real robots / third party simulation platform
Credits

- UAV video: microdrone GmbH (http://www.youtube.com/watch?v=Y4jtguSF0n4)
- Mapping robot: Tsubouchi Laboratory, University of Tsukuba
- Search and rescue Kenaf robot: Tadokoro Laboratory, Tohoku University