

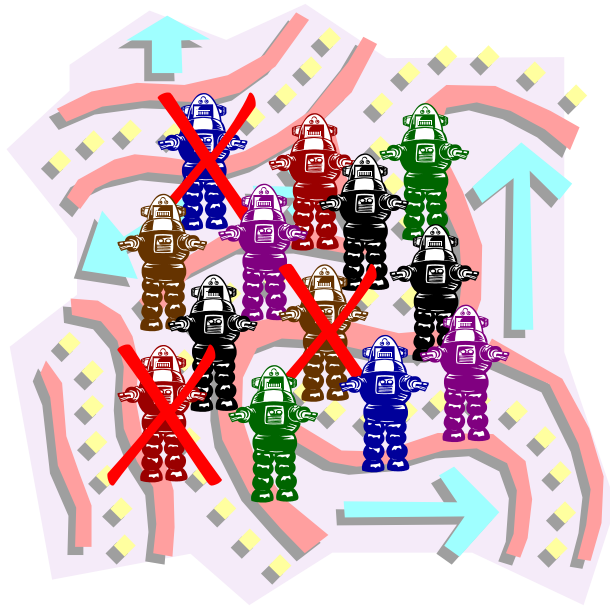
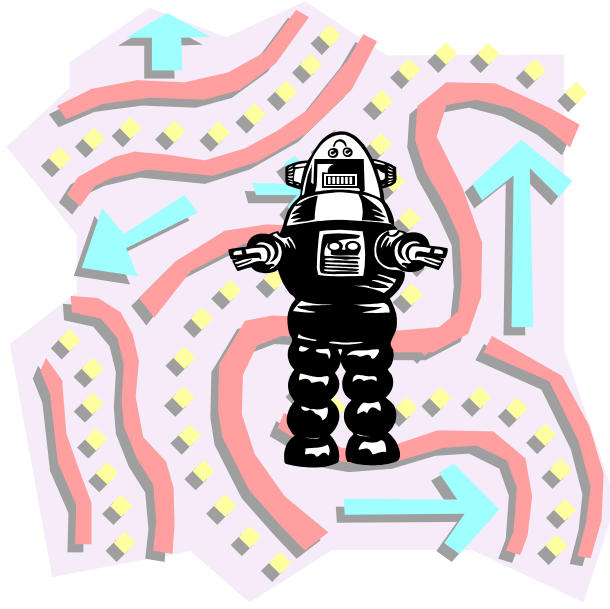
The auction-based approach to coordination of multi-robot teams

Justin Werfel

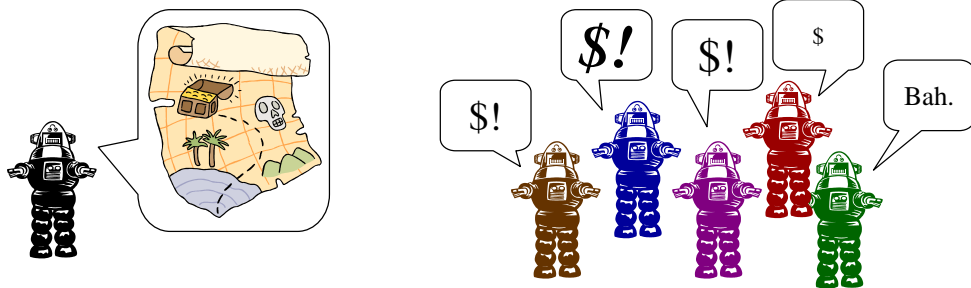
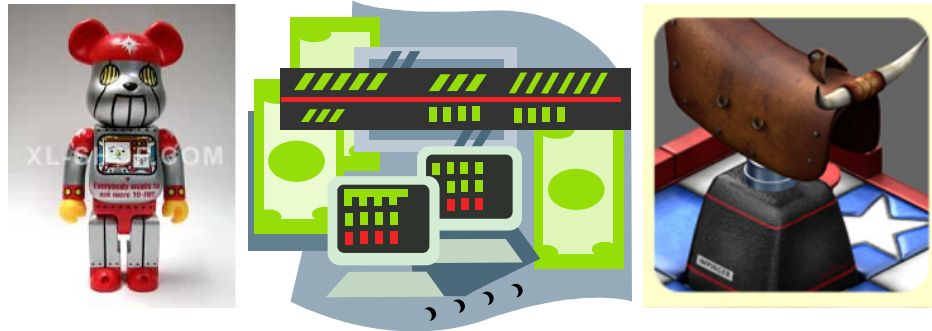
6.834/16.412 4/7/04

The Obligatory Outline

- Introduction to teams and markets
- Description of exploration algorithm
- Example
- Special cases
- Limitations



Robot economy



Important features

- Robust to partial or complete communication failure
- Robust to loss (or addition) of robots
- No central controller



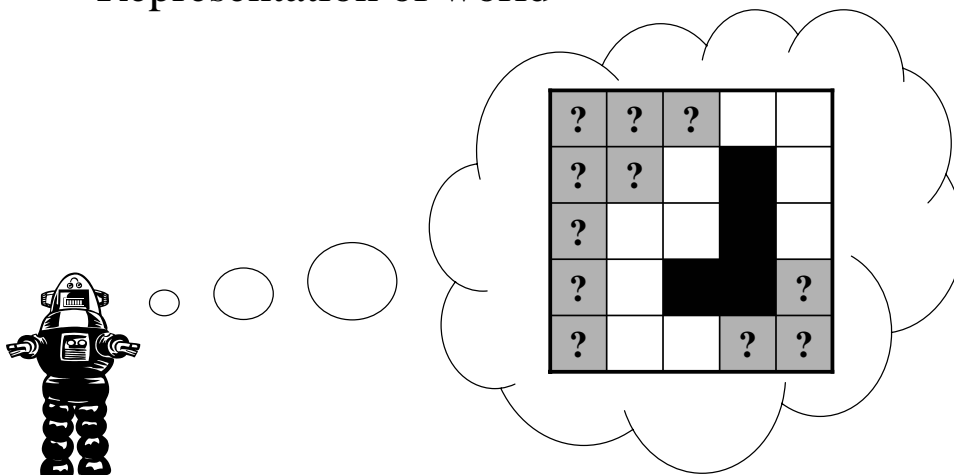
Multi-Robot Exploration Controlled by a Market Economy

Robert Zlot, Anthony Stentz,
M. Bernardine Dias, Scott Thayer

*Proceedings of the 2002 IEEE International Conference
on Robotics and Automation, May 2002.*

Multi-Robot Exploration Controlled by a Market Economy

- Representation of world



Multi-Robot Exploration Controlled by a Market Economy

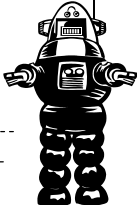
- Representation of world
- Revenue

\$	\$	\$		
\$	\$		█	
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Multi-Robot Exploration Controlled by a Market Economy

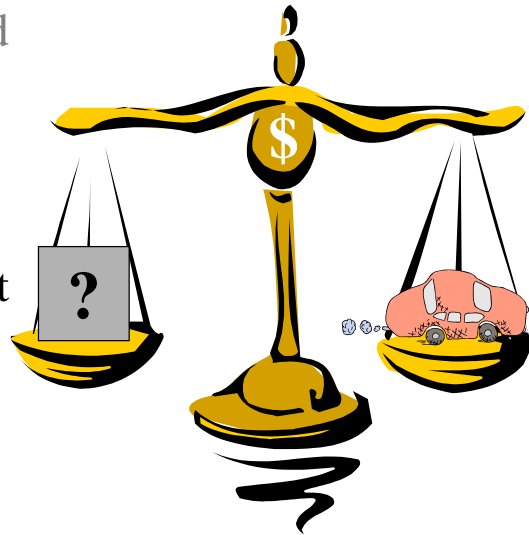
- Representation of world
- Revenue
- Cost



	\$	\$	\$
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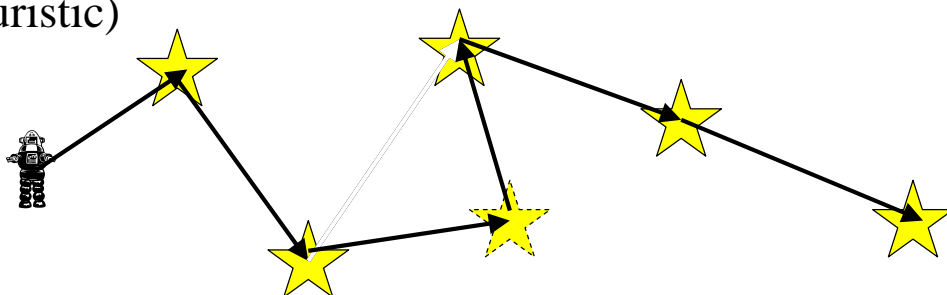
Multi-Robot Exploration Controlled by a Market Economy

- Representation of world
- Revenue
- Cost
- Profit = Revenue – Cost
- Commodity



Algorithm

- Robots deployed in unknown environment with known relative positions
- Generate lists of goal points
- Generate tours (NP-hard to do it right; use greedy heuristic)



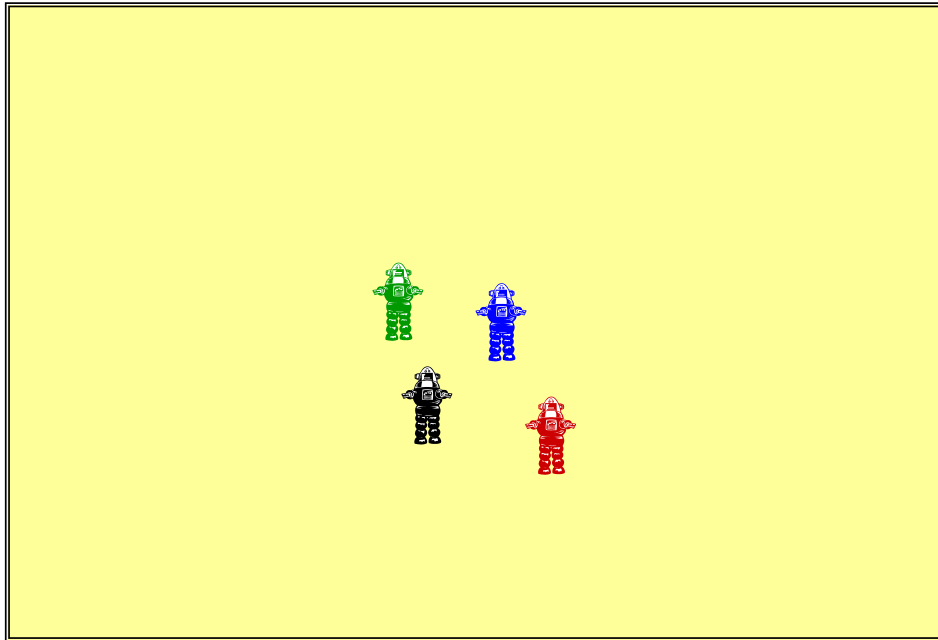
Algorithm

- Robots deployed in unknown environment with known relative positions
- Generate lists of goal points
- Generate tours (NP-hard to do it right; use greedy heuristic)
- Try to sell off all goals (via single-item first-price sealed-bid reserve auction)
- Go to next point on tour
- Repeat

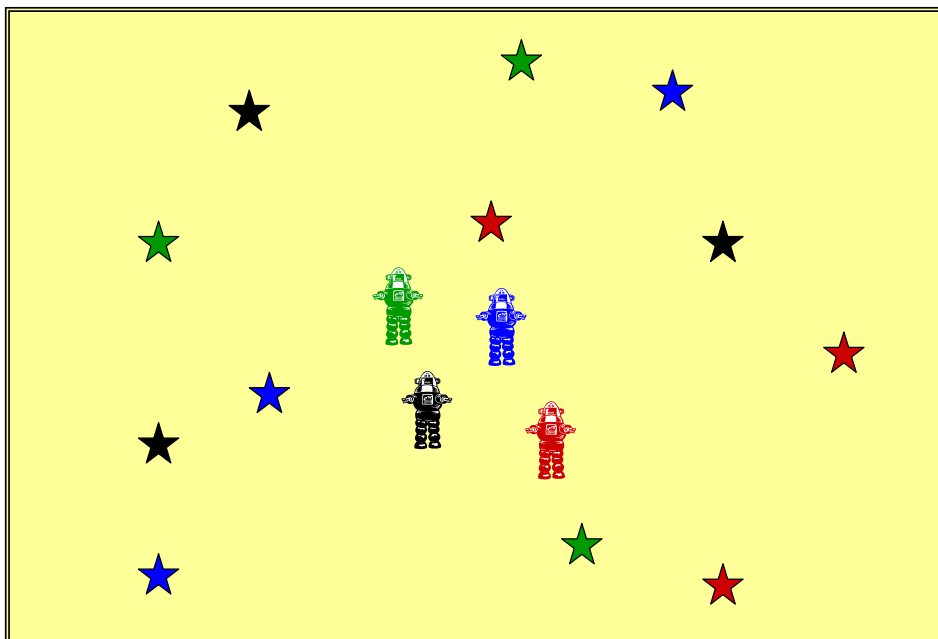
Auction details

- Auctioneer estimates expected profit v
- Announces reserve price $P_r = v + c$
- Other robots calculate their own valuations v_i and bid according to $B_i = P_r + \alpha(v_i - P_r)$
- Highest bid (including reserve price) wins

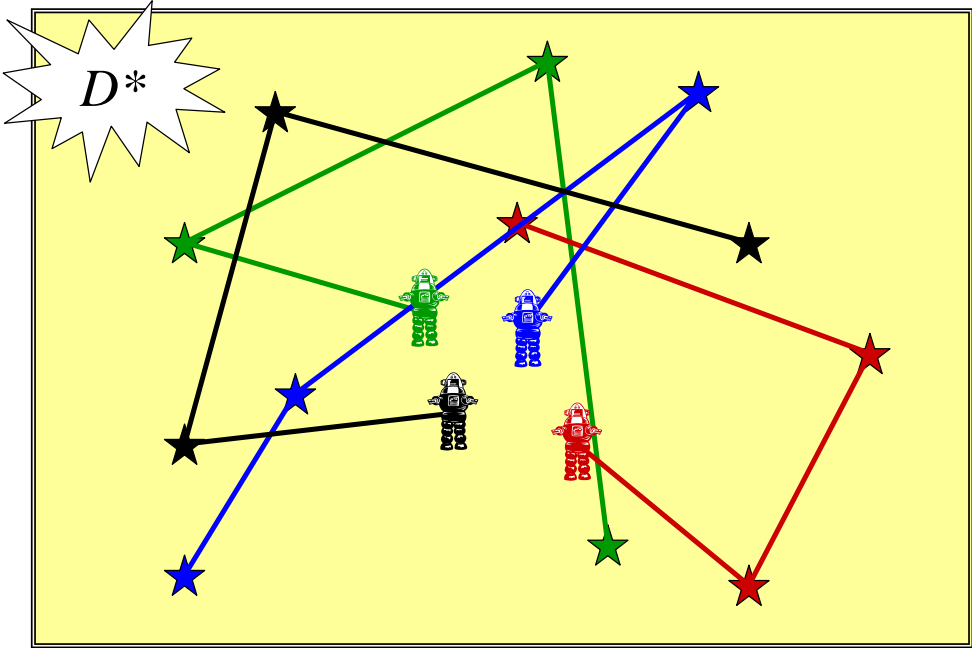
Example



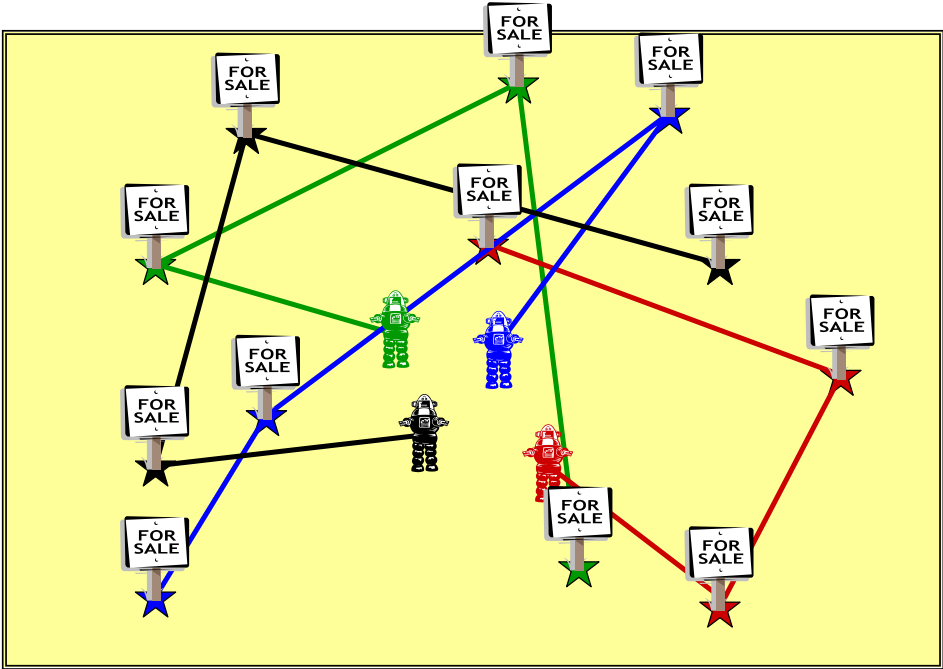
Generate goal points

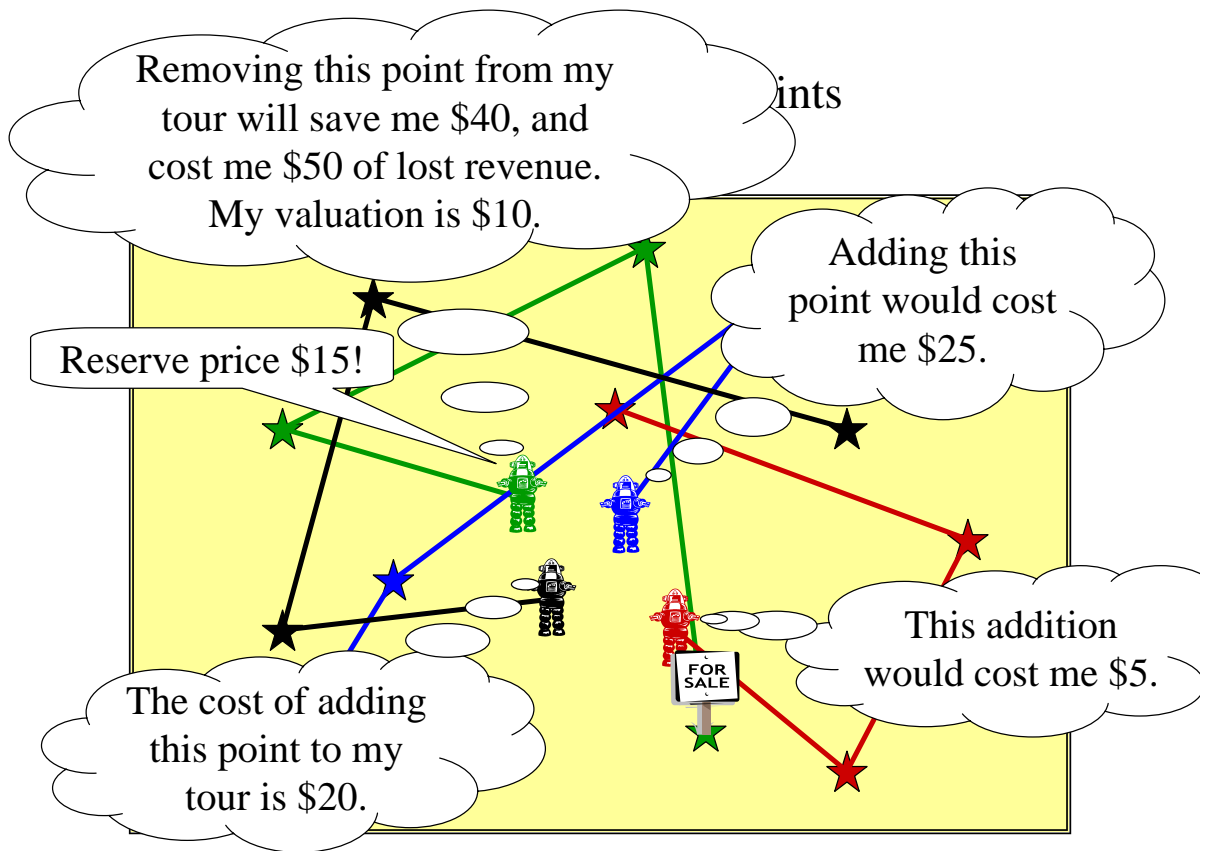


Generate tours

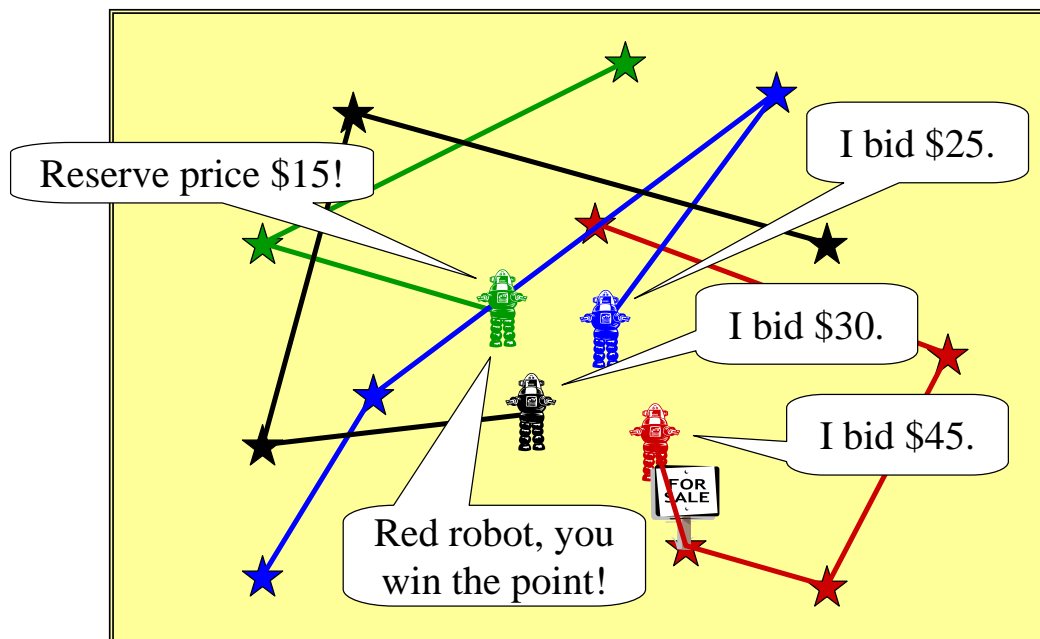


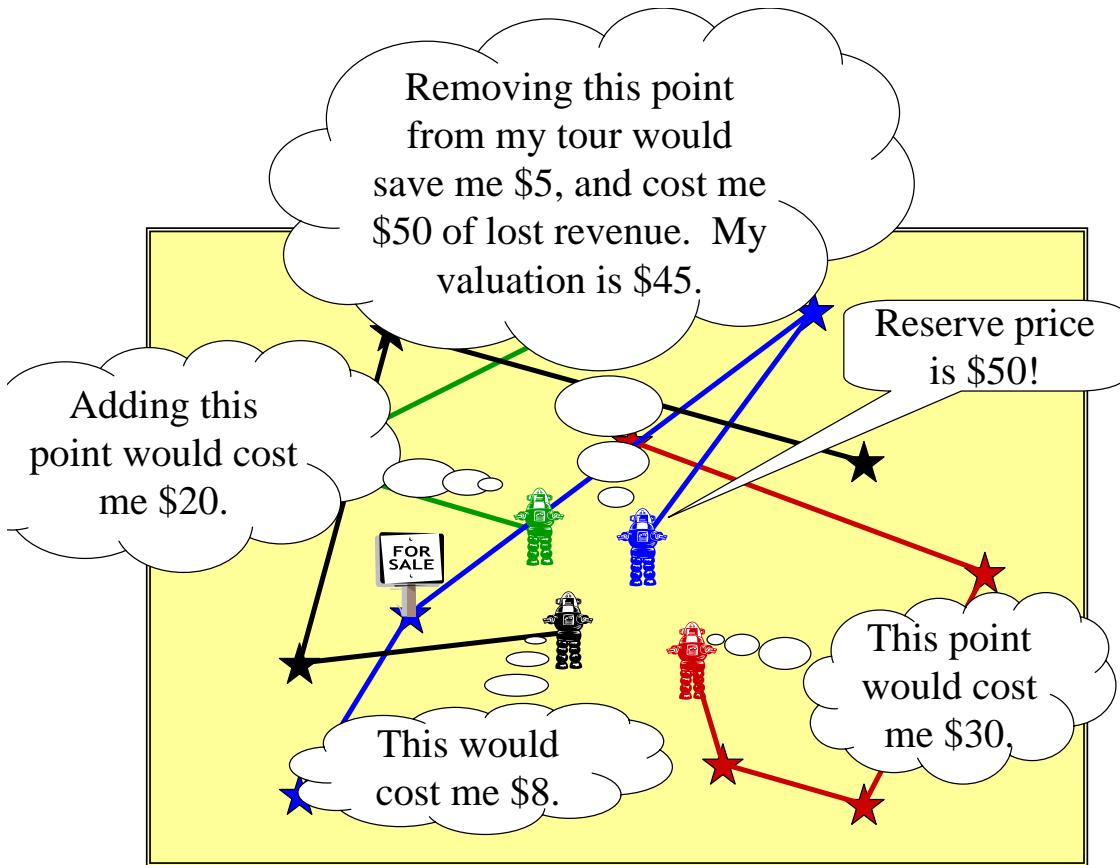
Auction off all goal points



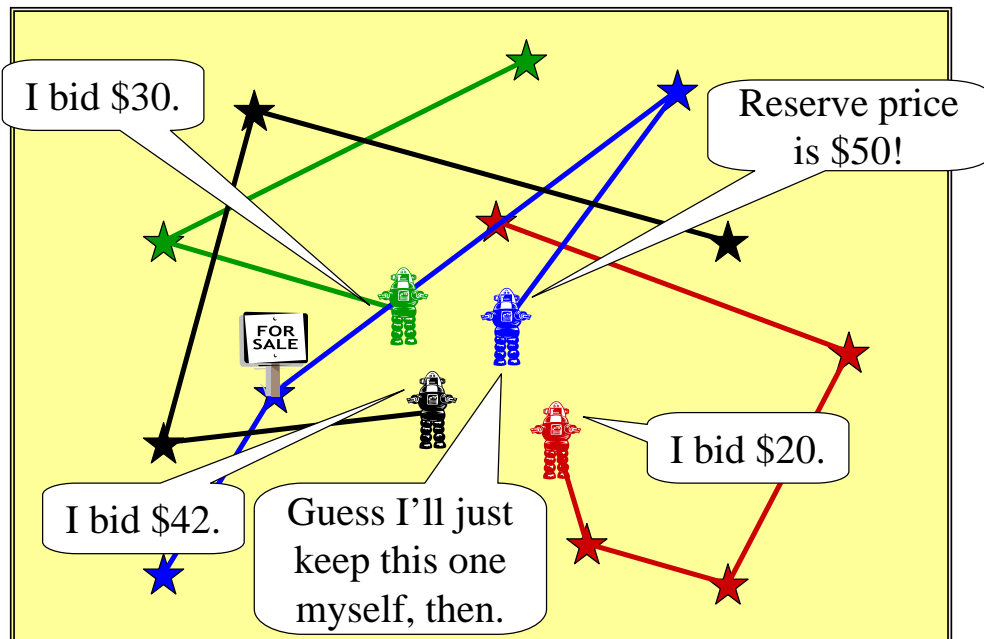


Auction off all goal points

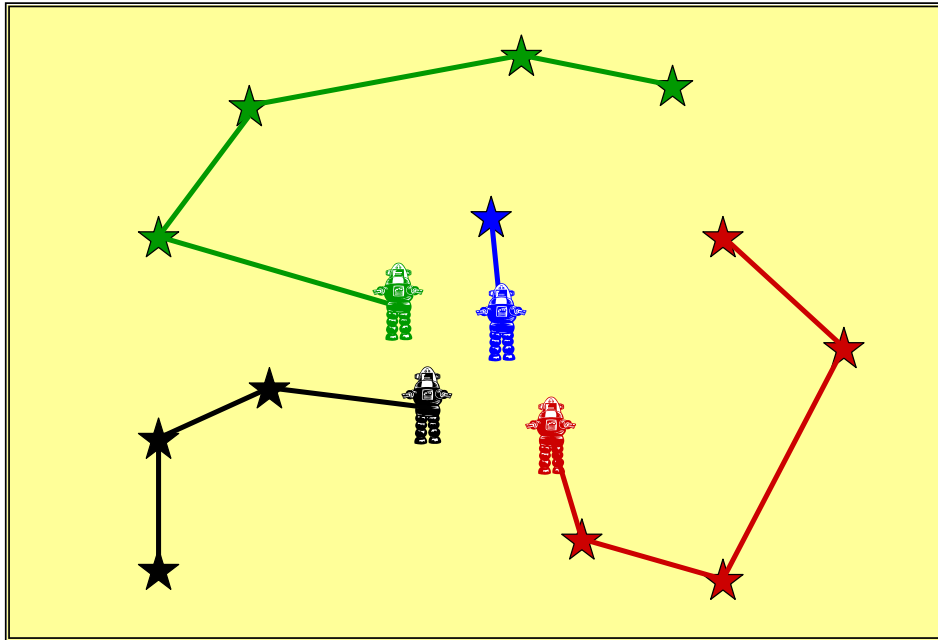




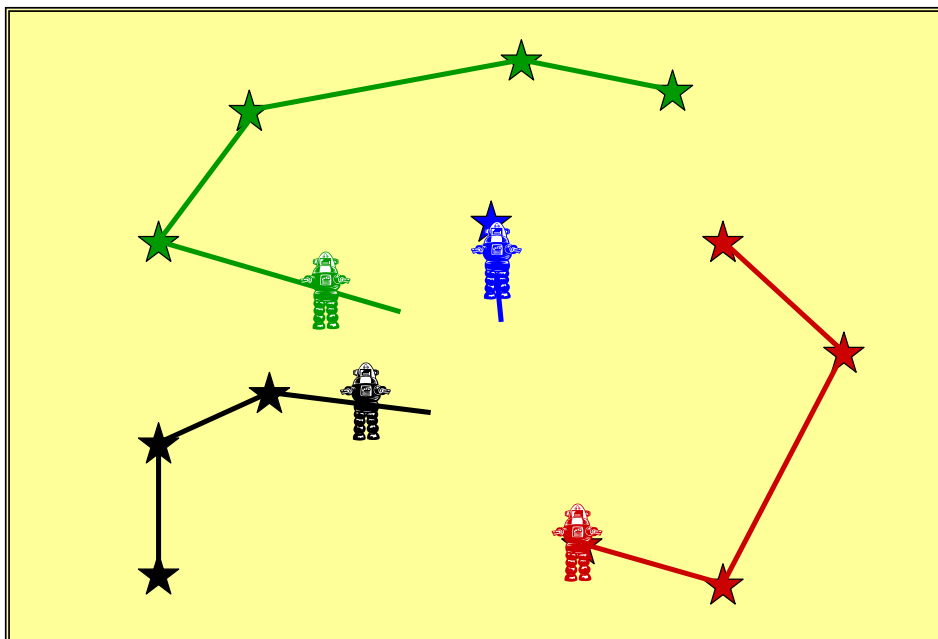
Auction off all goal points



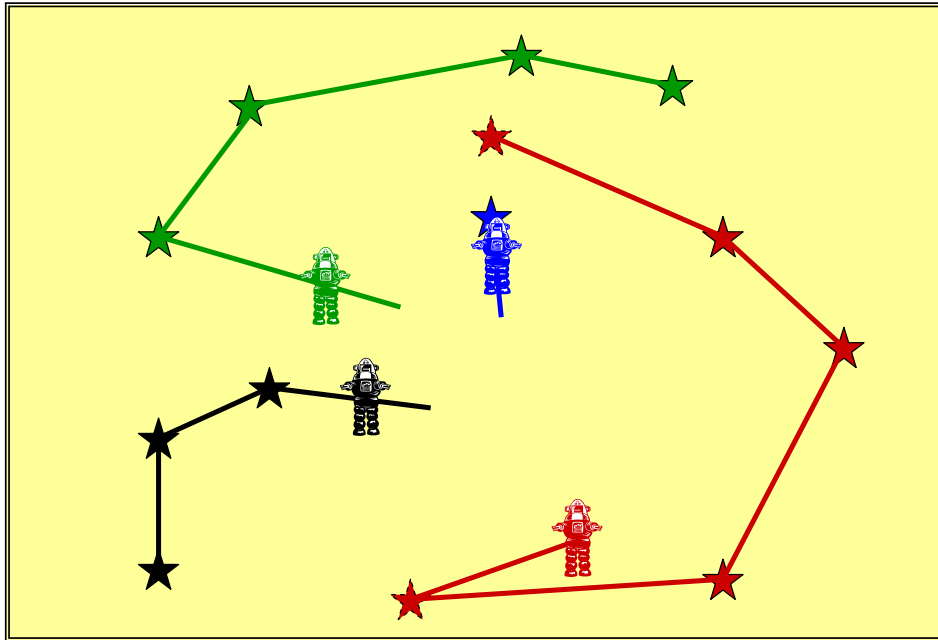
Auction off all goal points



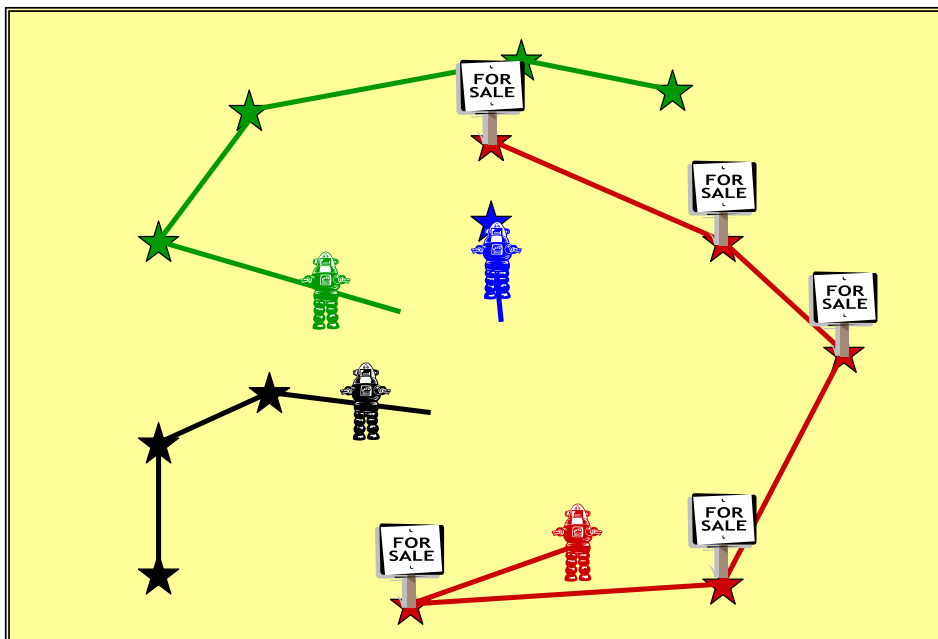
Go to next point on tour



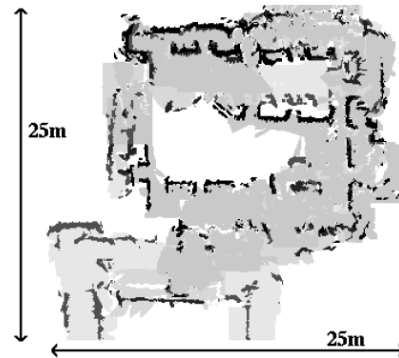
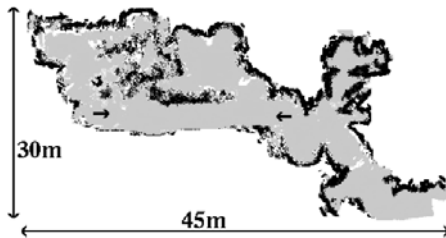
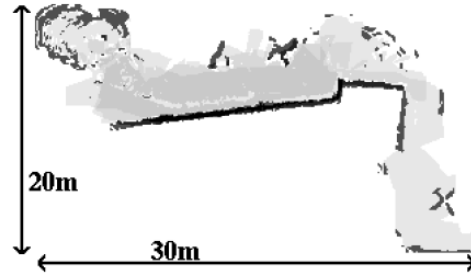
Generate new goal points and add to tour



Auction off all goal points

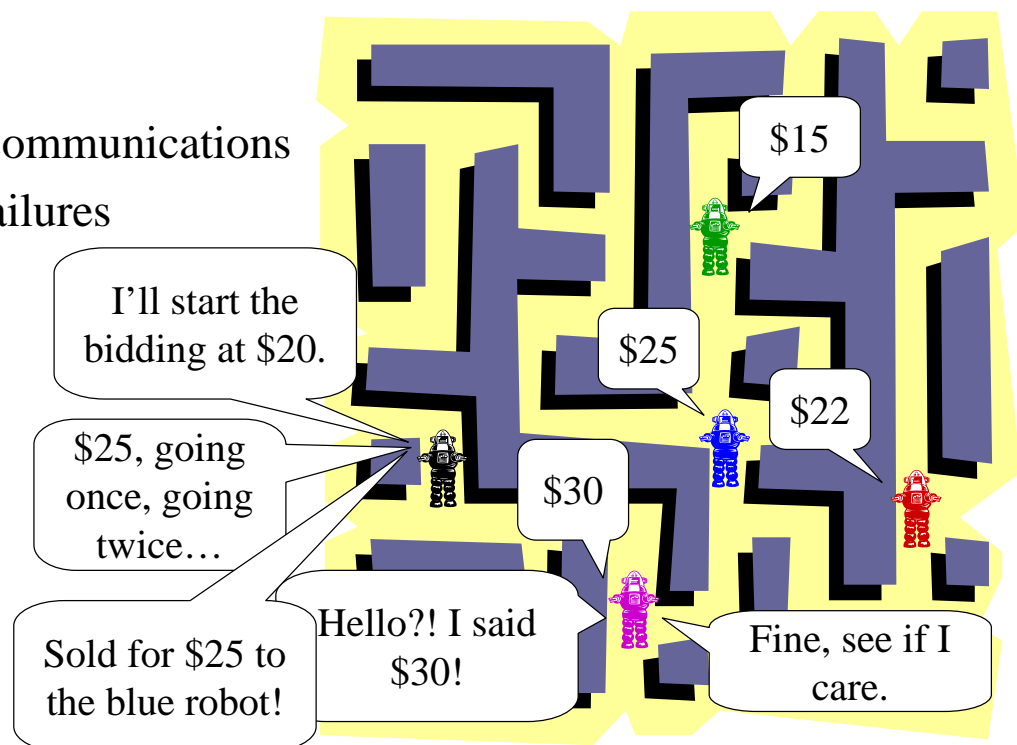


Examples of generated maps



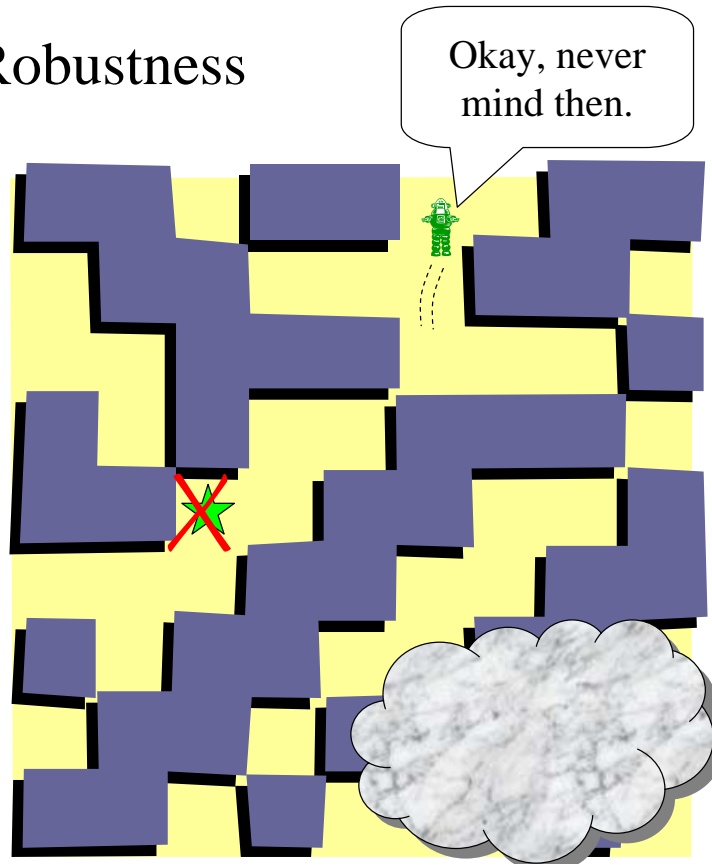
Robustness

- Communications failures



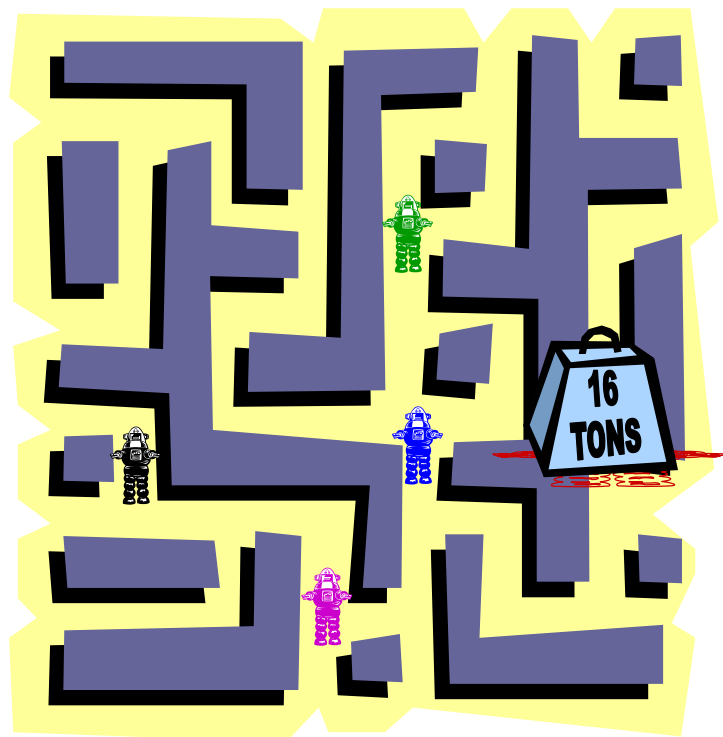
Robustness

- Communications failures
- Unreachable goals



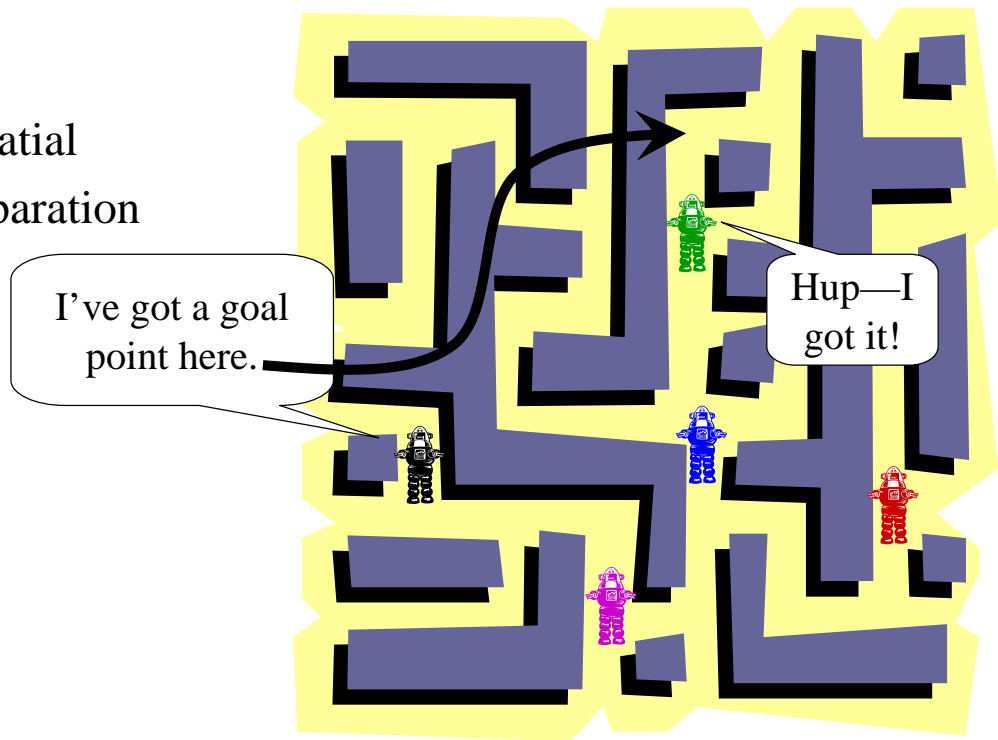
Robustness

- Communications failures
- Unreachable goals
- Robot loss



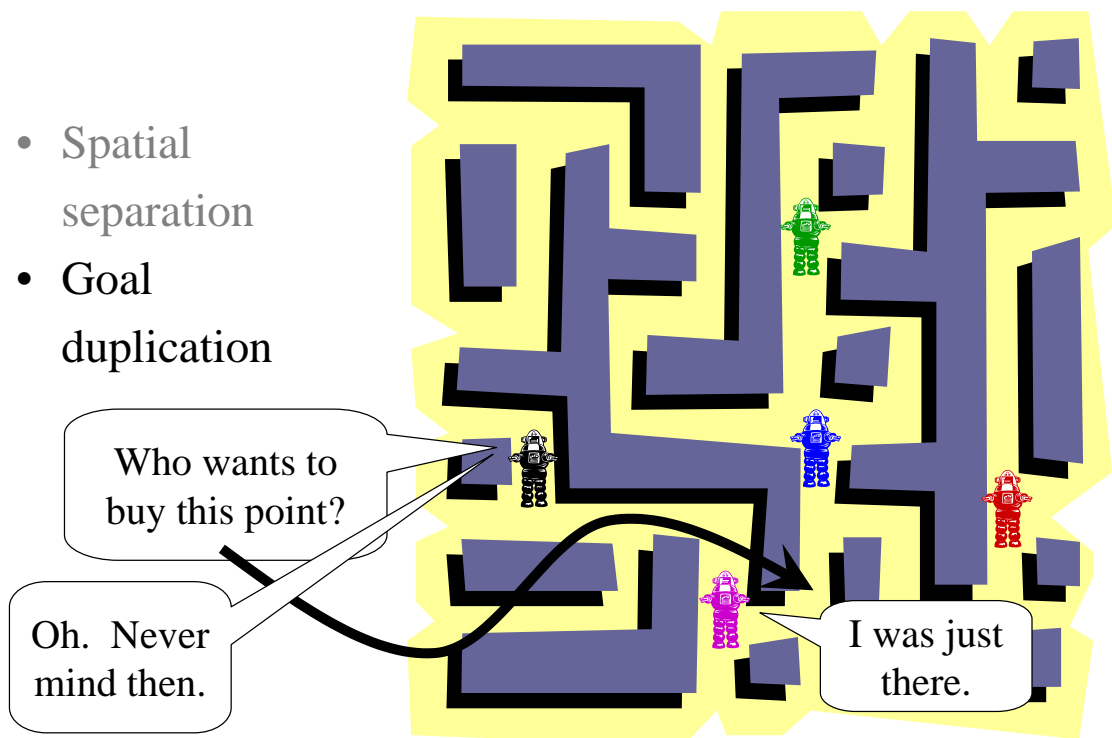
Communication

- Spatial separation



Communication

- Spatial separation
- Goal duplication

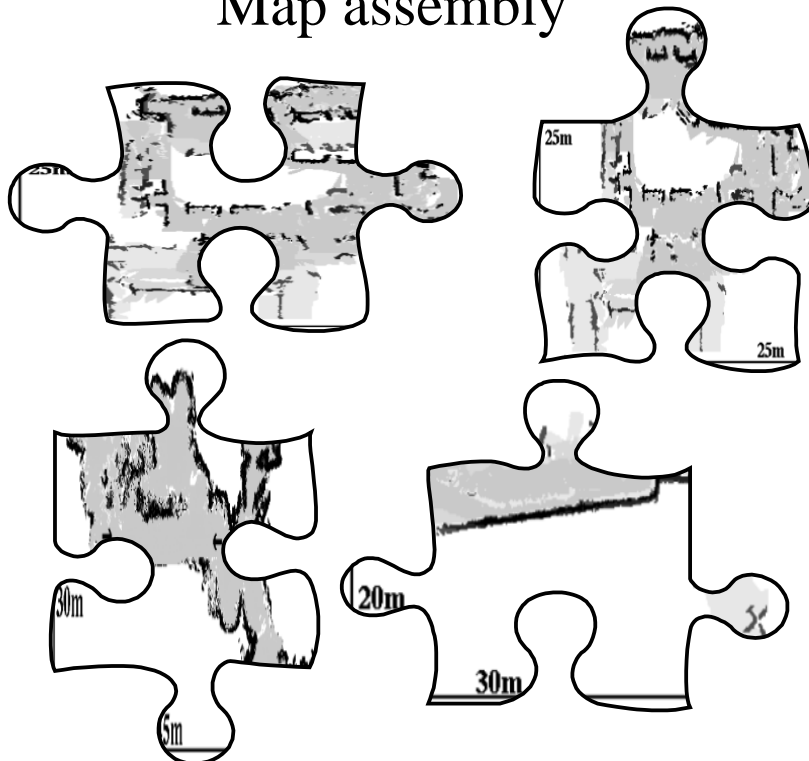


Communication

- Spatial separation
- Goal duplication
- Map sharing



Map assembly



Conclusions

- Limitations
 - Combining individual maps into unified whole
 - Maintaining accurate coordinate system
 - The most important robots to communicate with will typically also be the most difficult
- Subject to the above, an artificial economy is a strong approach for coordinating multi-agent systems
 - All kinds of robust
 - Flexible with respect to situation, changing circumstances, different tasks, etc.
 - Decentralized