

# **Sold!: Auction Methods for Multirobot Coordination**

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**Presented by Yohan Sawant**

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# Sold!: Auction Methods for Multirobot Coordination

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Available Online:

[http://robotics.usc.edu/~gerkey/research/final\\_papers/tra01.pdf](http://robotics.usc.edu/~gerkey/research/final_papers/tra01.pdf)

# The Problem

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- Need an efficient method for dynamically allocating incoming tasks to a physically embodied team of agents
- General assumptions for physical robots:
  - system composed of physically embodied robots
  - robots heterogeneous
  - communication, but messages sometimes lost
  - robots honest & cooperative
  - part, or all, of a robot may fail at anytime
  - a robot may not recognize its own failure

# The Problem

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- Assumptions specific to this model:
  - robots are multipurpose, rather than task specific
  - no model to describe the sequence in which tasks are generated
  - if a robot is to oversee a task, it can determine the progress and completion of the task
- The goal is to minimize:
  - resource usage
  - task completion time
  - communication overhead

# Approach

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- Anonymous communication via broadcast
  - saves bandwidth when sending messages to multiple recipients
  - allows robots to move in and out of range
- Hierarchical task structure
  - each task is a tree containing other tasks
  - flexible enough to handle a wide variety of tasks
- Auctions
  - scalable
  - cheap to broadcast and compute (only one round of bidding)
  - allow modularization
  - similar to CNP negotiation scheme, but without centralized broker

# MURDOCH

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- Publish/Subscribe messaging

- *subject-based addressing*: messages addressed by content rather than by destination
- a data-producer tags a message with a particular subject
- only data-consumers interested in the specified subject will receive the message
- subjects represent a robot's resources
- resources can be:
  - physical devices (e.g., **camera, gripper**)
  - high-level capabilities (e.g., **mobile, tracking**)
  - abstracted notions of current state (e.g., **idle, pushing-box**)
- for example, to send a message to all robots capable of retrieving a red can, a subject such as {**mobile, camera, gripper, idle**} would be appropriate

# MURDOCH

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- Auction Protocol

- a task can be introduced to the system by a human, an automated task generator, a higher level task already in progress, or many other ways

- each new task triggers a 5-step auction:

- 1) task announcement - an agent acts as “auctioneer”, publishing an **announcement** containing the details of the task and with an appropriate subject

- 2) metric evaluation - the **announcement** contains metric(s) to determine task fitness

- 3) bid submission - each candidate robot calculates and publishes its “score” as a **bid**

- 4) close of auction - the auctioneer processes the **bids** and sends a **close** message, the winner receives a time-limited contract to execute the task

- 5) progress monitoring/contract renewal - the auctioneer monitors task progress and continues to send **renewal** messages to the winner as long as progress is satisfactory, the winner replies to each **renewal** with an **acknowledge** message

# MURDOCH

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- time-limited contracts provide fault tolerance
- tasks are always assigned to the most capable robot, thus MURDOCH is an instantaneous greedy task scheduler
- compared to a centralized task allocation system:
  - PRO: tasks may be randomly input at anytime
  - CON: use of resources can not be optimized by analyzing concurrent tasks

# Testing

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- Closed indoor environment
- Pioneer 2-DX mobile robots
  - sensors(each robot has one or two): camera, laser range finder, tactile bumper
- Wireless ethernet with shared bandwidth of  $\sim 1.9$  Mb/s, allowing robots to communicate freely with one another at all times

# Testing

- Loosely coupled task allocation
  - long-term autonomy
  - randomly generated sequence of tasks
  - overhead-camera attached to desktop PC used as the sole auctioneer



- Results
  - system ran successfully over a period of about 3 hours
  - resources allocated efficiently, i.e., the most capable robot available was always assigned the new task
  - bandwidth usage was very small, implying good scalability

# Testing

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- Box pushing

- requires tightly coupled cooperation
- system composed of “watchers” and “pushers”
- the box is moved via the **pusher-watcher** approach:
  - watcher stays in front of box and measures angular error between box and goal
  - pushers move forward in such a way that angular error is reduced
- a watcher task is auctioned by the system whenever a box must be moved
- this watcher auctions two pusher tasks based on angular error
- the side of the box lagging behind gets the first pusher, thus if only one pusher is available it will continually switch sides as one falls behind the other

# Testing

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An example of one pusher failing, then recovering



recover\_push\_hi.avi

# Testing

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- Results

- out of 40 trial runs, task completed successfully 90% of the time
- partial pusher failure much more time-consuming than total pusher failure because the watcher had to recognize lack of progress, rather than simply lack of acknowledgement or resources
- allowing a failed pusher to rejoin proved time-saving
- the box was kept along a near-ideal trajectory

- More clips and info available at:

- <http://robotics.usc.edu/~gerkey/research/murdoch.html>

# Related Work

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- Unembodied task allocation
  - CNP, Open Agent Architecture, RETSINA: all use central broker
  - *Condor* : executes background jobs on idle workstations
  - *Challenger* : much like MURDOCH, but just recently moved to physical robots
- Embodied task allocation
  - ALLIANCE: all robots monitor each other's progress
  - BLE: distributed form of subsumption, more minimalist
  - both methods rely on behavior-based control
- Box-pushing
  - pushing control system similar to pusher-steerer and master-slave systems, but neither of these implement fault tolerance
- MURDOCH's results not directly compared to any other work

# Summary of MURDOCH

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- fully distributed method of task allocation
- anonymous, resource-centric communication
- hierarchical task structure
- each new task auctioned to the most capable agent available
- extremely reactive to environmental changes such as robot failure and randomly introduced new tasks
- empirically demonstrated on physical robots in situations involving both tightly coupled cooperation and long-term loosely coupled cooperation
- more work is being done to exploit MURDOCH in other domains

# Questions?

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