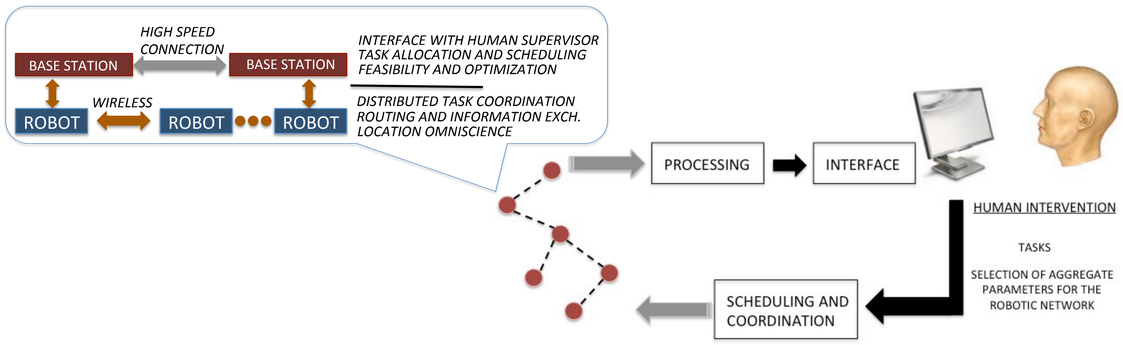
Semi-autonomous networks of miniature robots for inspection of large infrastructures

Michael Lin, Richard J. La, Nuno C. Martins

UNIVERSITY OF MARYLAND 18 56
INSTITUTE FOR SYSTEMS RESEARCH
A. JAMES CLARK SCHOOL OF ENGINEERING

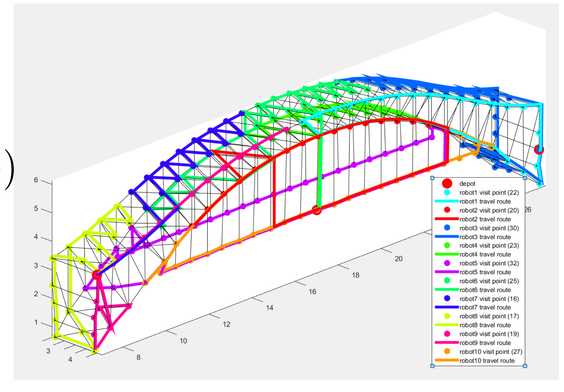
Goal of Project – Design a semi-autonomous network of miniature robots for bridge or other large infrastructure inspection with human inspectors in the loop

- Robots deployed to inspect various points and sites of a bridge
- Send measurements (e.g., pictures or videos) to human inspector(s) via base stations/gateways installed on the bridge



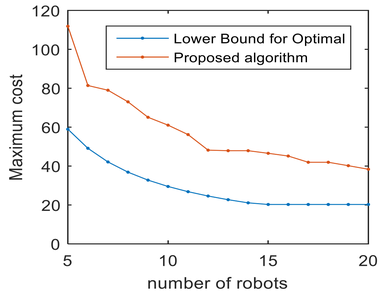
Robot Deployment and Path Planning

- Robots stationed at depots placed throughout the bridge
- Each robot assigned a set of points and sites to inspect and report
- Formulated as a **min-max cycle cover problem with constraints**
  - **Objective function** is (i) total inspection time or (ii) maximum energy consumption among deployed robots
  - **Vertex set** consists of points and sites to be inspected
  - **Edge weights** correspond to (i) travel time or (ii) required energy for travel
- Proposed an **approximation algorithm**
  - **Approximation ratio** $5+\varepsilon$, where $0<\varepsilon<1$
  - **Computational complexity** $O\left(n^2+2^{d-1}(\log(n)+\log(\varepsilon^{-1}))\right)$ where n is the number of vertices, and d is the number of depots



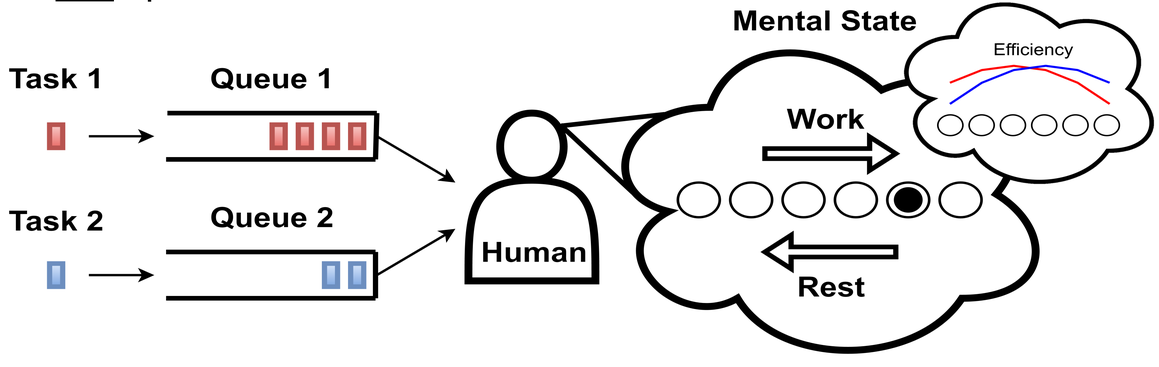
Numerical results for the proposed approximation algorithm along with a lower bound

- Proposed algorithm is within 2.5 times the lower bound for all considered cases, which is much smaller than the proven approximation ratio



Task Scheduling with Human-in-the-loop

- Pictures and videos reported by semi-autonomous robots inspected by a human inspector (**tasks** for human inspector)
- Efficiency of a human inspector depends on past workload or history
- **Goal:** Design a simple yet efficient **task scheduling algorithm** for human inspector, which maximizes the long-term throughput of human operator
- **Model**
  - Tasks arrive according to a stochastic process
  - Efficiency of human operator modeled as the state of a Markov chain
    - Transition probabilities are action-dependent (work vs. rest)
- **Main results**
  - There exists **an optimal threshold policy** that makes a decision solely based on the state of Markov chain (when queue is nonempty)
  - When there is more than one type of tasks (e.g., pictures and videos), randomizing between optimal single-queue policies is **not** optimal



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