

UNIVERSITY OF
BIRMINGHAM

Trustworthy and Explainable Autonomous Robotic Systems: Requirements and Solutions

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Autonomous robotic applications



Construction



Mining robots drilling



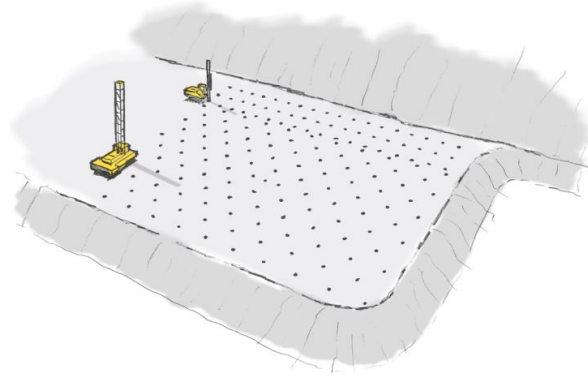
Waiter robot setting a table



Assembling of wiper
motors



The Drill Planning for open-pit mines

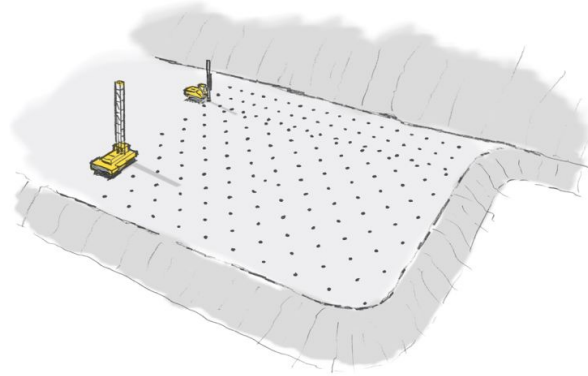


Problem: Plan motions and drilling sequences for multiple machines such that the makespan minimized.

Courtesy of
Epiroc



The Drill Planning for open-pit mines



Problem: Plan motions and drilling sequences for multiple machines such that the makespan minimized.

What are the requirements of a trustworthy and explainable drill plan?

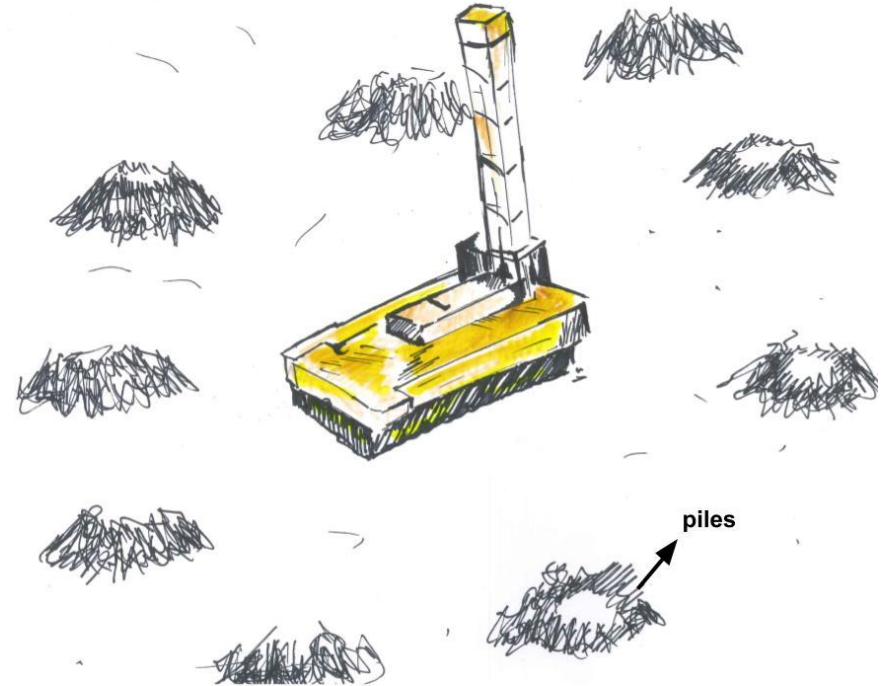


Drill Plan requirements

[M. Mansouri, et al., Multi Vehicle Routing Problem with Nonholonomic Constraints and Dense Dynamic Obstacles, IROS 2017]

The solution should consider:

- Uncertain navigation duration
- hardness of the rock
- Machine breakdown
- Robot-robot collision
-

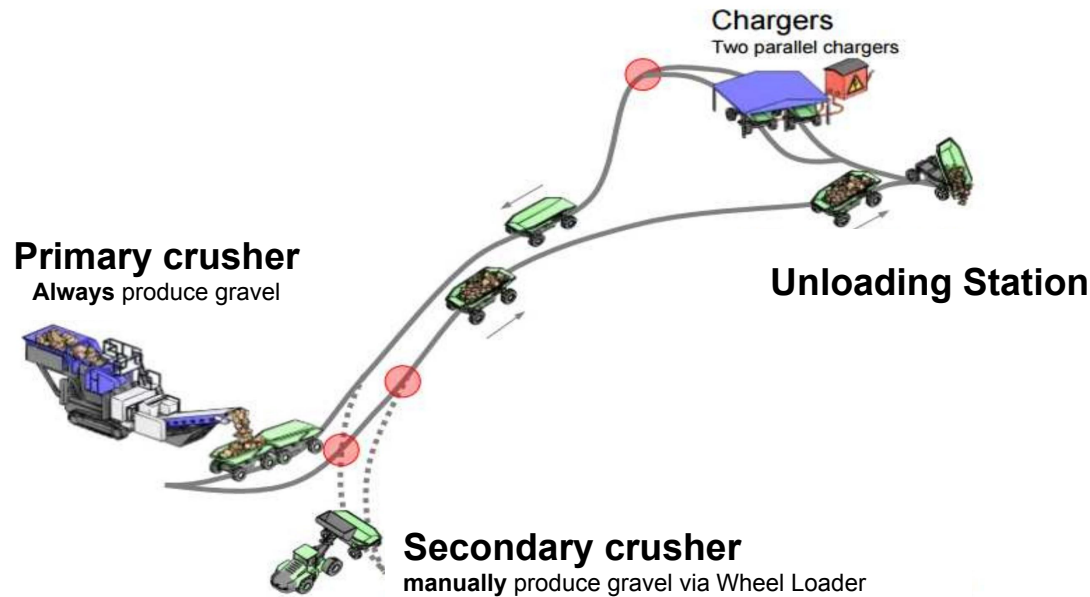


The Drill Planning for open-pit mines

[M. Mansouri, et al., Multi Vehicle Routing Problem with Nonholonomic Constraints and Dense Dynamic Obstacles, IROS 2017]



Multi-hauler planning for quarrying



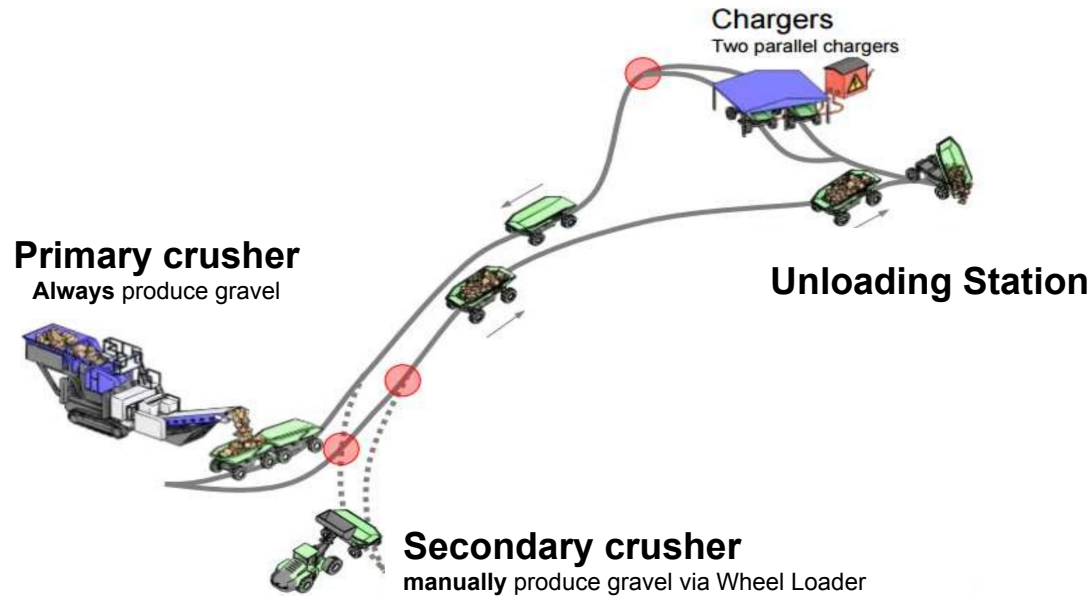
Courtesy of
Volvo CE

Problem: Multi-Robot Planning Under Uncertain Travel Times
and Safety Constraints



Multi-hauler planning for quarrying

[M. Mansouri, B. Lacerda, N. Hawes, F. Pecora, Multi-Robot Planning Under Uncertain Travel Times and Safety Constraints, IJCAI 2019]



What are the requirements of a trustworthy and explainable plan for the haulers?



Multi-hauler planning for quarrying

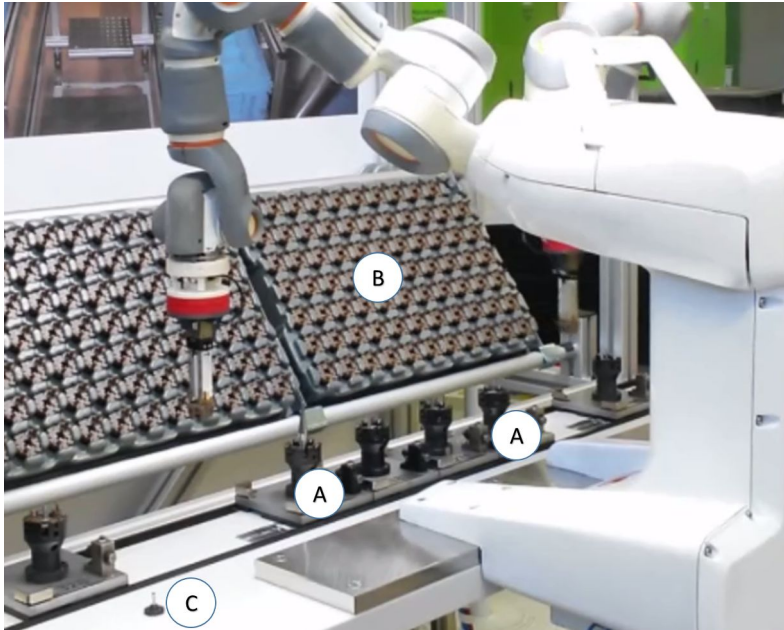
[M. Mansouri, B. Lacerda, N. Hawes, F. Pecora, Multi-Robot Planning Under Uncertain Travel Times and Safety Constraints, IJCAI 2019]



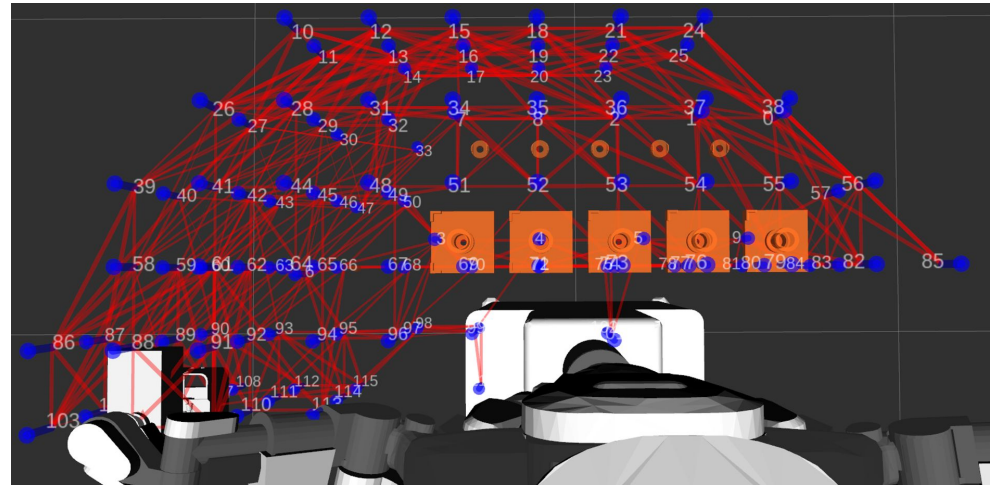
- Robot dynamics are **partially** known
- Robots may **navigate differently** in different parts of the environment
- There may be **task-dependent** factors affecting **how** robots navigate



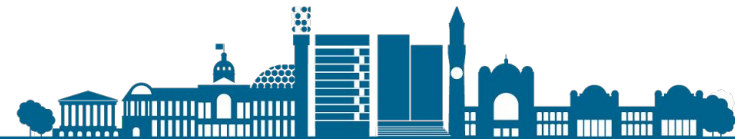
Assembly planning for industrial manipulators



Assembling of wiper motors

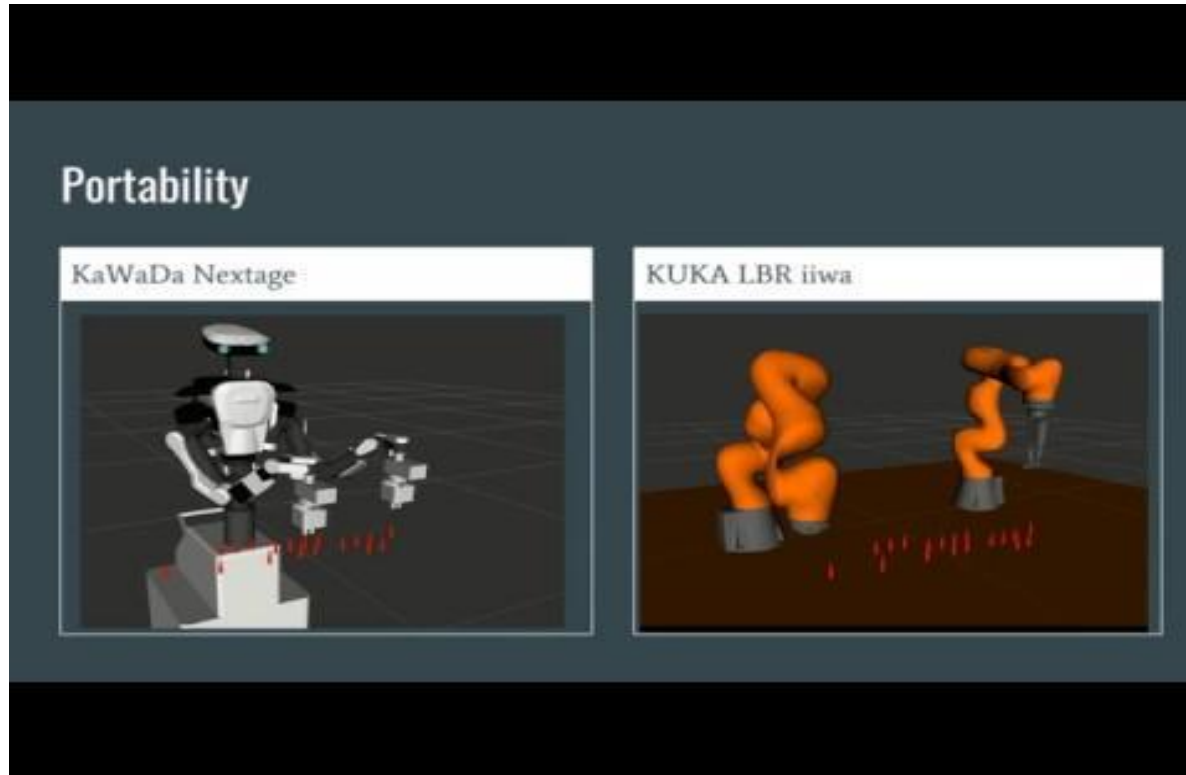


Problem: Simultaneous Task Allocation and Motion Scheduling for Industrial Dual-Arm Manipulation Tasks



Assembly planning for industrial manipulators

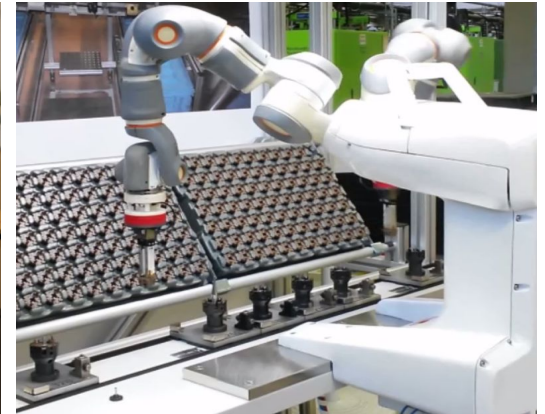
[JK Behrens, R Lange, M Mansouri, International Conference on Robotics and Automation (ICRA), 2019]



What are the requirements of a trustworthy and explainable plan of a assembly plan?



Autonomous robotic applications



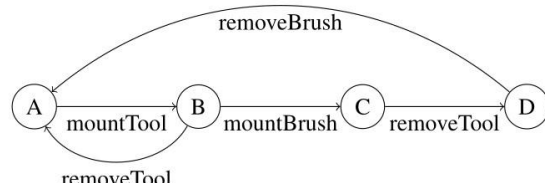
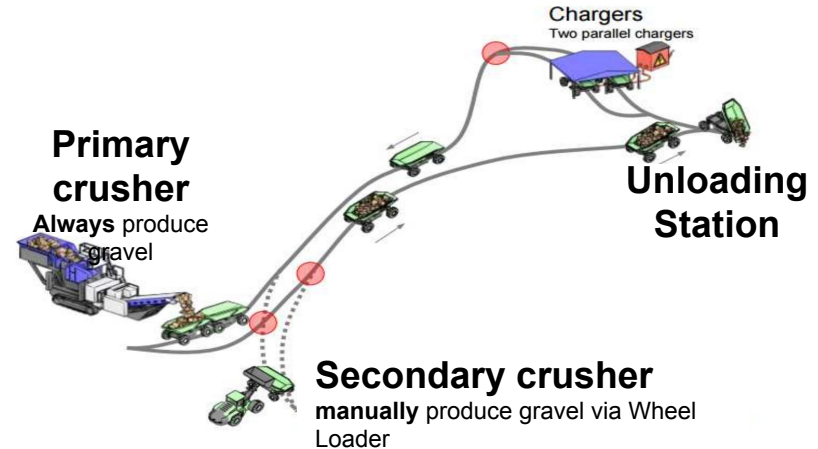
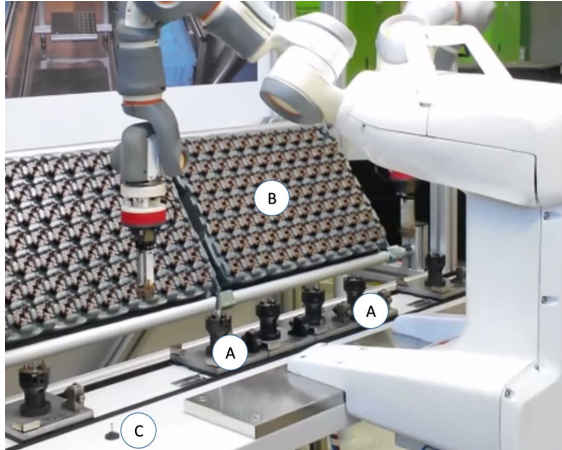
Necessary conditions for trustworthiness

- Planning with **formal methods**
E.g., Markov automata, LTL
- Planning with (multiple) **knowledge representation** and **reasoning** methods
E.g., constraint reasoning, temporal reasoning
- Planning with **systematic integration** methods
E.g., Meta-constraint reasoning



Explainability: specifying vs. learning

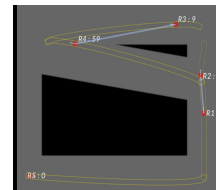
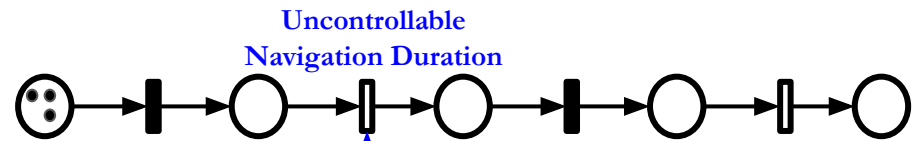
[M. Mansouri, F. Pecora, P. Schüller, Combining Task and Motion Planning: Challenges and Guidelines, Frontiers in AI Robotics, to appear, 2021]



```

1 constraint
2   forall(t in steps) (
3     forall(s in slots) (
4       (slotOcc[t,s] != 0 <->
5         pos[t,slotOcc[t,s]] == s)
6       /\
7       (slotOcc[t,s] == 0 <->
8         not exists(p in parts)
9           (pos[t,p] == s))
10    )
11  /\
12  alldifferent_except_0(row(slotOcc,t))
13 );

```



Simulation environment

Markov Decision Process (MDP) → Team Policy



Culturally competent robots?

- Specifying “culture” using knowledge representation
- Implicit assumption: We can program ‘culture’ into the robots, and the only question is how to do it.



Robot decides how far it has to stand in front of human based on their nationality



Equating 'culture' to nationality:

[M. Mansouri, Can Current Methods in Knowledge Representation and Reasoning Make Robots Culturally Robust? Proceedings of Robophilosophy, 2020]

- **ignoring** cultures within a nation-state that are more **distinct** from the dominant culture
- resulting in implicit support for **conservative** social policies
- resulting in reproduction of **cultural stereotypes**



Acknowledgments



Thank you!

