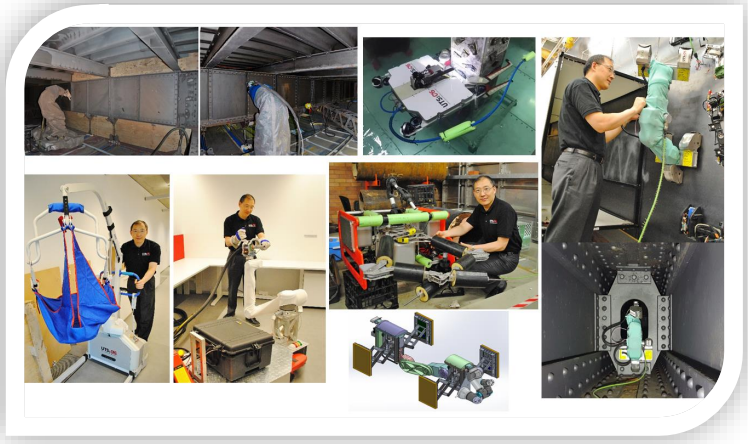
Human-Robot Teaming

---- for Building Construction and Maintenance



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Profile: https://uts.edu.au/staff/Dikai.Liu

Introduction: Humans are still doing labour intensive and dangerous jobs in hazardous environments

https://www.reminetwork.com/articles/construction-and-maintenance-work-among-the-most-dangerous-jobs/

https://www.healthyhearing.com/report/53178-Workers-comp-hearing-loss-tinnitus

- One of the industry sectors with the lowest level of automation.
- One of the most hazardous occupations

https://neuroject.com/important-tips-for-building-maintenance/

https://wollamconstruction.com/key-performance-indicators-in-construction-why-it-matters/

Intelligent Robots:

--- to transform concrete construction and maintenance by improving worker safety, streamlining processes, and reducing costs

https://www.bizjournals.com/washington/news/2021/09/01/how-robots-are-changing-the-construction-industry.html

Robots need to be capable of operating in

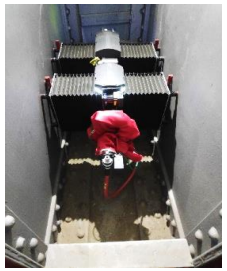
- Unstructured construction environments
- Cluttered environments
- Unknown or partially known environments
- Underwater environment with strong water current
- Collaboration with people

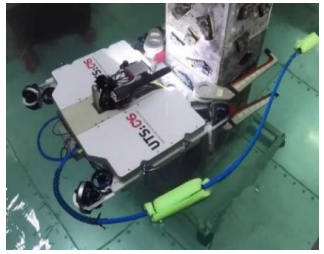
Intelligent robots for civil infrastructure

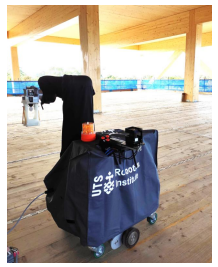
Autonomous robots for civil infrastructure

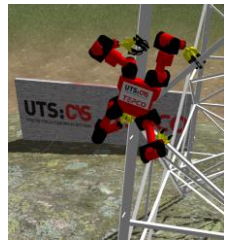
2006-2013


2010-2016


2016-2019


2014-2019


2021-2022


2017--

Human-robot collaboration (H+R) for civil infrastructure


2009-2014

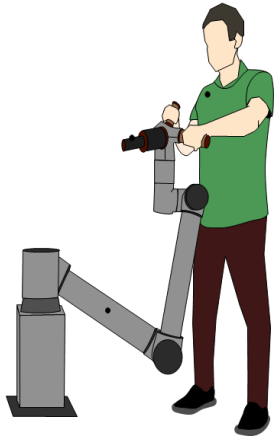

2011-2018


2022--

Human-robot teaming (mH+nR) in construction


2021 --

Robots in well structured environments



Robotic co-workers: human-robot collaboration

Fully autonomous robots

Next generation of automation technology

Core technologies:

1: Robot's **physical capability**

- Mechanical and electronic system design
- Control and software
- Sensing

2: Robot's **intelligence**:

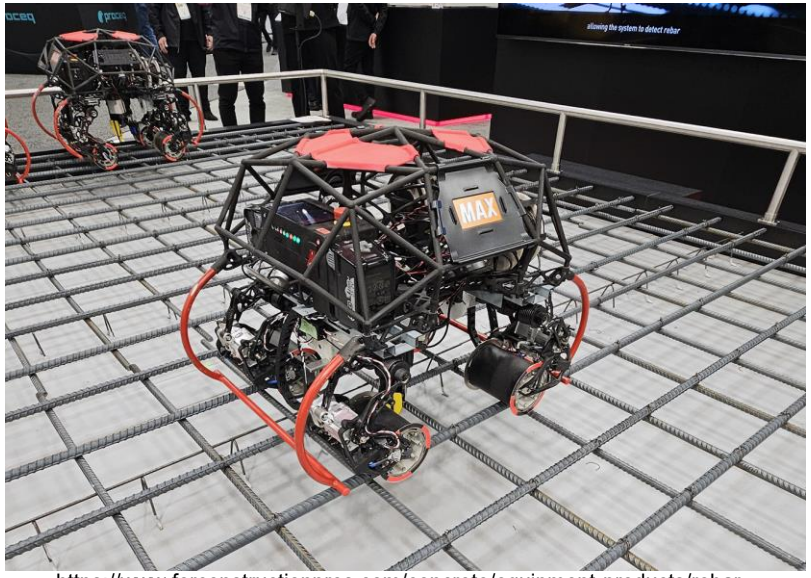
- Perception, navigation, mapping and localisation
- Environmental and operational awareness;
- Motion planning and collision avoidance;
- Robot learning

3: Robot's **capability of collaborating with humans or other robots**

- Human-robot collaboration;
- Uncertainty and incomplete information
- Multi-robot coordination and control

Examples of robots for construction

Rebar Tying Robots:

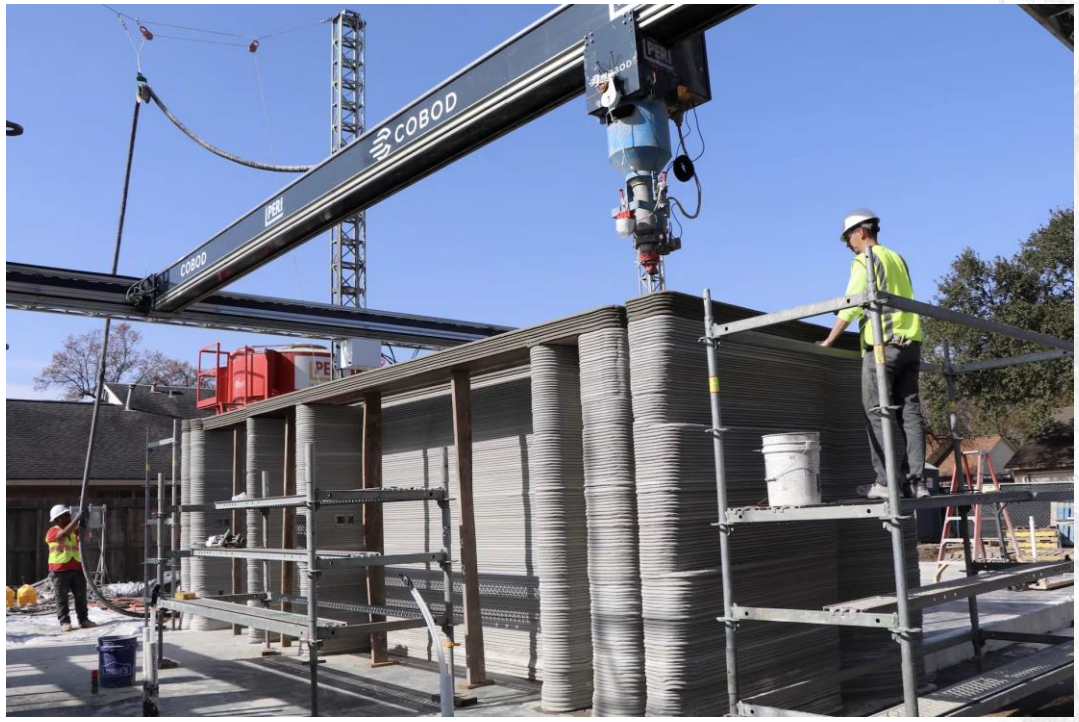


https://www.forconstructionpros.com/concrete/equipment-products/rebar-accessories-equipment/article/22866696/advanced-construction-robotics-rebar-tying-robot-helps-wisconsin-subcontractor

Concrete Slab Finisher robot

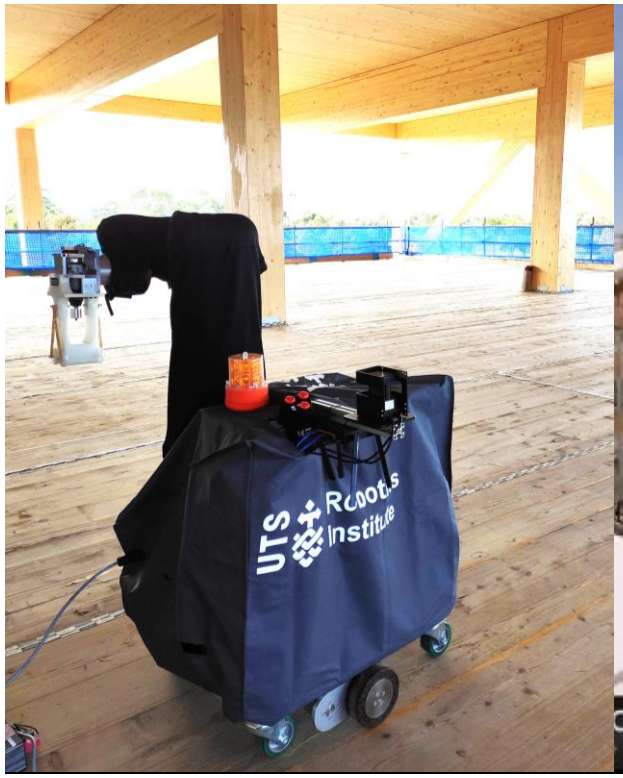
https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DkyBuMxqpy-o&psig=AOvVaw2ZEOzpTgFFFqziJ81Jt_p5&ust=1744695732238000&source=images&cd=vfe&opi=89978449&ved=0CBcQjhxqFwoTCIiJzaHo1owDFQAAAAAdAAAAABA2

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.heidelbergmaterials.com%2Fen%2Fsustainability%2Fwe-decarbonize-the-construction-industry%2F3d-concrete-printing&psig=AOvVaw0pKIQZbnq8RajPcynaLGED&ust=1744695451240000&source=images&cd=vfe&opi=89978449&ved=0CBcQjhxqFwoTCICP053n1owDFQAAAAAdAAAAABAU



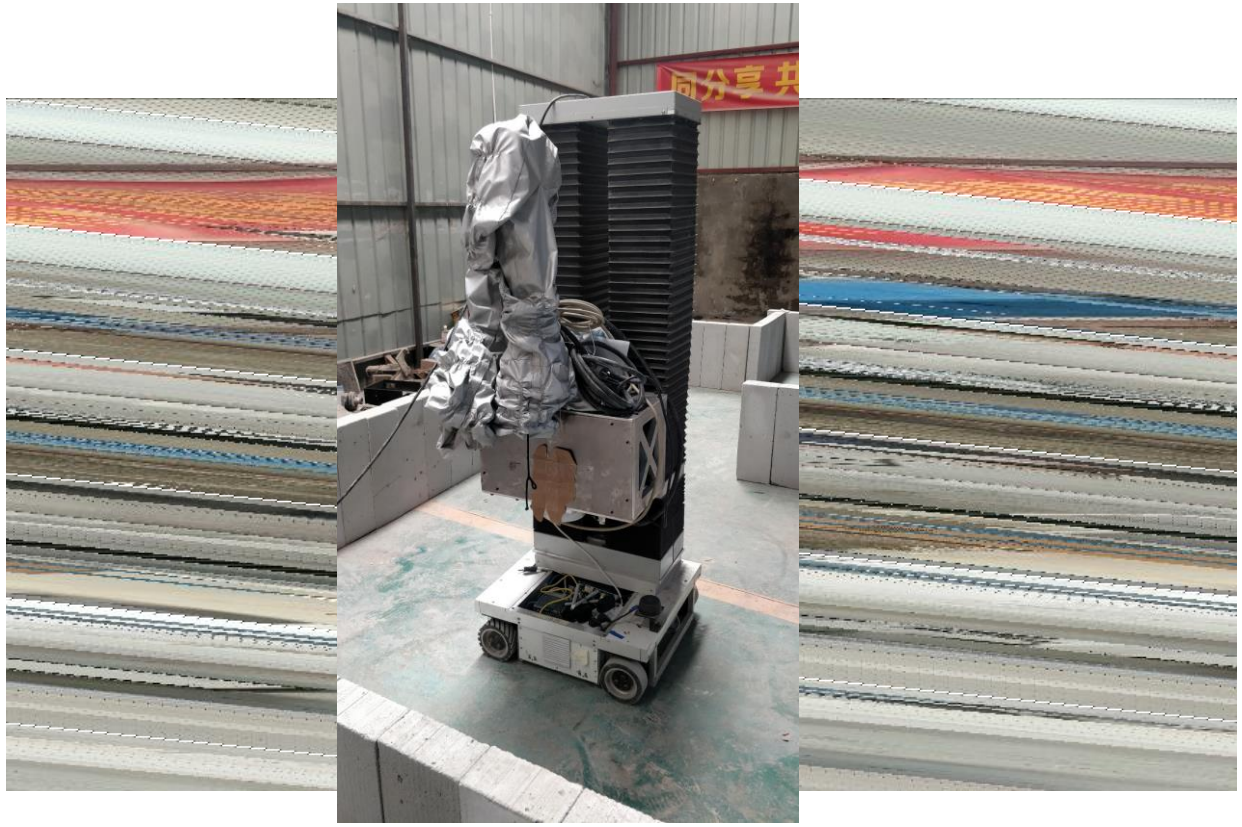
https://www.google.com/url?sa=i&url=https%3A%2F%2Fparametric-architecture.com%2F3d-concrete-printing-in-construction-applications-benefits-and-challenges%2F&psig=AOvVaw0pKIQZbnq8RajPcynaLGED&ust=1744695451240000&source=images&cd=vfe&opi=89978449&ved=0CBcQjhxqFwoTCICP053n1owDFQAAAAAdAAAAABAJ

Autonomous robots for construction (2023)



Human-robot collaborative operation in construction (2023)

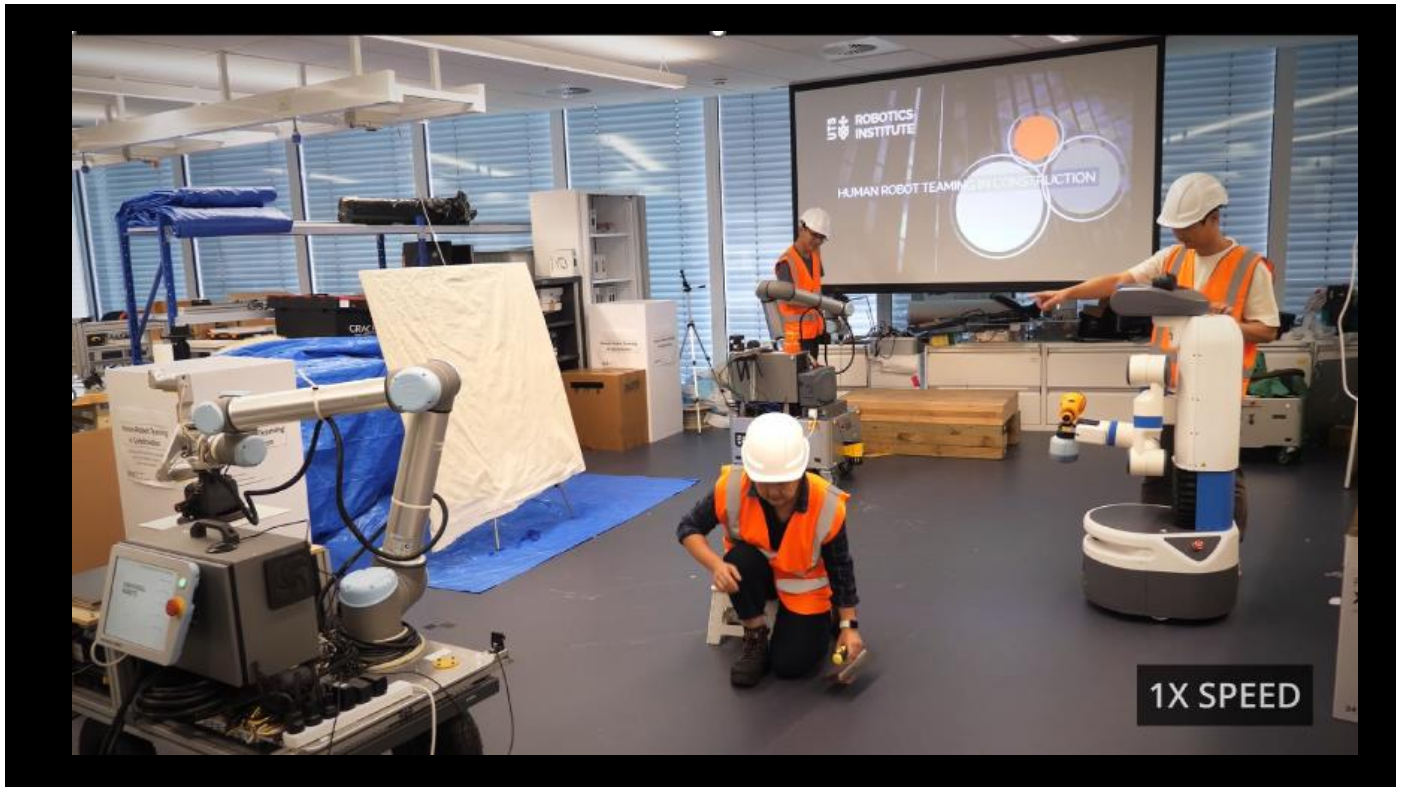
Rendering of concrete and brick walls (2020)



Human-robot teaming (2024)

Robot intelligence:

- Physical
- Cognitive
- Computational
- Linguistic

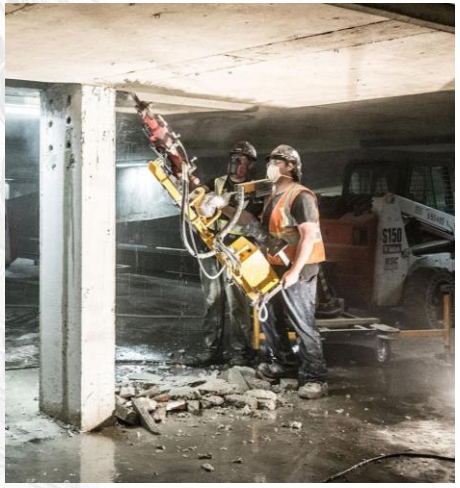


Karyne Ang, Maleen Jayasuriya, Augustine Le, Gibson Hu

Example: *HRC for painting*

Example: *HRT for drilling and anchoring tests*

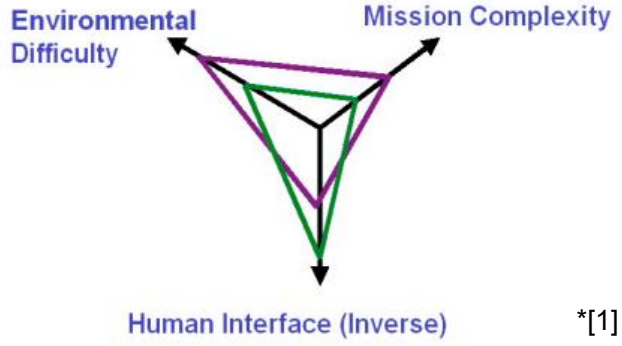
Example: *HRT for demolition tasks*



Many questions:

Level of autonomy? manual/remote operation → full autonomy

- Static or dynamic
- Terrain, soil
- Weather
- Mapping
- Localisation
- Objects
- Safety
- Threats



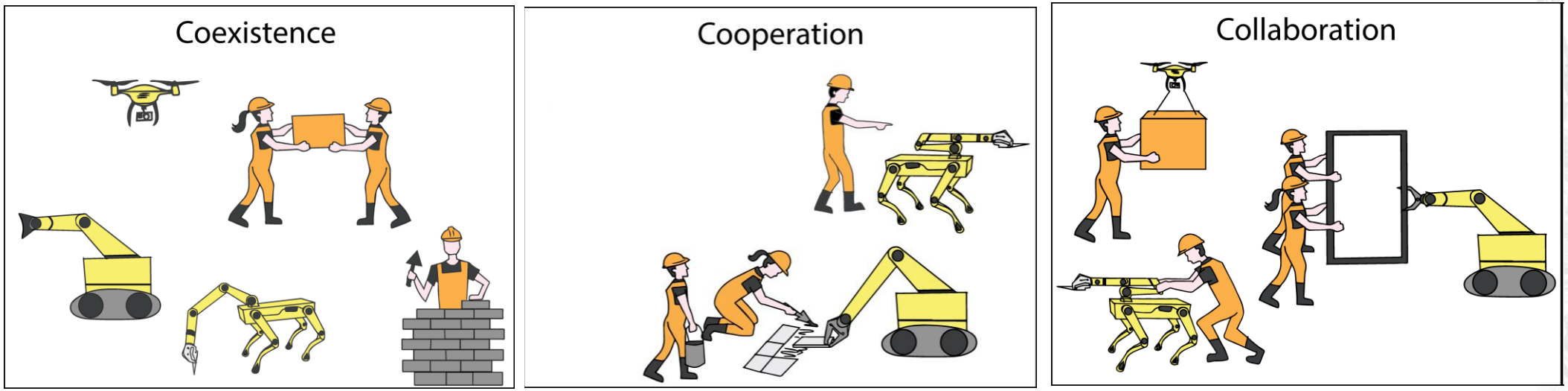
*[1]

- Sub-tasks
- Accuracy, efficiency
- Planning
- Control
- Perception, decisions
- Situation awareness
- Operational awareness

- Human workload,
- Safety
- Trust
- Frequency, duration
- Skills
- Human preferences

*[1] Hui-Min Huang, et, al, "Autonomy Measures for Robots", Proceedings International Mechanical Engineering Congress, November 13-19, 2004 (IMECE2004-61812)

Human-robot relationship?



- Assistance-as-needed?
- Human role vs robot role?
- Trust between humans and robots
- Cognitive workload and physical workload
- Safety

Personalized robots?

- AI makes it possible – robot learning
- Robot understanding of humans
- Robot trust in humans
- Co-learning
- Co-design

Robots learning human skills

Research vs practical application?

– the gap between what researchers think and what construction workers expect?

Key questions researchers may ask

- Fundamental research questions
- Technical feasibility
- Human-robot collaboration
- Adaptability and learning
- Impact on humans:
- Physical workload
- Psychological workload
- Societal and economic impact
- Integration with BIM and digital twins

Concerns construction workers may have

- Easy of use
- Safety
- Reliability
- Job security
- Performance
- Durability
- Maintenance
- Confidence (working alongside robots)

Acknowledgements:

- Colleagues in UTS
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- Roads and Maritime Services of NSW
- 13 Industry partners, RMS, Burwell, Patrick, TEPCO, ……
- ……

THANK YOU!