Deep Reinforcement Learning-enhanced Digital Twin for Robot Control in Robotized Off-Site Construction

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Robotized Off-site Construction (ROSC)

ECC Bricks
*ECC: Engineered Cementitious Composite, Damage-tolerant, reconfigurable prefab bricks

Robotics
Refurbish
(Reconfiguring)

3D Printing
(Sensor attached)

Delivery

Construction
(Assembly and Disassembly with robots)
Digital Twin for ROSC

Digital Twin
“Virtual Replica of physical assets”

Managing life cycle of ECC bricks

IoT Sensors (real-time connection)

Manufacturing

Shipping

Logicistics

Assembly

Physical object

Virtual object

“Simulation & Optimization”
Expectation is High

Unstructured

(D. Obermeier, 2020)

Evolving over time

(J. Solkoff, 2020)

High Performance Expected

Robots need adaptive control skills to improve project performance

(D. Obermeier, 2020)

(J. Solkoff, 2020)
Reinforcement Learning (RL) for Robot Control

- RL is an area of machine learning technique that enables an agent (robot) to **autonomously** discover an **optimal behavior** through trial-and-error interactions with its environment (RS Sutton, 1991).

(D. Nelson, 2019)

(S. Castro, 2019)
Deep RL for Robot Control in ROSC

- Recent advancements in deep RL has enabled robot to learn more sophisticated and adaptive control skills (Gu et al. 2017, Tai et al. 2017)

![Diagram showing an agent, DNN, actions, rewards, observations, and environment](image1)

![Image of a robot](image2)

(Mohammadi et al. 2018) (WYSS Institute, 2014)
Objective

“test a deep RL-enhanced digital twin to find an optimal policy in response to dynamic site conditions”

Digital twin

Sensor data

GPS
Properties

Real-time

Observe state

Environment

Take action

Agent

Agent 1

Agent 2

Reward
Case Study

- Small-scale robotic bridge construction w/ prefabricated bricks while site conditions are changing over time

Stockyard: Bricks arrive randomly

- Brick loading
- Delivery
- Obstacles move randomly
  - Assembly
  - Bridge
Testing Scenario for RL Learning

States (site conditions) change

Delivery status

Obstacle status

RL Agents take actions

Agent 1
Assembly robot

Agent 2
Loader robot

Assembly sequence
Loading quantity
Delivery path
Delivery Speed

Performance are estimated

Productivity
Task Duration
Travel time

Feedback (rewards)
“We will test whether RL agent can learn better policy stably over time on the dynamic ROSC environment”
Ongoing Research

Making digital twin for testing RL learning
Summary

• This study will explore the feasibility of Deep RL for adaptive robot control in ROSC.

• If Deep RL agent can find better policy over time and if its learning curve is stable while learning in dynamic ROSC site conditions (environment), it might be used for real world robot controls in the future.
Acknowledgement
References


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