

Centre of Excellence in Modelling and Simulation for Next Generation Ports Faculty of Engineering



Simulation with Learning and Optimization

Three Carriages Driving the Development of Intelligent Digital Twins for Port Applications

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Ingredients for AI Simulation + Optimization + Learning



Recognition

What are they? Functionality, Advantage, Limitation



Integration

How optimization work with learning? Role of Simulation



Extension

Expedite smart digital twins Ecosystem and driving force



Opportunity New research problem & engineering trends



Methodology Solutions applied or to be developed



Synergy Initiatives for collaboration across domain experts





Recognition - What is "Learning"?





Analyze and obtain rules from the data, and use the rules to predict unknowns



Advantage

A well-trained model can be quickly applied, suitable for real-time scenarios



Limitation

Depends on historical data, not for optimal decision-making or new scenarios



Recognition – What is "Optimization"?





Functionality

In a specific scenario, look for decisions to maximize performance measure



Advantage

Optimality ensured and not necessarily rely on the historical data

Limitation

Long computational time, need to balance speed and accuracy for real-time usage



Recognition – What is "Simulation"?



SingaPort Studio, developed by C4NGP



Functionality

Model and simulate system behaviors to characterize key characteristics



Advantage

Describe close to reality, and quantify the complex interaction in a system



Limitation

Time-consuming evaluation with only preset decisions and rules



Recognition – How Optimization works with Learning?

"Learning" need to be "Optimized"

Select the proper model and parameters to improve the learning efficiency and quality

> "Learning" is an "Optimization"

A process to minimize the error between the knowledge and the observed results



"Learning" accelerates "Optimization"

Predict solution space with better performance to guide the search for optimal solution

"Learning" from "Optimization"

Combine 2 advantages into 1, a key approach for real-time intelligence



Recognition - The Role of "Simulation"?



Reinforcement Learning + Deep Learning





Recognition - The Role of "Simulation"?

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Learning



Optimization



Simulation



Recognition - The Role of "Simulation"?



01 Realistic and Formal Problem Description

Needs to define quantify the stochastic and dynamic interactions and system behaviors at the desired precision level

)2 Efficient Virtual Deduction Environment

Need fast computation to deduce the dynamic impact of various decisions under stochastic scenarios via complex system structure

03 Reliable Decision Verification Platform

Need to calibrate with the real system to verify the performance of decisions made, and ensure credibility of verification results





Opportunity – New Trends for Research & Development





Methodology – Framework for Simulation Optimization and Learning



O²DES Simulation Framework



Methodology – Improved Simulation Modeling Formalisms



O²DES Simulation Framework Event-based Approach Precise but tedious



Methodology – Improved Simulation Modeling Formalisms





Fidelity - SINGAPort Studio







Methodology – Improved Simulation Modeling Formalisms



Efficiency – SINGAPort Studio





Methodology - Learning with Simulation





Scenario \rightarrow Optimal Decision

Scenario + Candidate Designs → Optimal Choice



Methodology - Learning with Simulation



Scenario + Decision \rightarrow Performance



Current + Past Observation → Future Observation





Thank You!



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