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OVERVIEW OF SANTTU PROJECT – SIMULATION AND AI TOWARDS AUTONOMOUS HEAVY MACHINERY

Grzegorz Orzechowski

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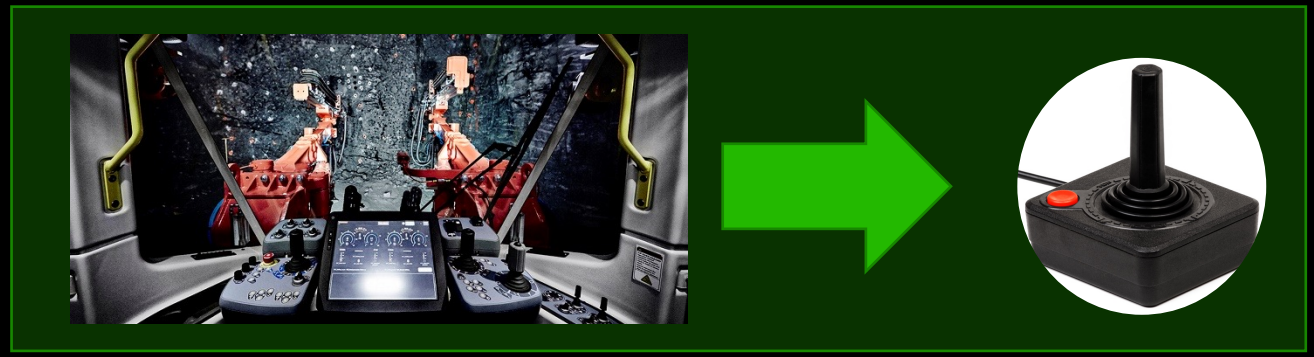
WHAT IS SANTTU PROJECT



- Machine operator assistance system that reduces stress and complexity for the operator while improving performance and consistency of the working process.
- Five piloted use cases during project:
  - UC1: Collision protection
  - UC2: Preventing overload and excessive equipment stress
  - UC3: Maintaining accuracy by compensating for boom flexibility
  - UC4: Human centric HMI-UX development
  - UC5: Experiential work routine automation

WHO

- LUT HMI – Remote operation, Human-centric HMI-UX
- OULU – Flexible body simulation for data generation
- AALTO – Virtual environment sensor fusion, semantic segmentation
- LUT SIM – Virtual machine models for control and collision avoidance

CONTACT LIST

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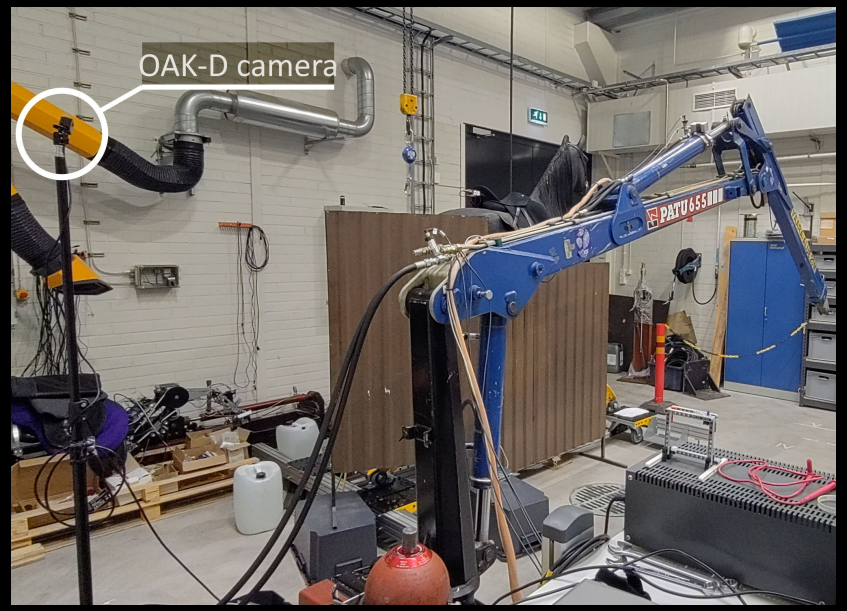
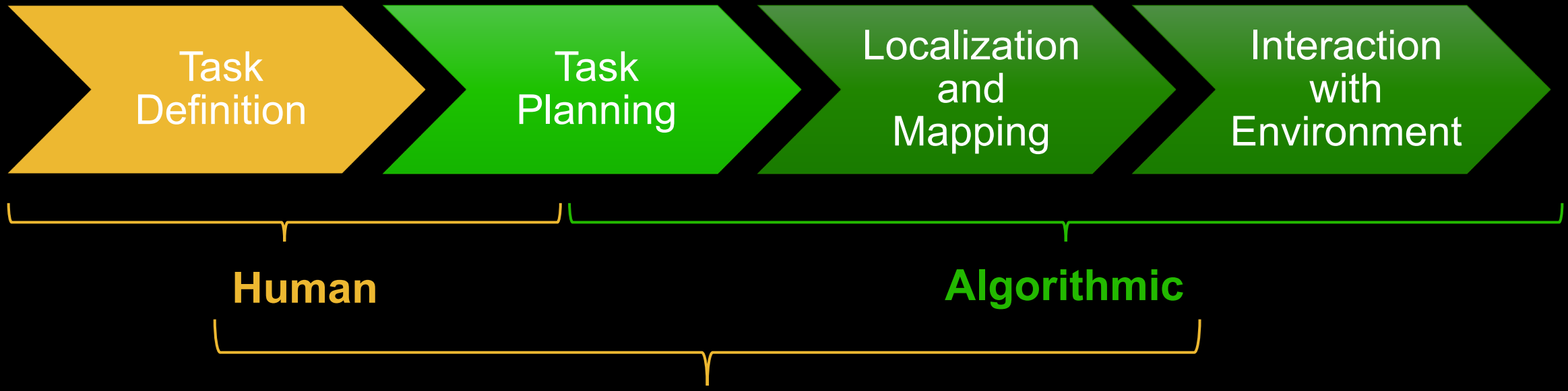
- OULU – Emil.Kurvinen@oulu.fi, Qasim.Khadim@oulu.fi
- AALTO – Ville.Kyrki@aalto.fi, Francesco.Verdoja@aalto.fi
- LUT SIM – Aki.Mikkola@lut.fi, Grzegorz.Orzechowski@lut.fi

CASE EXAMPLE – PATU LOG CRANE



SANTTU

WORKFLOW TOWARDS AUTOMATION



SPATIAL MAPS SEMANTIC SEGMENTATION

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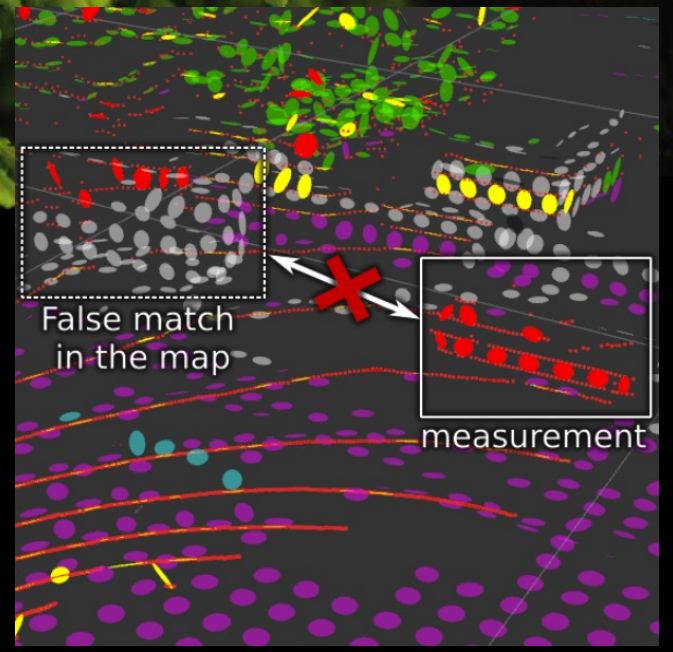

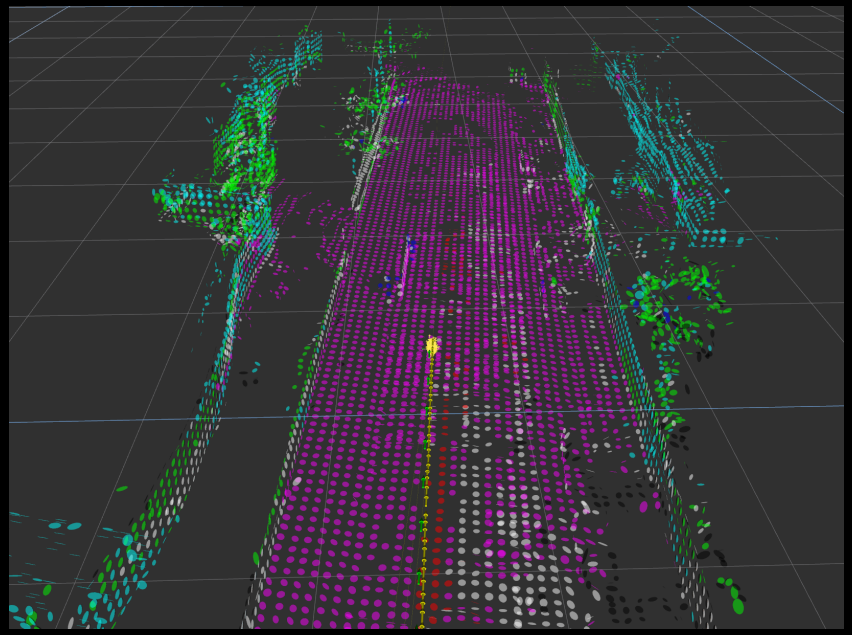

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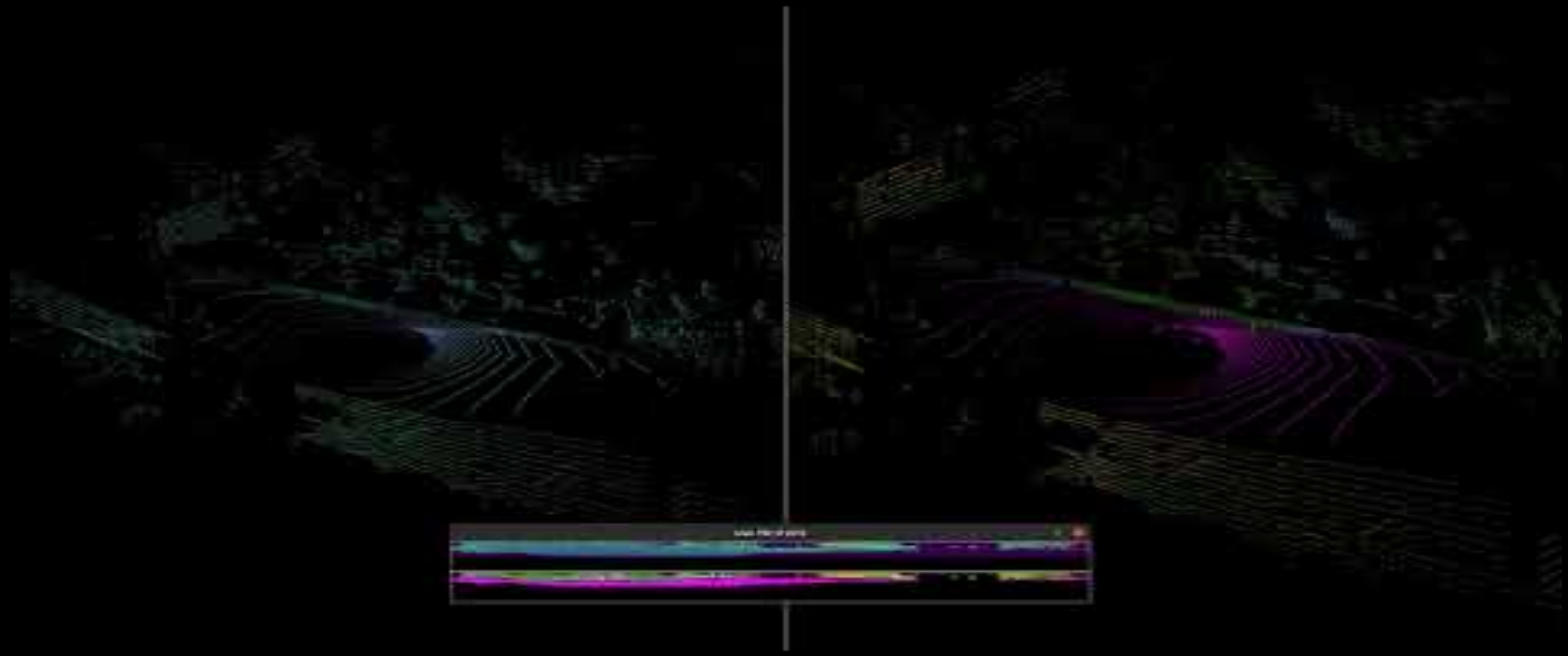
SEMANTIC-DYNAMIC LOCALIZATION



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A?
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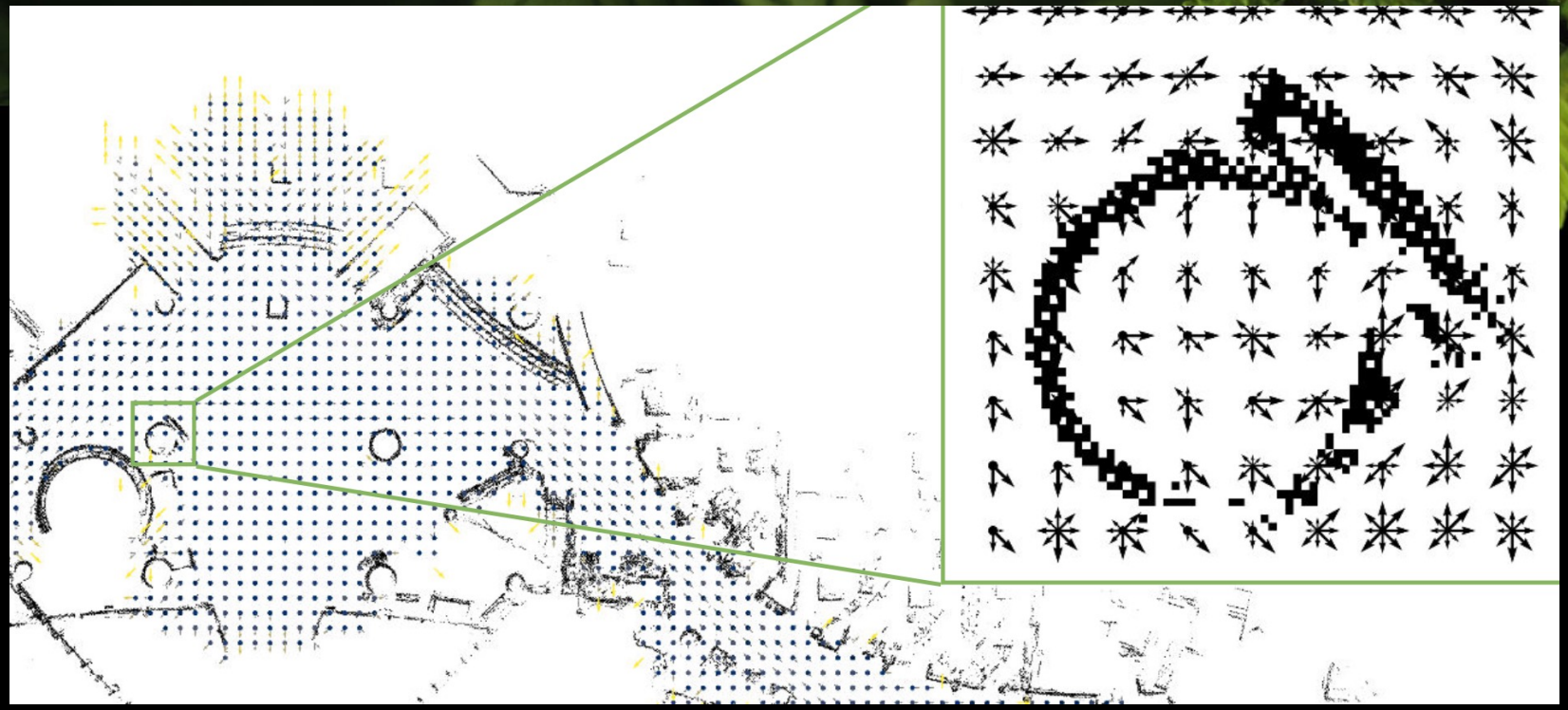
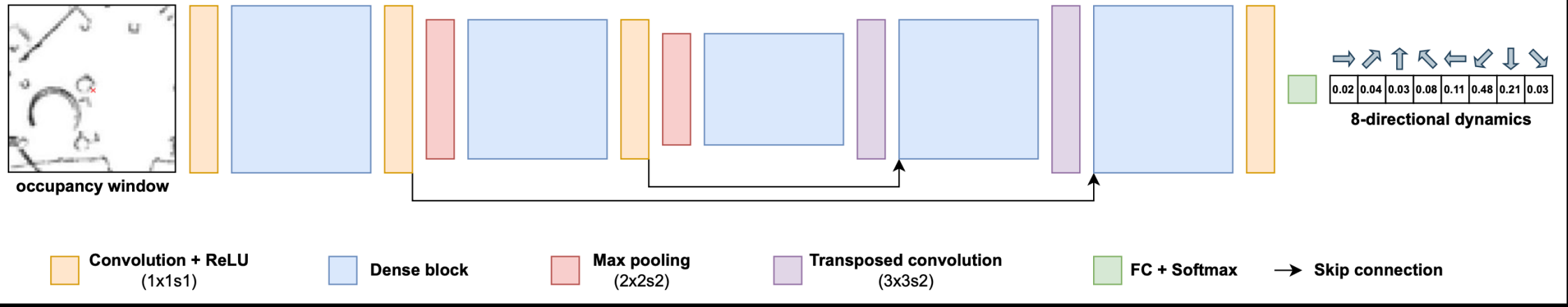
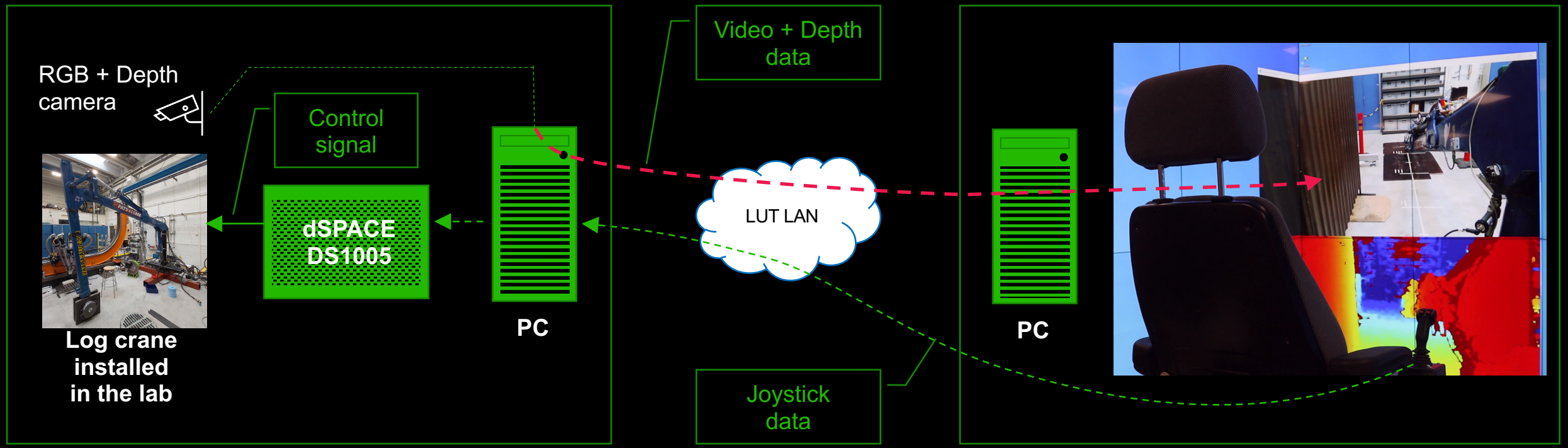




REMOTE CRANE OPERATION FROM ANOTHER LAB – HMI

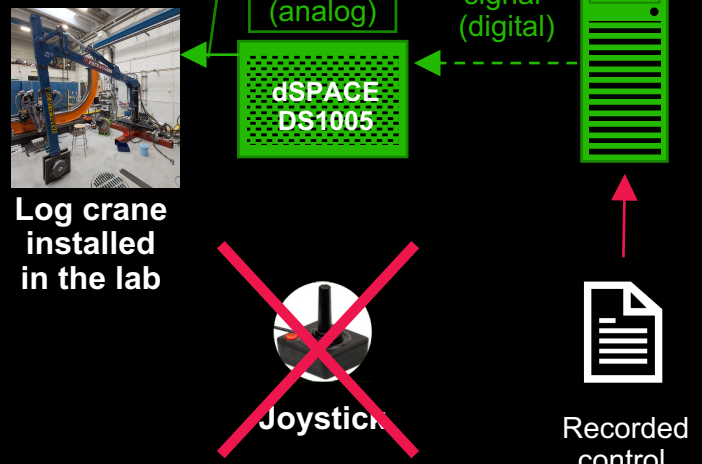
Demo video

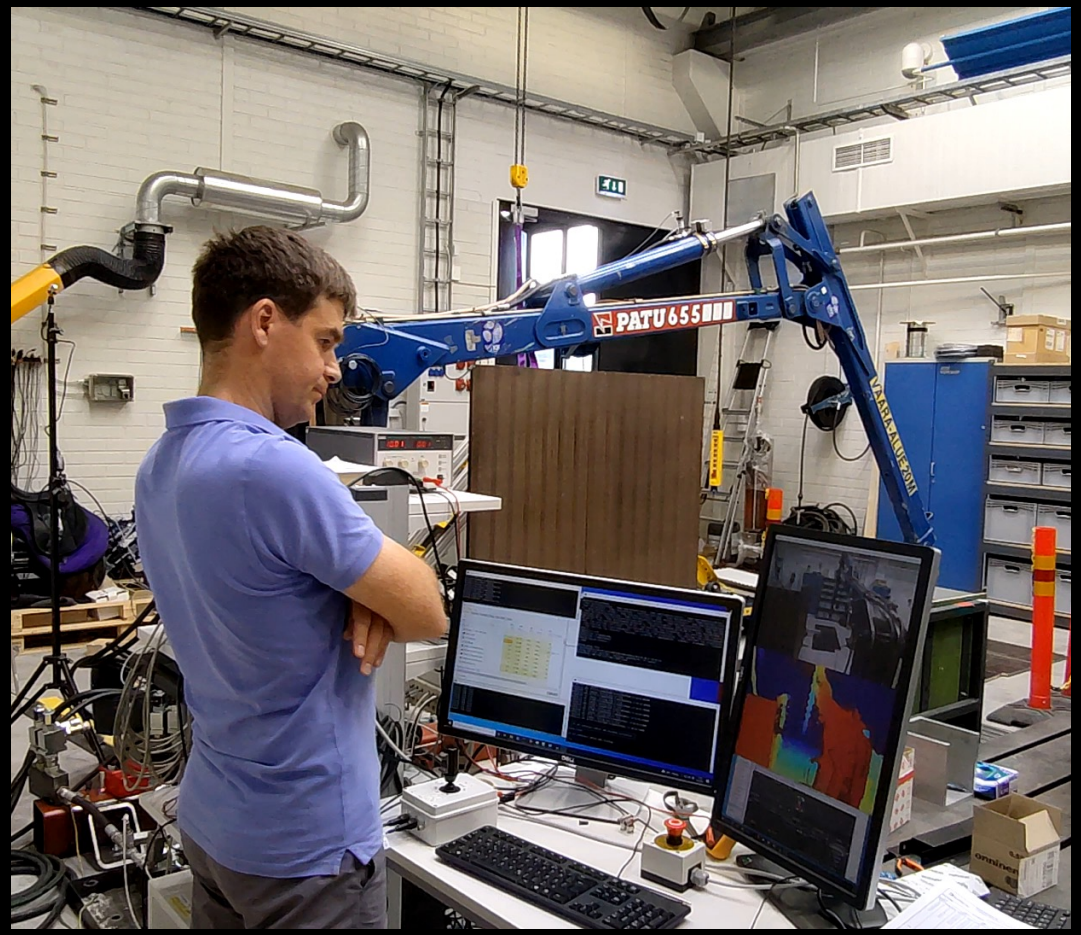


Tests implemented. Working on HMI improvement.

LUT, Laboratory of Intelligent Machines. Heikki Handroos, Victor Zhidchenko, Egor Startcev

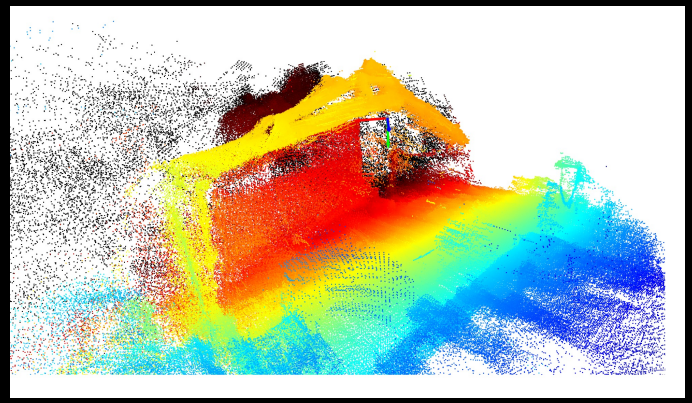
REMOTE PATU: GETTING READY FOR AUTOMATIC CONTROL – HMI



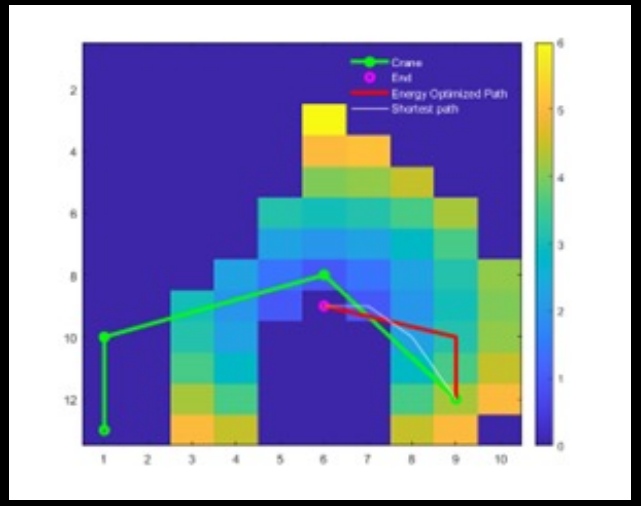


ENERGY-EFFICIENT PATH PLANNING – HMI

1) Scan the working environment



2) Build an optimal path

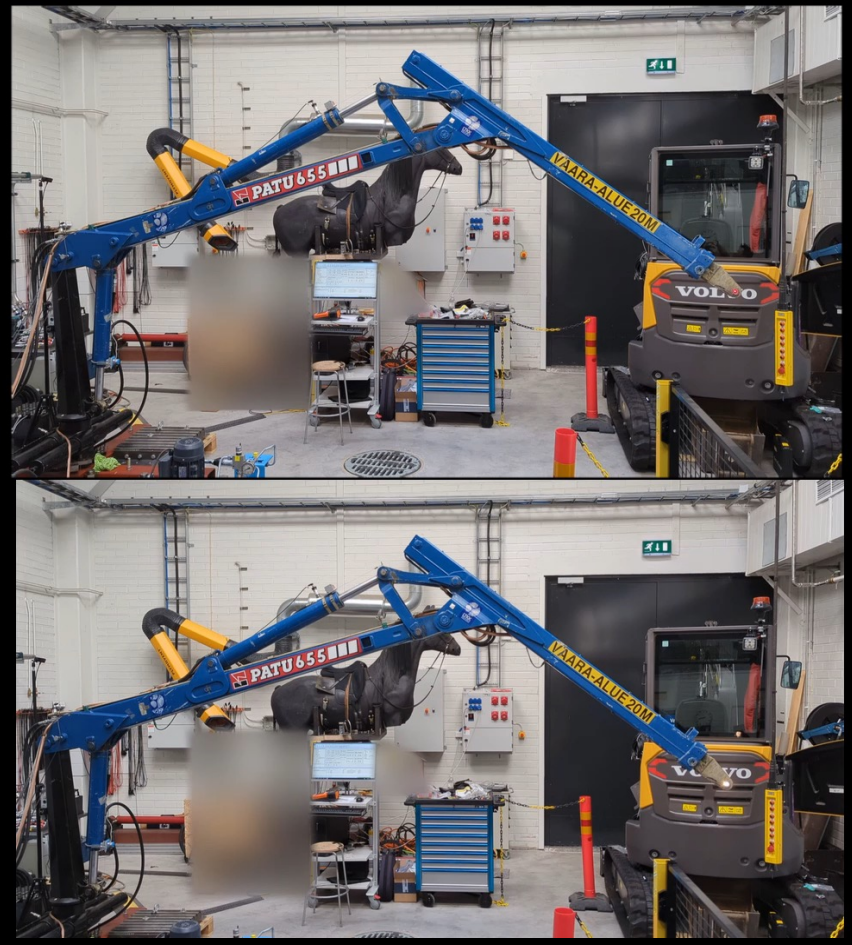


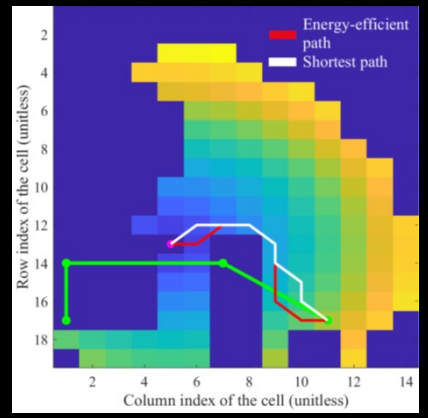
3) Move the crane automatically

ENERGY-EFFICIENT PATH PLANNING – HMI

Shortest path

Efficient path

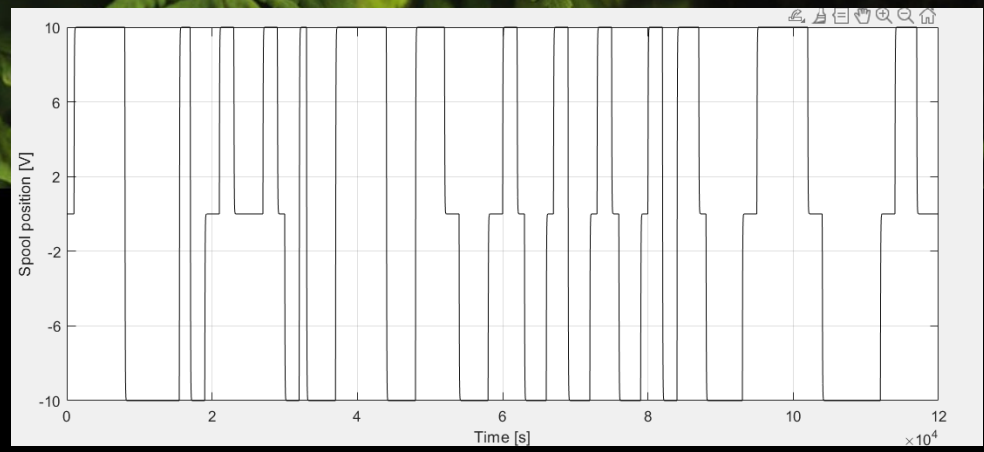




2% faster
5% less energy

NN AND BOOM DEFLECTIONS

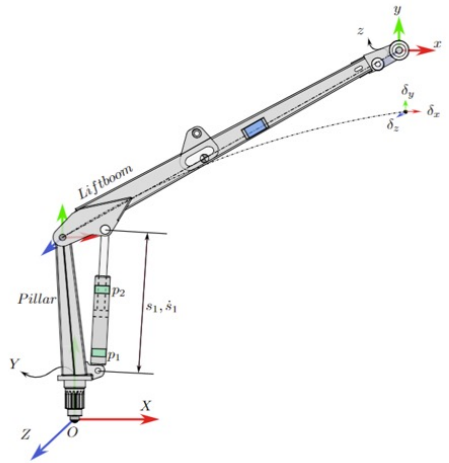
(SIM LUT + OULU)



FFNN ARCHITECTURE

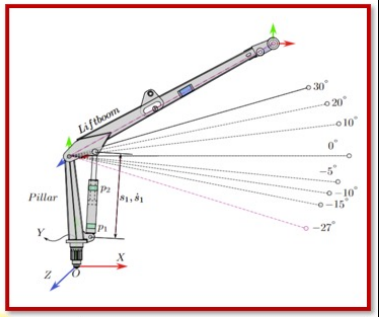
$$\begin{bmatrix} s \\ \dot{s} \\ p_1 \\ p_2 \\ \dot{\theta}_x \\ \dot{\theta}_y \\ \dot{\theta}_z \\ U \end{bmatrix}$$

INPUT LAYER

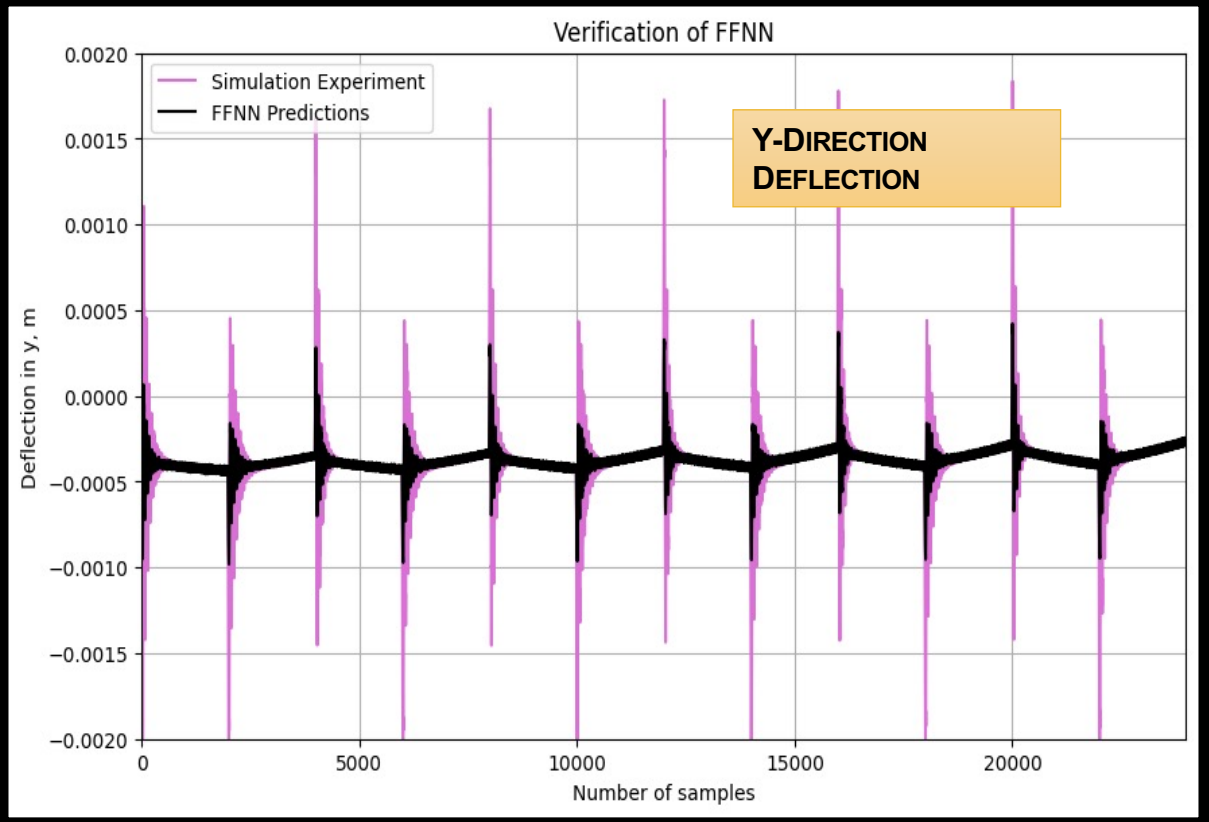


$$\begin{bmatrix} \delta_x \\ \delta_y \\ \delta_z \end{bmatrix}$$

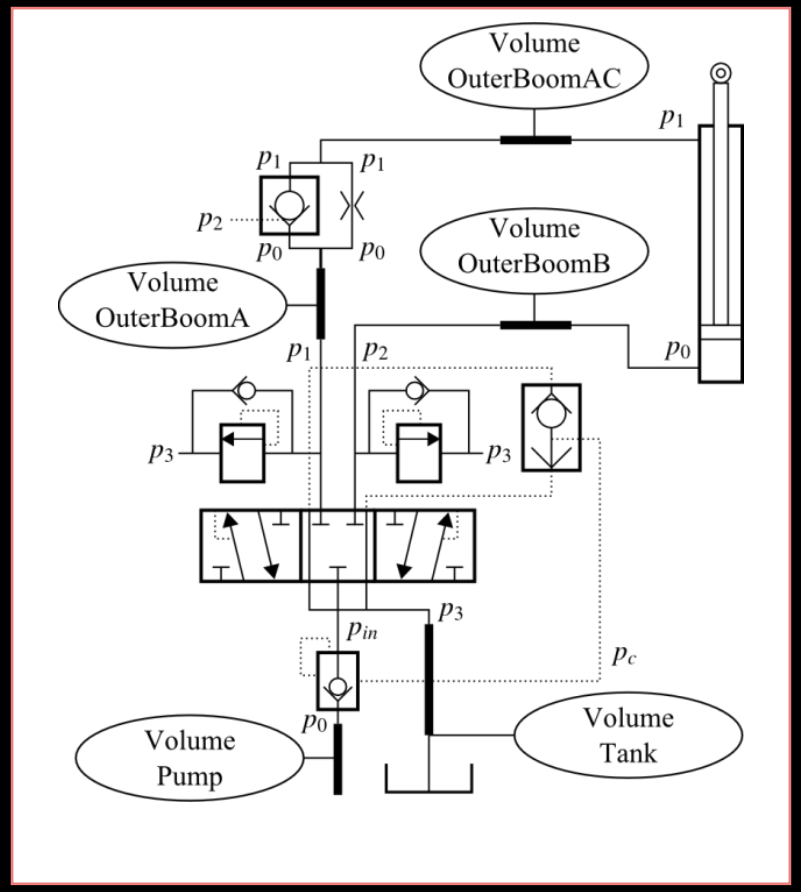
OUTPUT LAYER



SIMULATION TRAINING DATA



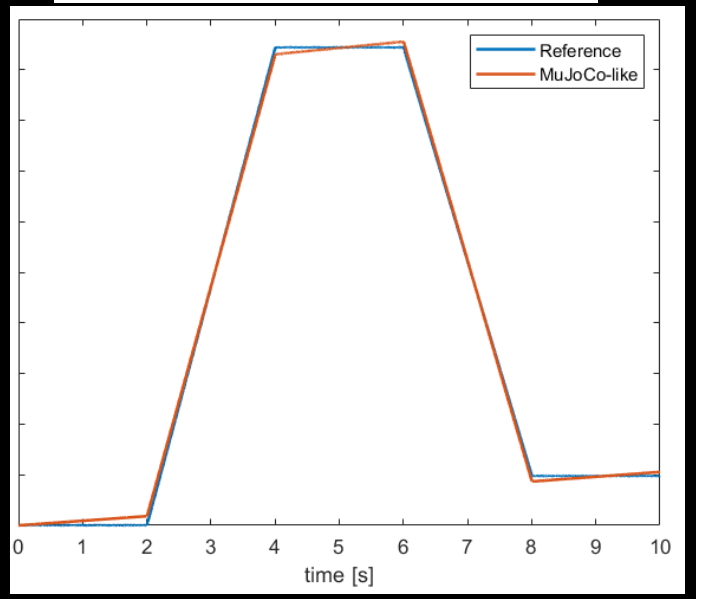
EFFICIENT HYDRAULICS



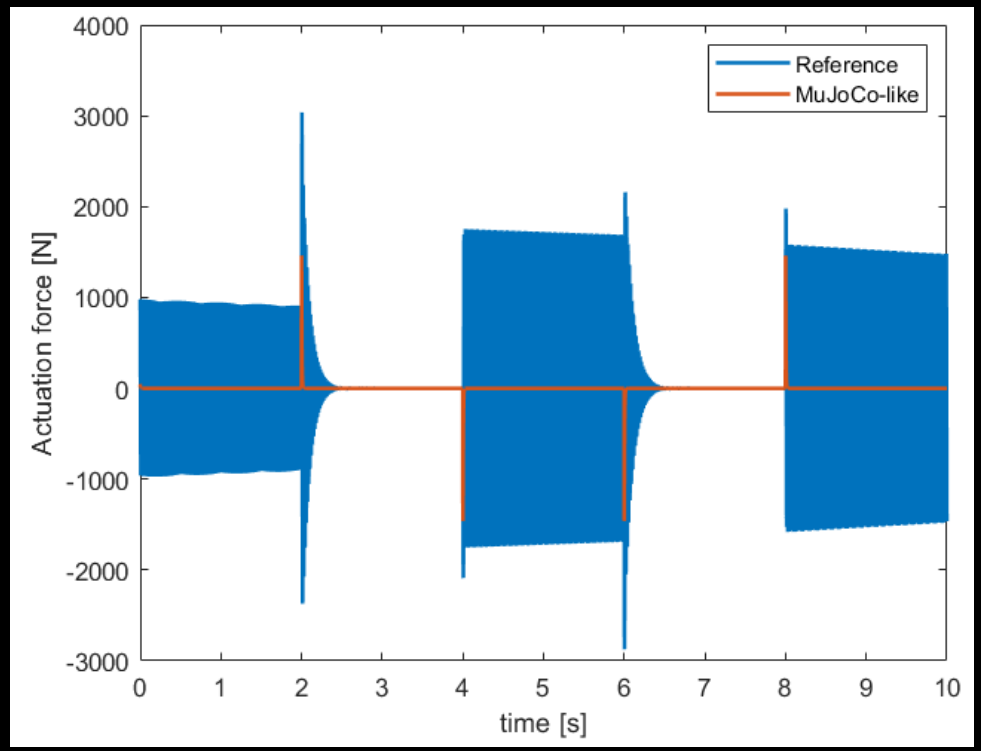
$$\dot{p}_1 = h_1 = \frac{B_{e1}}{V_1}(Q_{31} - A_1\dot{s})$$

$$\dot{p}_2 = h_2 = \frac{B_{e2}}{V_2}(A_2\dot{s} - Q_{2V})$$

$$\dot{p}_3 = h_3 = \frac{B_{e3}}{V_3}(Q_{V3} - Q_{31})$$



$$F_{mjc} = au + b_0 + b_1 s + b_2 \dot{s}$$



AI (Perttu Hämäläinen – Aalto)

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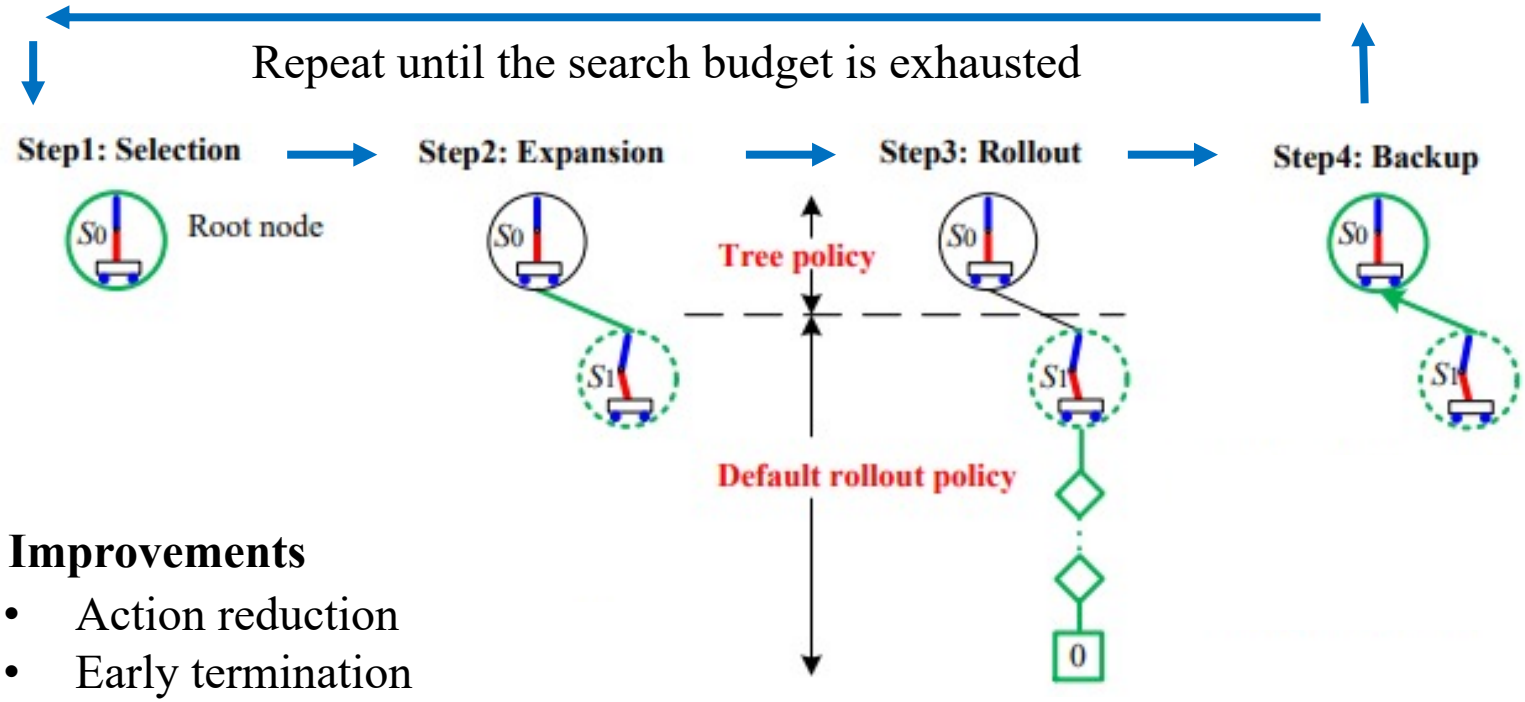
The core of MCTS and its improvements – SIM

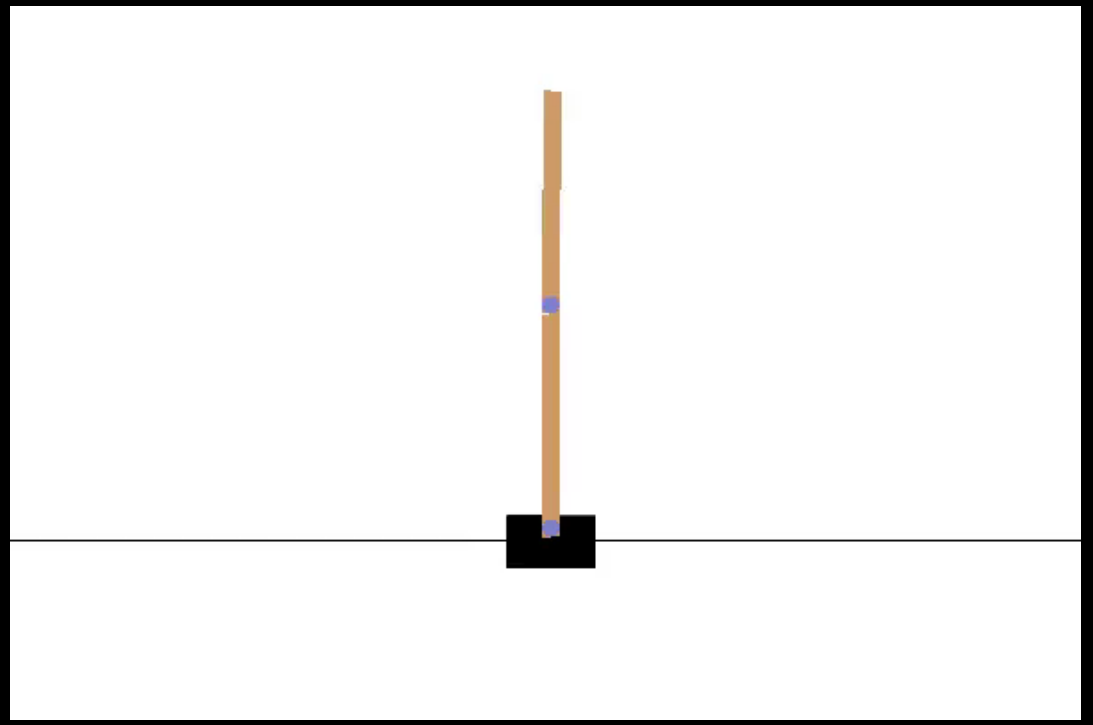
The core of MCTS is an iterative process divided into four steps



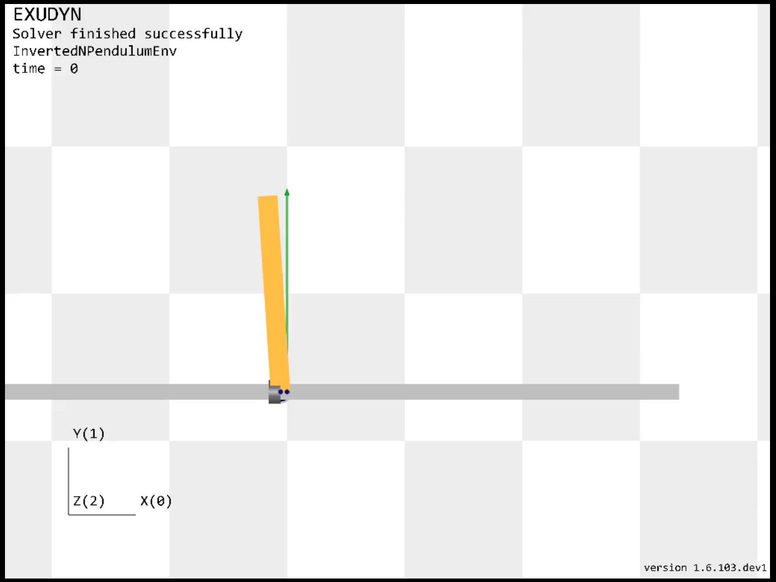
Improvements

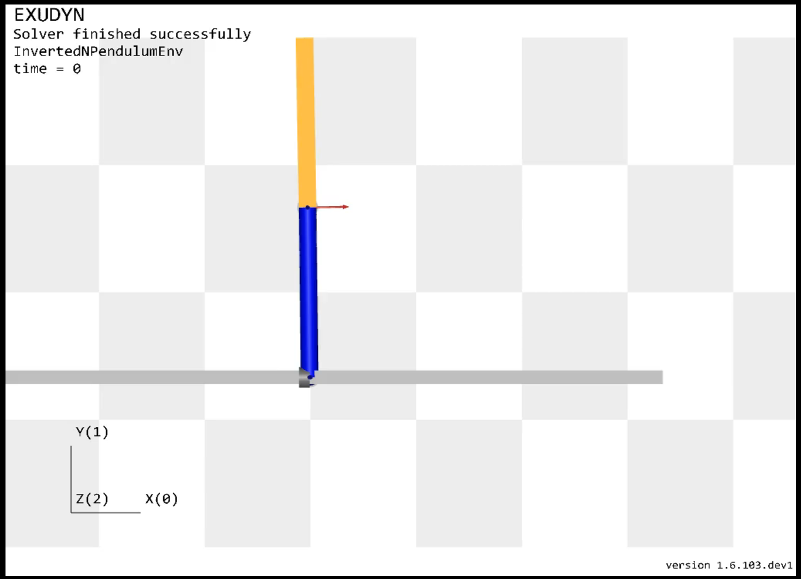
- Action reduction
- Early termination
- Trade-off parameter design
- Reward function design

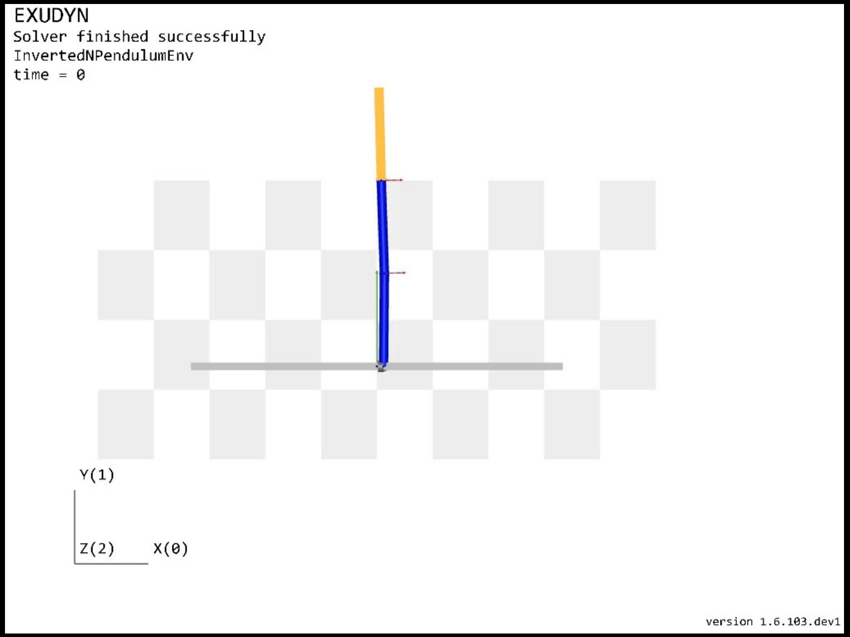
LEARNING VS SEARCHING – SIM



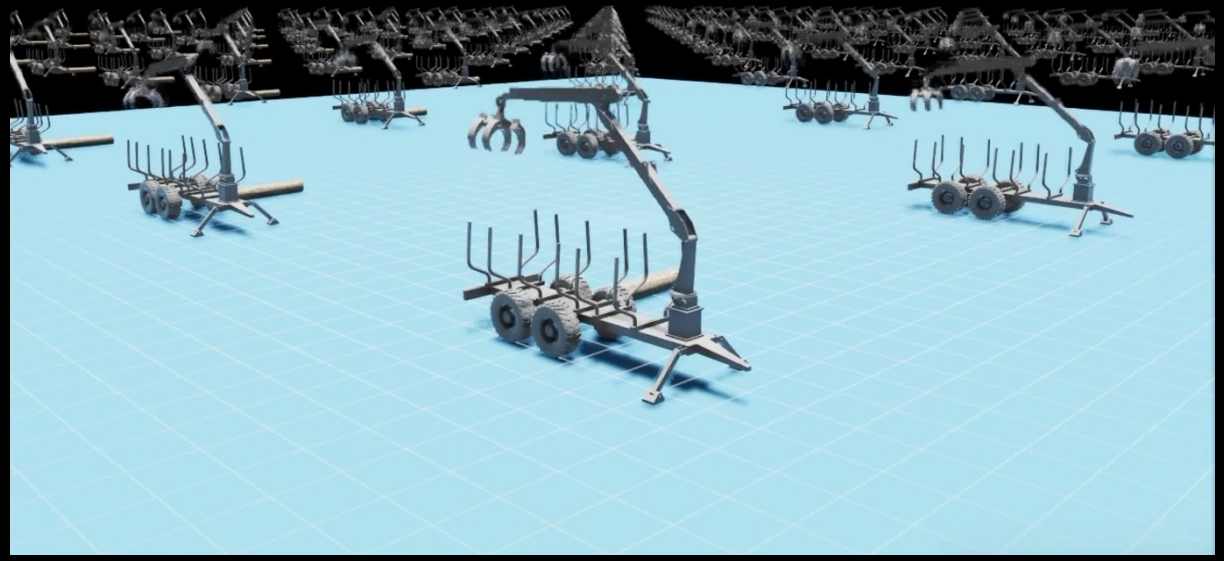
COMBINING AI WITH MULTIBODY SYSTEMS – SIM



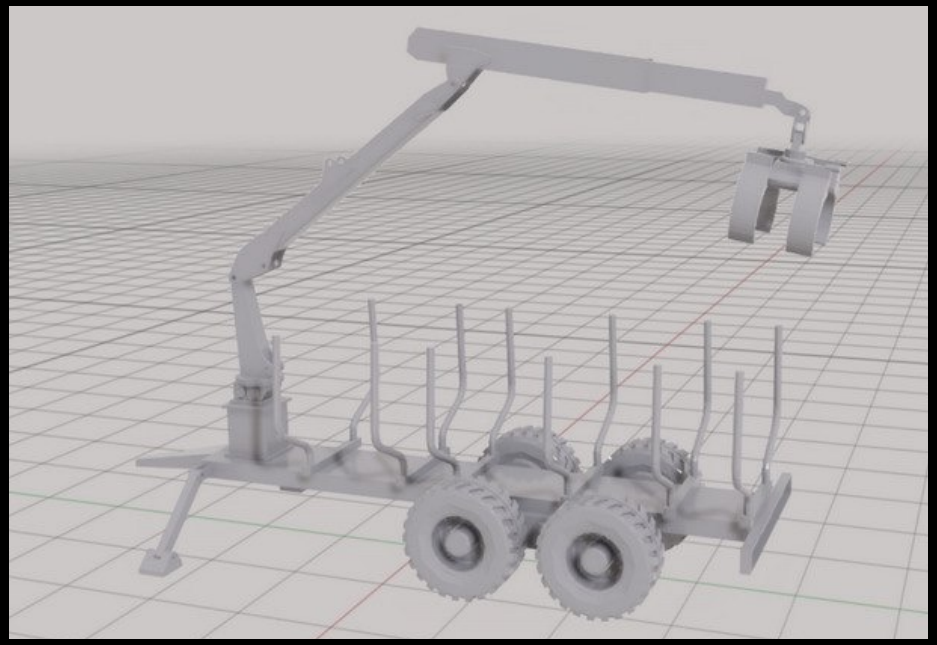




ISAAC GYM ENVIRONMENT – SIM



Isaac Gym environment



Forwarder model

NEXT STEPS

Future customer value

- Fleet operation
- Autonomous level increase

- Virtual material manufacturing
- AI and robotics applied to ship recycling
- Digital technologies for Remanufacturing and circularity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