TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

Aalto University
School of Engineering

SEASPIDER - Cooperative Heavy-Duty Hydraulic Manipulators for Sustainable Subsea Infrastructure Installation and Dismantling

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INTRODUCTION

Interest in the Arctic region and the exploitation of resources in the Arctic Ocean is continuously increasing because of climate change and the exhaustion of ground resources. Evidently, Finland has a strong interest in retaining its leading position in the sustainable development of the Arctic region [1].

Arctic subsea operations are extremely challenging. Last year, Shell withdrew from the Alaska coast, without drilling no oil, as it hit technical and legal (safety) hurdles [2]. Currently, subsea operations are carried out with surface-operated platforms supported by small, submarine-like remotely operated vehicles (ROVs) whose safety and payload capacity are not adequate for harsh Arctic conditions and strong tidal currents.

Finland already has an existing strategic industrial sector comprising heavy-duty offshore platforms and cranes; mining and construction machinery; and material handling manufacturers with significant global markets. Therefore, **we envisage the next generation of subsea mobile working machines** to be composed of decentralized hydraulic heavy-duty manipulators carried by seabed crawlers.

OBJECTIVES AND HYPOTHESIS

- **The main objective** is to overcome four main challenges found in the control of cooperative heavy-duty hydraulic manipulators for subsea tasks:
  1) The cooperative manipulators must simultaneously grasp the object, move it along a desired trajectory on the environment, exert a pre-specified contact force on the environment, and regulate the internal force in the object.
  2) The imprecisions in the positioning of the robot base on top of a slowly moving crawler vehicle on an uneven seabed.
  3) Commercial robot force/moment sensors do not exist on the market for robots with over 500 kg and high contact forces.
  4) The subsea environment places strong practical limitations on real-time information flow among different vehicles.
- **The main hypothesis:** Despite the design challenges mentioned above, it is possible to establish a stability-guaranteed comprehensive control framework for underwater assembly tasks using two decentralized hydraulic robot arms.

IMPLEMENTATION

- To reserve the best available research resources needed in this highly ambitious project a consortium between Tampere University of Technology and Aalto University is formed
  - **TUT:** Hydraulic robotic manipulator control & Supervisory control systems
  - **Aalto:** Multi-sensor estimation and control & Learning in robotic manipulation
- The work in the project is carried out in three work packages (WPs)
  - **WP1:** Stability-guaranteed decentralized control of collaborative hydraulic manipulators (TUT)
  - **WP2:** Learning-interaction dynamics of collaborative manipulators using multi-sensor feedback (Aalto)
  - **WP3:** Integration and demonstration (TUT/Aalto)

WP1

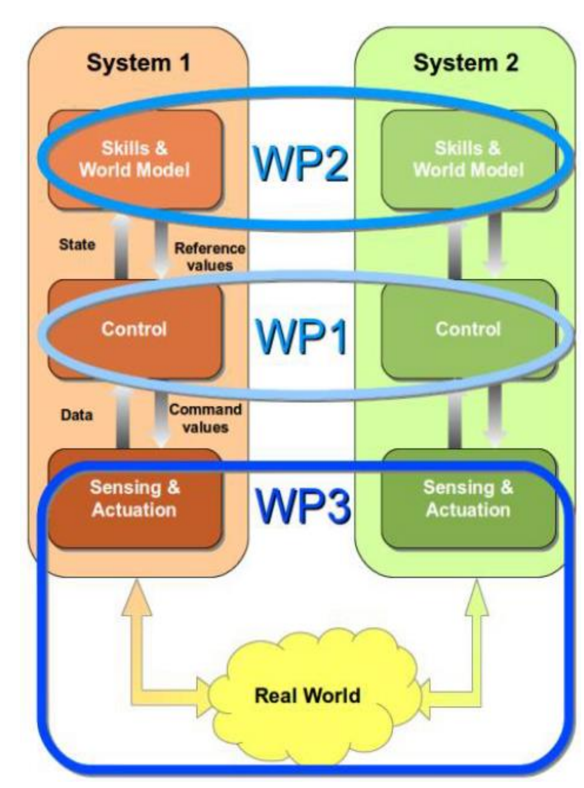
- A stability-guaranteed model-based control system (that considers a system dynamics model, including environmental contact, water drag and model uncertainties) is developed for the decentralized cooperative manipulators.
- To overcome the limitations of the current complete-dynamics-based control approaches, the detailed system modeling and control system design will be based on the subsystem dynamics-based control design [3].

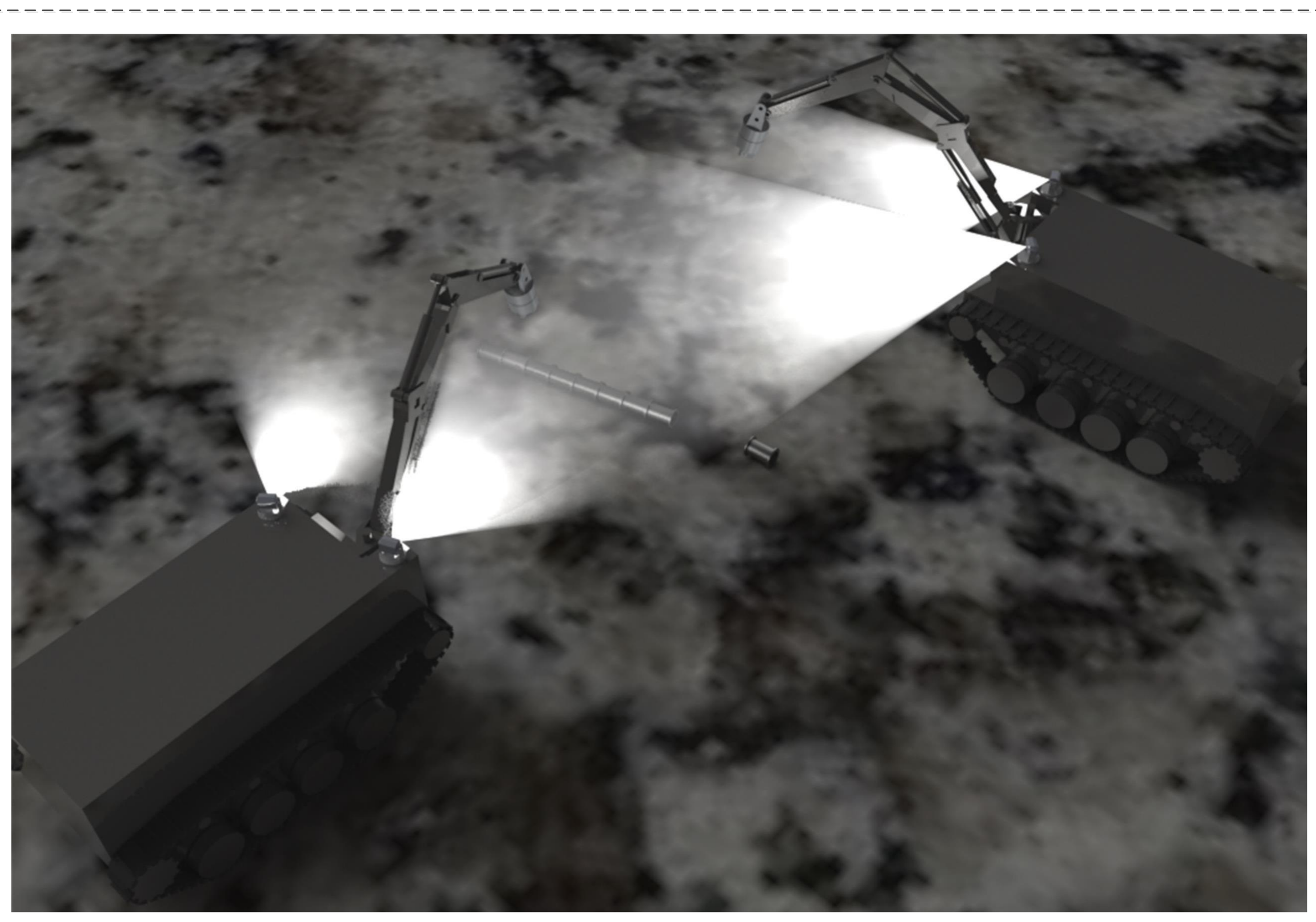
WP2

- Learning-based methods will be developed to estimate the unmodelable factors in the interaction dynamics.
- Complementary sensor data (vision and indirect force/torque identification) will be used to detect different types of contact state changes.
- The changes in the states are expected to be detected automatically to perform joint-optimization of continuous and discrete dynamics, without direct supervision.

WP3

- Integrates results from WP1 and WP2.
- The viability of the main hypothesis will be tested in IHA's 10-m-deep water tank with the two hydraulic manipulators and the pipeline assembly work mock-up.





EXPECTED OUTCOME

- Extend the current state-of-the-art solutions in
  1) the control of the cooperative hydraulic manipulators
  2) the robotic learning of the hybrid dynamical systems
- The control framework for the next generation of subsea mobile working machines to be composed of decentralized hydraulic heavy-duty manipulators carried by seabed crawlers
- To maximize the scientific impact, the each WP will produce 2-3 research papers, which will be published in top high-impact (robotic) journals.

[1] Finland's Strategy for the Arctic Region 2013, Prime Minister's Office Publications, 16/2013.
[2] USA Today, http://www.usatoday.com/story/money/business/2014/01/30/shell-suspends-arctic-operations/5050919/, 30/1/2014
[3] Zhu, W.-H., *Virtual Decomposition Control – Toward Hyper Degrees of Freedom Robots*, 2010, Springer-Verlag

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