A Universal Control Architecture for Maritime Cranes and Robots

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INTRODUCTION

This work presents a flexible and general control system architecture that allows for modelling, simulation and control of different models of maritime cranes and robotic arms by using the same universal input device regardless of their differences in size, kinematic structure, degrees of freedom, body morphology, constraints and affordances. The manipulators that are to be controlled can be added to the system simply by defining the corresponding Denavit-Hartenberg table and their joint limits. The models can be simulated in a 3D visualisation environment. The presented architecture represents the base for the research of a flexible mapping procedure between a universal input device and the manipulators to be controlled. The idea is shown in Fig. 1.

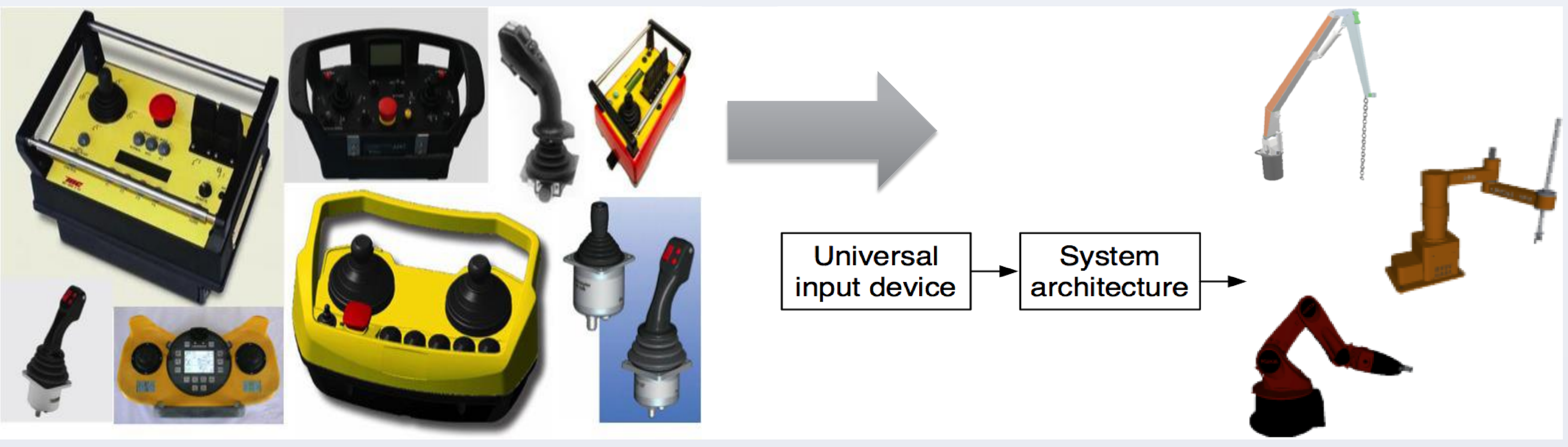

Fig. 1 The idea of realising a universal control architecture for maritime cranes and robots.

SYSTEM ARCHITECTURE

The proposed control system architecture is shown in Fig. 2. It is a client-server architecture with the input device running as a client and communicating with a server where the logic of the control algorithm is implemented. The control objective is that when the operator makes a movement such as lifting, handling, transportation or other manipulations by using the universal input device, the controlled robot should make an analogous motion. The proposed architecture provides the possibility of controlling the arms in position mode or velocity mode. For all the different models to be controlled, the mapping methods have to implement the classic inverse kinematic functions that can be generalised as follows:

$$\theta_d = f_s^{-1}(\boldsymbol{x}_{ds}),$$

concerning position control, and

$$\dot{\theta}_d = f_v^{-1}(\theta_a, \dot{\boldsymbol{x}}_{ds}),$$

for velocity control, where θ_d and $\dot{\theta}_d$ are the desired joint values and velocities respectively, $\boldsymbol{x}_{ds}$ and $\dot{\boldsymbol{x}}_{ds}$ are the desired end-effector's position and velocity respectively and θ_a is the actual joint angles vector.

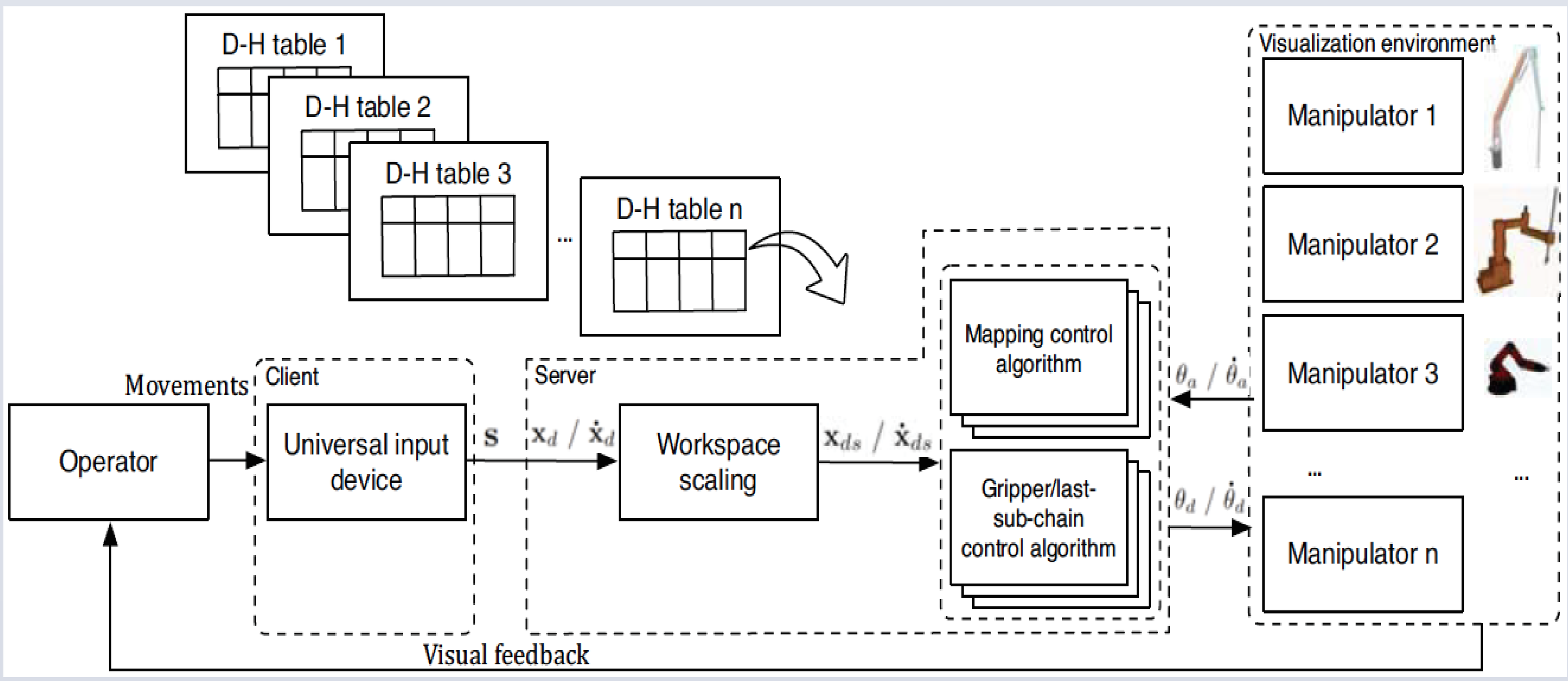

Fig. 2 The system architecture: a master-slave modular pattern is used for the communication protocol.

CONTROL METHODS

A classical kinematic approach is not suitable when planning to control different arms using a universal input device because several inverse kinematic (IK) models are needed: one for each arm or crane to be controlled. Several alternative control methods are investigated. In [1], a Genetic Algorithm (GA) is used as a possible mapping approach. Using this bio-inspired method, the system is able to automatically learn the inverse kinematic properties of different models. The flowchart is shown in Fig. 3-a. In [2], a new control method that is based on the use of an Artificial Neural Network (ANN) is presented. Learning is done iteratively based only on observation of input-output relationship, unlike most other control schemes. The network architecture is shown in Fig. 3-b.

SIMULATIONS AND EXPERIMENTAL RESULTS

For each of the controlled models, a trajectory tracking analysis of the Cartesian paths for X, Y and Z coordinates was performed. The simulation and the results for a knuckle boom crane model controlled with the control algorithm based on GA are shown in Fig. 4-a and Fig. 4-b respectively. The possibility of providing the user with an intuitive force feedback is also investigated as shown in Fig. 5, where the same knuckle boom crane model is controlled with a Force Dimension Omega.7 haptic device.

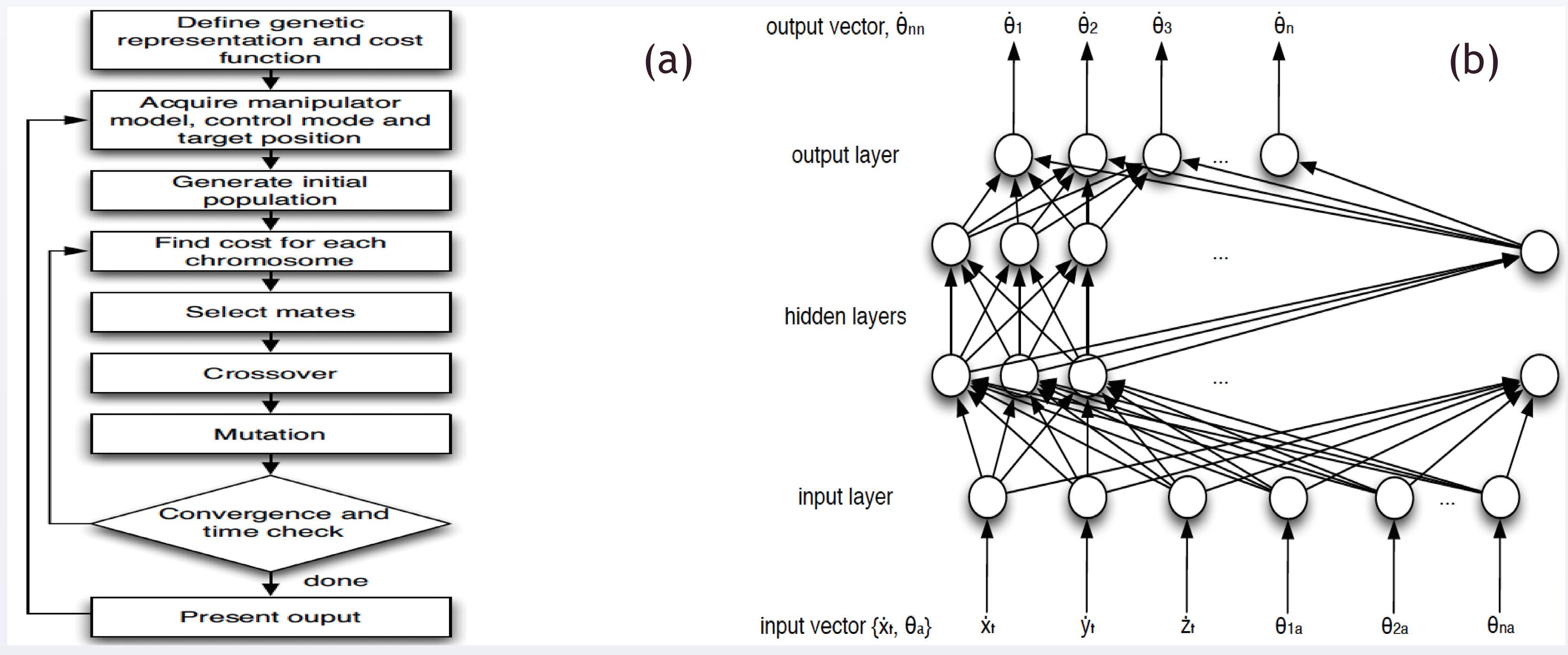

Fig. 3 Alternative algorithms: (a) the GA flowchart and (b) The ANN architecture.

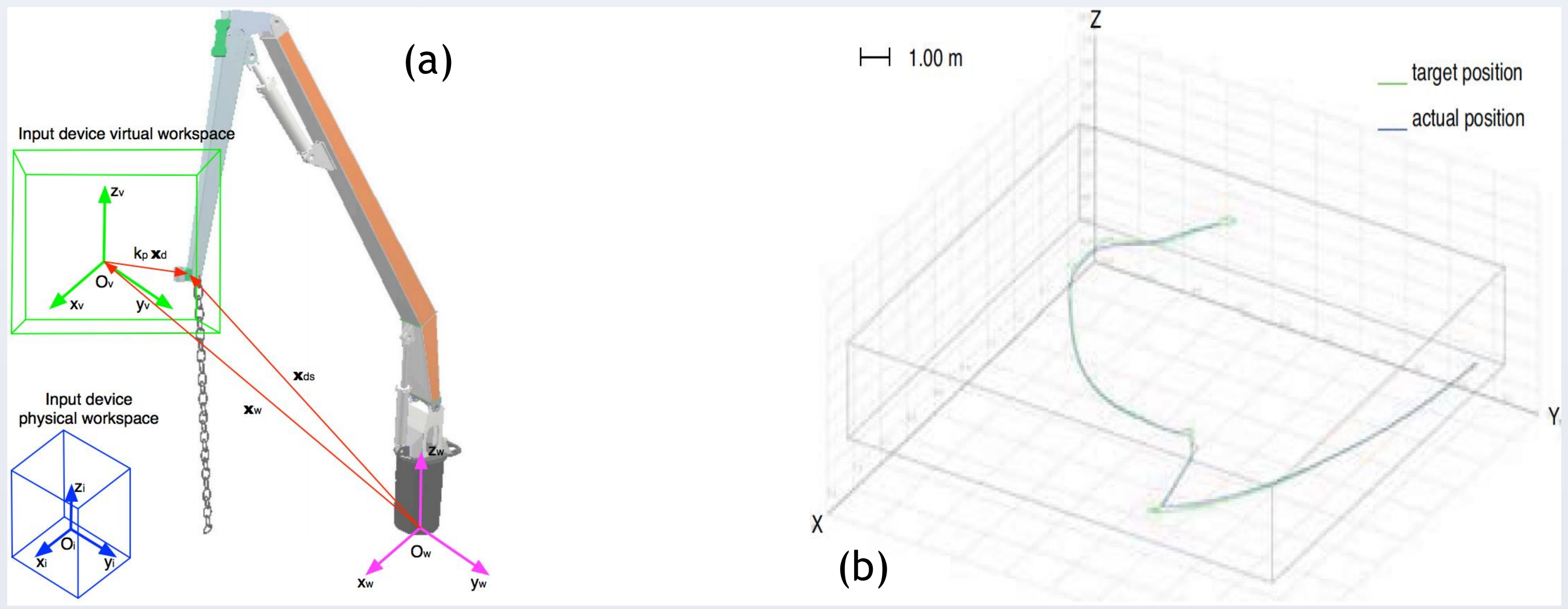

Fig. 4 (a) The simulation of a knuckle boom crane model and (b) the trajectory tracking of the corresponding Cartesian paths in X, Y and Z coordinates.

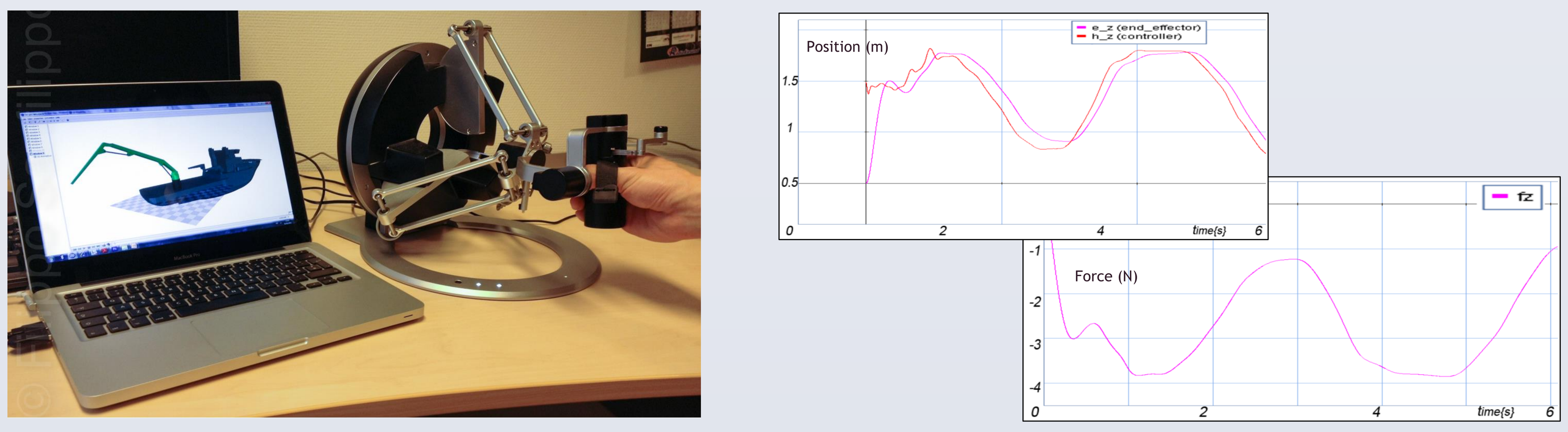

Fig. 5 The crane operator is provided with an intuitive force feedback.

The proposed control architecture is integrated with the crane/winch simulator developed by one of our research partner in Aalesund, the Offshore Simulator Centre AS (OSC), for training and educational purposes, as shown in Fig. 6.

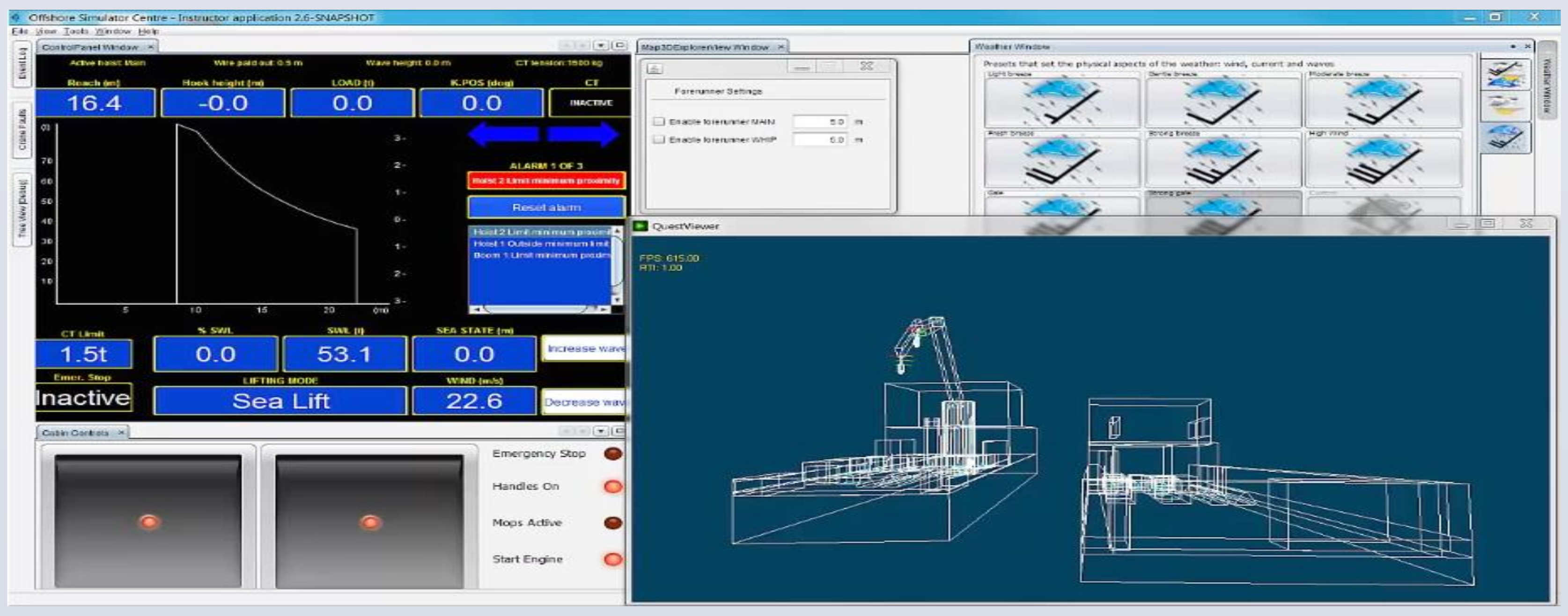

Fig. 6 The integration of the framework with the OSC crane/winch simulator.

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[2] Filippo Sanfilippo, Lars Ivar Hatledal, Houxiang Zhang and Kristin Ytterstad Pettersen. A Mapping Approach for Controlling Different Maritime Cranes and Robots Using ANN. In Proceeding of the IEEE International Conference on Mechatronics and Automation (ICMA), Tianjin, China. 2014, 594-599.

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