Waves Simulator and Active Heave Compensation Framework for Demanding Offshore Crane Operations

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INTRODUCTION

In this work, a framework that allows for reproducing in a laboratory setup the same challenging operation scenario of controlling offshore cranes is presented. This framework can be used for testing different control approaches and for training purposes. The system consists of an industrial robot, the Kuka KR 6 R900 SIXX (KR AGILUS) manipulator, and of a 3 degrees of freedom motion platform, as shown in Fig. 1. The motion platform is used to simulate the waves effects, while the robotic arm is controlled by the user with a joystick. The waves contribution is monitored by means of an accelerometer mounted on the platform and it is used as a negative input to the manipulator's control algorithm so that active heave compensation methods can be achieved. Concerning the system architecture, the presented framework is built on open-source software and hardware.

Related simulations and experimental results are carried out to validate the efficiency of the proposed framework. In particular, it can be certified that this approach allows for an effective risk reduction from both an individual as well as an overall evaluation of the potential harm.
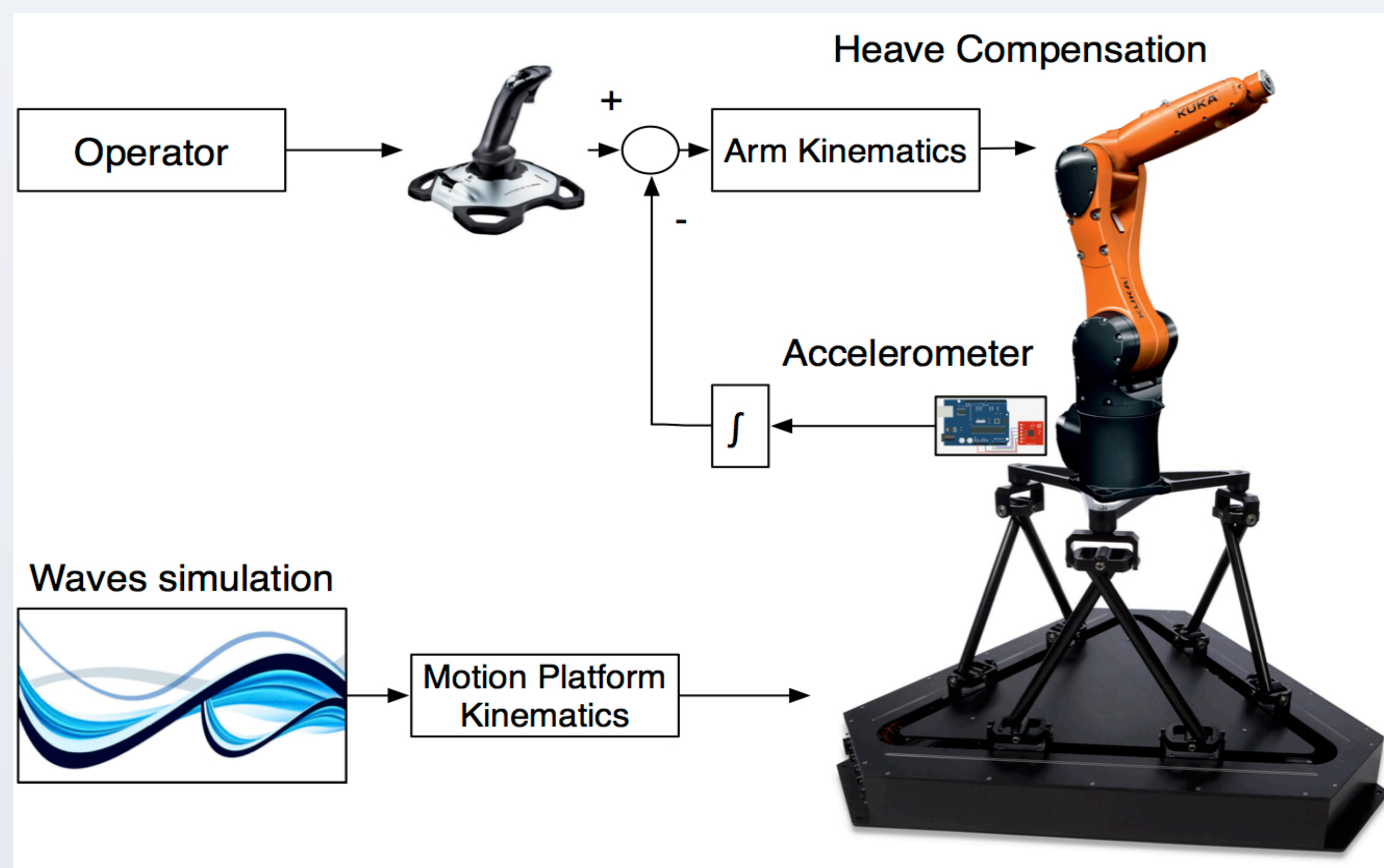

Fig. 1 The proposed waves simulator and active heave compensation framework for demanding offshore crane operations.

BACKGROUND

Under rough sea conditions, offshore activities involving crane operations result in many problems such as load sway, positioning accuracy, collision avoidance and manipulation security. Even though the operating environment can be very challenging, it is still quite common to use relatively simple control interfaces to perform offshore crane operations. In most cases, the operator has to handle an array of levers and buttons to operate the crane joint by joint [1]. When considering working efficiency and safety, this kind of control is extremely difficult to manage and relies on extensive experience with high operating skill level of the operators. In particular, when a large load sway occurs under extreme sea conditions, reliable control is almost impossible to be manually achieved. Currently, a huge amount of resources are spent on training operators and a great deal of cost can be wasted during the downtime waiting for a better weather condition. In this optic, more flexible and reliable control approaches are needed. Several research groups are investing resources in this direction. However, testing new control methods in a real setup environment is very difficult because of the challenging work-space in which maritime cranes are operated. For this reason, several studies have been performed by using a simulation environment. For instance, an effective heave compensation control approach for offshore crane operations, which is based on robotic arm kinematics and energy dissipation principles, was proposed by our research group in [2]. The system architecture integrates the control model for crane operations, the hydraulic system model for hydraulics characteristic analysis, the 3D model of the crane to be controlled, the vessel and the environment for visualisation. The proposed control algorithm and simulation model can be extended to any type of crane model regardless of its configuration or DOFs without influencing the effectiveness of the method. However, a simulation approach is always limited compared to a realistic experimental setup.

In order to give researchers the possibility of testing alternative control algorithms for maritime cranes in a realistic and safe laboratory setup, a waves simulator and active heave compensation framework for demanding offshore crane operations is proposed in this work.

METHODS

The adopted 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 presented framework is built on open-source software and hardware. The authors intend this work to be the first in a series of open-source designs to be released, and through the contributions of the open-source user community, result in a large number of design modifications and variations available to researchers.
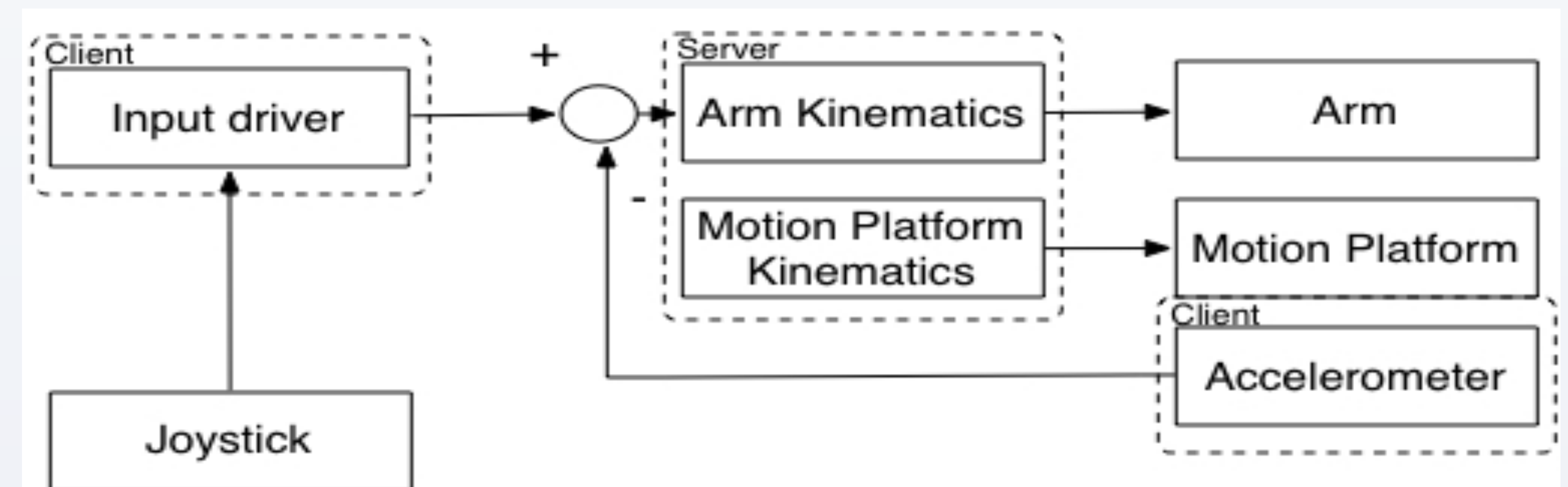

Fig. 2 The proposed client-server architecture.

Concerning the software, the communication between the server and the robotic arm is achieved by using JOpenShowVar, an open-source cross-platform communication interface to Kuka robots [3]. As shown in Fig. 3., all the hardware components of the proposed architecture are also open-source or semi-open-source. In particular, the server runs on an Odroid-U3 microcomputer. The Odroid-U3 is a powerful single-board computer equipped with a Linux operating system. The client that collects the accelerometer data runs on an Arduino board. On the software side, Arduino provides a number of libraries to make programming the micro-controller easier. The choice of using Arduino makes the proposed framework easy to maintain and makes it possible to add new features in the future.
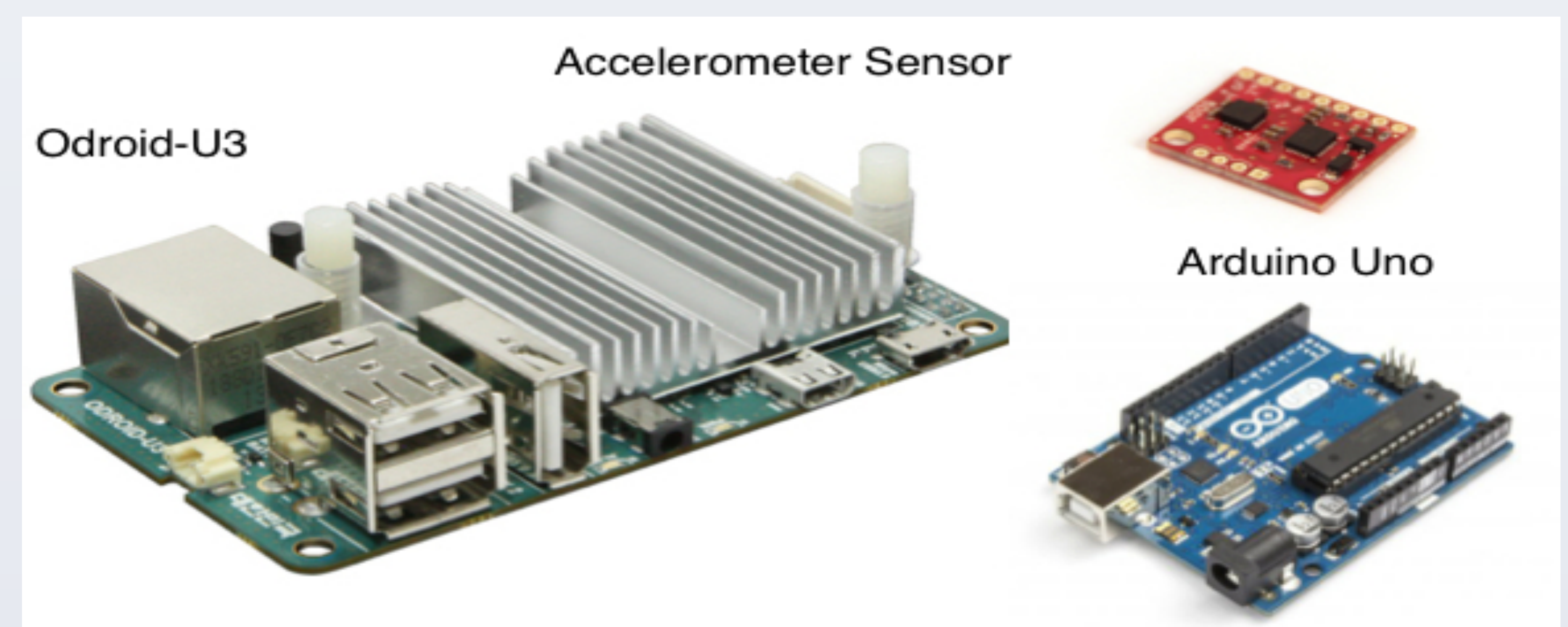

Fig. 3 All the hardware components of the proposed architecture are open-source or semi-open-source.

CONCLUSIONS

This paper highlights the features of a flexible framework that allows for reproducing in a laboratory setup the same challenging operation scenario of controlling offshore cranes. The system can be used for testing different control algorithms as well as for training purposes. In the future, different control algorithms such as the ones implemented in [4] may be tested as alternatives to the standard kinematic method.

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