STATUS REPORT 1

May 30, 2022

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SEA

PREFACE AND CONTENTS

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Preface

This report summarises the work, both planned and executed, the results and findings so far in the project SEACo – Safer, Easier and more Accurate Co-simulations. This report is the first official status report in the project and will therefore report on the status for the elapsed project period. Future status reports will report on the news since the last status report.

The intention with these status reports is to inform the steering committee, as well as the advisory board, about the developments in the project. These status reports are classified as open documents and are freely distributable. The plan is to publish at least two status reports per year.

Contents

OVERVIEW AND OUTLOOK

Project Metrics:

- KSP project
- September 2021 – June 2025
- 19.5 MNOK (5.6 MNOK to industry)
- **2022:** 5.3 MNOK
- 5 technical work packages
- International Advisory Board
- One Ph.D. position (NTNU, N/A)

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Safer, Easier and more Accurate Co-Simulations

Project description

During the last few years, the maritime industry has started using co-simulation successfully to boost digital collaboration and innovation based on existing investments and knowledge. Still, several technical challenges remain, and collaboration is inhibited by tools that are often too complicated to use and not unified.

In the SEACo project, we aim to tackle these inhibitors of rapid digital innovation head on. We seek to contribute to more reliable and easier-to-use co-simulations of maritime systems by drawing on the knowledge and the skills acquired over the past decade. To ensure high interactivity and value creation, several key partners from academia and the industry are committed and eager to contribute: SINTEF, DNV, Kongsberg Maritime, Equinor, Aukra Maritime and NTNU.

The project consists of five technical work packages (WPs). A short presentation of each WP will be given in this status report.

Status

The project officially started on the 1st of September 2021, but due to delays in contractual matters, most project work was postponed to the start of 2022. A physical kick-off meeting was scheduled to be held in Trondheim in January. However, because of restricitions due to the COVID-19 pandemic, we were not able to meet in person and had to change the kick-off to an online meeting, which took place on the 20th of January. A meeting with the advisory board was conducted on the 7th of February. The advisory board consists of MARIN, Damen, Blue Ctrl, MacGregor, and Fraunhofer IWES.

The first steering committee meeting was held on the 11th of March, where also the project plan for 2022 was approved. This steering committee consists of a represent from each project partner and chaired by Arne Fredheim from SINTEF Ocean.

The SEACo project has yet to employee a Ph.D. candidate. After the first advertisement we received several applications, but none met our requirements. Hence, the advertisement text was changed slightly and has now been republished, and you are hereby encouraged to share it with your network.

Martin Rindarøy, who formerly led the first WP in the project, has left SINTEF Ocean. Karl-Johan Reite has taken over as the new WP leader. However, the work in this WP has been postponed to after summer.

A few other projects related to SEACo, such as TwinShip and DTYard, are in their final stages, and therefore, some of the work in SEACo has been postponed to be able to pick up from where these other projects end.

Outlook

We hope to have the Ph.D. candidate ready early after the summer, and since no physical meeting has yet taken place in the project, we plan to have a workshop in late September/ start of October with all project partners. This will most likely take place in Trondheim.

IDENTICAL ENVIRONMENTAL CONDITIONS

Work Package Metrics:

- WP number 1
- 15.2% of total budget
- 771 000 NOK in 2022

WP Leader:

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Description

In this work package we will seek to standardise the description of environmental models for current, wind, and waves as used in most maritime co-simulation systems and develop a standardised co-simulation interface for each. Added focus is put on waves because of their higher complexity and fidelity.

For multiple models to share the same environment one typically can either share values (e.g. sharing the surface acceleration for given positions) or formulations (e.g. parameterised predefined models). These have different pros and cons, such as the ability to include vessel-generated waves or estimating values between time steps. It is therefore possible that multiple sharing strategies should be available, to suit different use cases.

Another important issue is to what extent extensions to the standards can be proposed to facilitate more efficient environment sharing strategies.

Status

Karl-Johan Reite took over as new leader of this WP on the 1st of May, after Martin Rindarøy left SINTEF Ocean. Due to this change in leadership, the work in this WP has been postponed to after the summer and some changes in the work schedule have been made. Nevertheless, the final scope and objectives of the WP are not changed.

Plans for next period

- Identify relevant environmental models:
  - Literature study
  - Project group discussions
  - Document the identified environmental models, with pros and cons for use in co-simulation
- Investigate possible environmental sharing strategies
  - Identify possible sharing principles and their pros and cons when applied to different scenarios and models.
  - Implement proofs of concept as needed to better understand the characteristics of different sharing principles.
  - Document the most promising strategies, particularly with respect to applicability and how they conform to the standards relevant for co-simulation.

COORDINATE SYSTEM TRANSFORMATIONS

Work Package Metrics:

- WP number 2
- 16.9% of total budget
- 672 000 NOK in 2022

WP Leader:

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Description

In this work package, we seek to establish a method for communicating and solving coordinate system representations between independent models reliably. The aim is to detect whether a given transformation can be safely performed outside the models (when time lags cause no issues). And, if not, to find the best method for performing the transformation without introducing significant inaccuracy.

Status

There has been little activity in this work package so far. The main focus has been to study the problem, have initial discussions with stakeholders working in the participating companies, and to make an initial suggestion for how handling different coordinate systems in connections between co-simulation models can be made simpler. The ongoing work aims to make an initial description of the problem and how we suggest to solve it, as a basis for discussions with stakeholders. We are also wrapping up another project, where we are doing an update of the Open Simulation Platform Interface Specification (OSP-IS), which will enable the user to tag interface signals with coordinate system axis (e.g. x, y and z).

There are also strong links between WP2, WP3 and WP, and proper coordination and close collaboration, both between researchers and the industry partners, are deemed necessary to reach the project goals.

Plans for next period

The following work is planned for 2022:

- Review state of art and study the problem
- Create a problem description and suggested approach document
- Distribute the document and survey stakeholders needs and feedback
- Decide approach for solution
- Describe the transformations that are to be covered by SEACo

MODULAR TIGHTLY COUPLED SYSTEMS

Work Package Metrics:

- WP number 3
- 23.2% of total budget
- 1 022 000 NOK in 2022

WP Leader:

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Description

There are several examples of interesting maritime systems that are *tightly coupled*, such as the connection between a ship's hull and its crane. Such systems are by nature poorly suited for co-simulation, and attempts to do so will usually be riddled with stability and performance issues. Still, the advantages of co-simulation are so many that it is worth investigating how to tackle these issues.

In this work package, we will perform a systematic and exhaustive study of tightly coupled maritime systems. We will examine the effects of different types of simulation techniques and algorithms and consider their suitability in a practical industrial setting. Based on the results, we will develop model interfaces to support modular modelling and co-simulation of tightly coupled systems.

Status

There has been no activity in this work package yet. Work is scheduled to start in summer 2022. The delay in this year's activity is due to the fact that similar projects that both SINTEF, DNV and Kongsberg take part in are in their final stages and the effort has been directed towards those projects, to provide an even better foundation for SEACo to continue the research.

Plans for next period

The following work is planned in 2022:

- Review state of the art.
- Survey and systematise relevant tightly coupled systems.
- Make a set of simplified model systems.
- Test and compare methods for splitting/solving tightly coupled systems.

We expect the first two tasks to be completed in 2022, while the other two will continue into 2023.

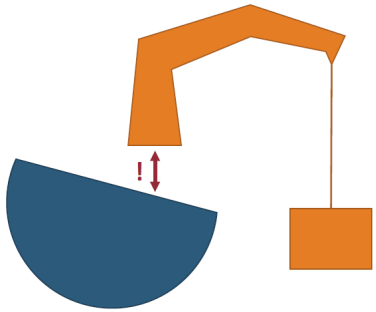

Figure 4.1: A crane and a hull that are connected through tight couplings when modelled as separate subsystems, assuming no simplifications, e.g. due to light lifts.

MORE ACCURATE AND RELIABLE CO-SIMULATIONS

Work Package Metrics:

- WP number 4
- 22.1% of total budget
- 1 026 000 NOK in 2022

WP Leader:

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Description

The *energy-conservation-based co-simulation method* (ECCO) monitors the flow of energies between models, estimates co-simulation errors reliably, and chooses optimal co-simulation step sizes to control efficiency and accuracy. It poses no additional requirements on the models (such as re-stepping or interface derivatives) and can be used for any power bond connection between models. As such, it presents a promising choice for an easy-to-use and robust co-simulation algorithm. Here, we aim to extend the theory of energy-based co-simulation algorithms to make them more useful and more powerful.

Status

This work package will pick up where the TwinShip[1] project leaves off in terms of co-simulation algorithm development. TwinShip ends in June 2022, and we have therefore focused our efforts on the work to be done on ECCO there. This includes

- formulating a new step size control algorithm (specifically, an adaptive PI controller)
- drafting a manuscript for a review article about step size control in co-simulations
- studying multi-rate co-simulation techniques (i.e., different macro step sizes for different subsystems)

A workshop with some of the libcosim developers from the OSP project was scheduled 19th-20th of May. During these days the ECCO algorithm were presented and discussed, and a plan for implementing it in libcosim was sketched. In the last part of the workshop a coding session was initiated to start experimenting with the implementation of ECCO in the OSP software. It is possible to follow the progress and the development on github, the branch `feature/ecco`.

A simple co-simulator framework, named `CoPylot`, has been made in Python for core research and development purposes, first and foremost to further develop the ECCO algorithm. However, it is expected that this framework will be a good tool for the other work-packages in SEACo as well, especially when testing different concepts for treating tightly coupled systems.

Plans for next period

All the work from the TwinShip project will be continued directly in SEACo WP4 immediately after TwinShip ends in June this year. In addition, we will continue to work on

- generalization to step sizes per coupling, and
- generalization to energy-agnostic couplings.

[1] *Digital Twins for Vessel Life Cycle Service*, Research Council of Norway grant no. 280703 (2018–2022).

TESTING AND VERIFICATION

Work Package Metrics:

- WP number 5
- 13.2% of total budget
- 715 000 NOK in 2022

WP Leader:

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Description

The assurance of complex systems and operations based on simulation models requires established trust in chosen simulation technologies. Here, we will develop and implement a case study for testing and demonstration of the methodology developed in WP1 – WP4. We will also develop efficient methods for independent verification of the fitness of given component models and simulation configurations.

All the aforementioned work packages will provide input to a joint case study specified in this work package, e.g. A marine operation where a load is transferred between two floating platforms, one of which is a ship that carries the lifting crane. This case involves all the project's research areas, as it requires a shared sea environment for the floaters, multiple frames of reference (global, ship bodies, payload), and centres on a quintessential tightly coupled system (ship and crane), all of which pose a significant challenge to co-simulation accuracy.

Status

- On 3. mars Siegfried Eisinger provided a 1-hour introduction webinar for DNV-RP-0513 Assurance of Simulation Models as a basis for the work to be done in this work package. The webinar was well attended with a good Q&A session at the end.
- Contribution to detailed specification of pilot case. The basis was laid in two working meetings between a few participants. The results from these meetings will now be summarised so that the other participants can comment and the pilot case(s) can be agreed.

Plans for next period

The detailed case study is to be decided later in 2022. When this is done a selection of experts will be invited for a working meeting on risk analysis, as the risk analysis will set the stage for verification and validation efforts. The risk analysis will address

- issues with respect to modelling weaknesses if SEACo issues are not detected or addressed, and
- issues with respect to the increased complexity of SEACo algorithms which could cause modelling errors.

The goal will be to establish dedicated advise on how to avoid and control such risks in relation to the general risk level of the simulation application.

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