INNO2MARE – Pilot projects to strengthen the capacity and scientific excellence of Slovenian and Croatian innovation ecosystems

Petra Pintar, Marko Šimic, Niko Herakovič

Abstract:

The INNO2MARE project aims to enhance maritime innovation ecosystems and bridge knowledge gaps through three pilot projects: (1) a VR model for fire evacuation in a ship's engine room, (2) a digital twin with AI for energy management, and (3) AI-supported autonomous vessel navigation. Pilot Project 1, led by the Faculty of Maritime Studies in Rijeka (PFRI), focuses on developing a VR fire evacuation model to improve maritime safety training. Pilot Project 2, involving ISKRA, DIGITEH, and the University of Ljubljana (UL), targets AI-driven digital twins for efficient energy use in maritime operations. Pilot Project 3, led by the University of Rijeka (UNIRI/FIDIT), explores AI techniques for autonomous navigation and sea condition assessment. Slovenian and Croatian ecosystems will benefit from Flemish expertise, fostering innovation and collaboration in the Adriatic maritime industry.

Keywords:
INNO2MARE, Excellence hub, maritime, Innovation, AR/VR, digital twins, autonomous shipping, AI, machine learning.

The LASIM laboratory at the Faculty of Mechanical Engineering, University of Ljubljana, is coordinator of the INNO2MARE project, which aims to strengthen the capacities for excellence in the innovation ecosystem of Western Slovenia and the Adriatic Croatia through a set of jointly designed and implemented actions that will support the digital and green transition of the maritime and related industries. The project is being carried out in collaboration with the University of Rijeka, the University of Antwerp, and 16 partners from Slovenia, Croatia, and Belgium, covering all four key stakeholders: academia or science, industry, governmental, and non-governmental organizations.

The main part of the project is related to three pilot projects that address some of the challenges related to advanced approaches to education and training in a virtual environment, maritime safety for vessel autonomy with the support of artificial intelligence and the efficiency of the use and management of alternative energy sources for production systems and processes with the support of digital twins.

The goal of the INNO2MARE project is to develop a joint research and innovation strategy to strengthen the excellence of maritime innovation ecosystems and contribute to the knowledge gap in the field of maritime research and innovation by co-designing and jointly implementing three pilot projects: (1) Improved fire evacuation VR model of a ship engine room , (2) Digital twin with artificial intelligence (AI) for sustainable and efficient energy management for production needs and (3) Technologies for autonomously guided vessels supported by artificial intelligence (AI).

Pilot Project 1, spearheaded by the Maritime Faculty of Rijeka (PFRI), seeks to refine the VR model of a ship's engine room for fire evacuation, thereby enhancing fire safety in maritime operations and advancing the digital transformation of Maritime Education and Training (MET). This initiative will facilitate training in both on-site and online settings, providing a more immersive and secure environment for shipboard firefighting personnel.

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By leveraging cutting-edge Virtual Reality (VR) technology, the project aims to develop a highly realistic model for fire evacuation within a ship's engine room, creating an enriched and safer virtual training environment, as depicted in Figure 1.

The project addresses the application of virtual reality (VR) for the development of a safer working environment, with an enhanced VR model for fire evacuation within a ship's engine room. This model focuses on simulating the spread of fire in the engine room, as illustrated in Figure 1.

Figure 1 : *VR-model of fire spreading in a ship engine room.*

The proposed model is grounded in evidence-based research, whereby the fire spread is initially modelled using computational fluid dynamics (CFD). The results obtained from this modelling are then integrated into the virtual reality environment (VR). The insights gained from this endeavour have the potential to contribute to the establishment of an improved VR environment, enhancing Maritime Education and Training (MET), as well as safety and protection within the maritime industry through the utilization of digital technologies. Furthermore, the comparison of these results with the baseline VR model holds significant promise for future research and innovation.

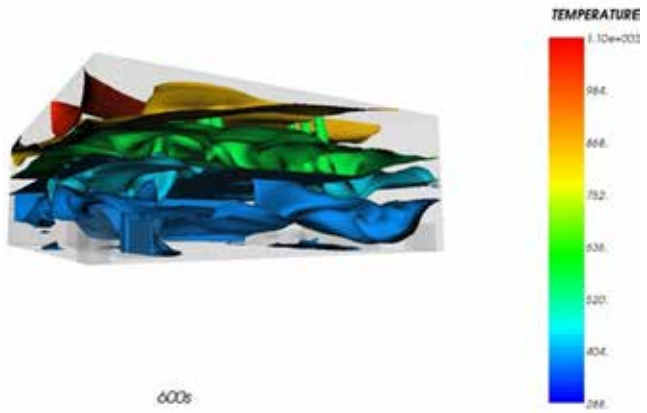

Figure 2 : *CFD model of fire spreading.*

The results of the research will support the existing solution and address gaps in current studies, as a foundational VR model of a ship's engine room and a CFD model of fire spread will be developed (as illustrated in Figure 2). Additionally, an enhanced, fully functional, and tested VR simulator for fire evacuation will be created, aiming to provide a practical VR model for fire spread within the ship's engine room. The project is planned to reach a technology readiness level (TRL) of 4/5, indicating that the technology will be developed and tested first in a laboratory setting and subsequently in a real-world environment.

The aim of **Pilot Project 2** is to design and implement solutions for digital twins, enhanced by artificial intelligence. These solutions will enable the effective and secure management of energy generated from solar power plants and other alternative sources, as well as energy sourced from the electrical grid, thereby addressing production requirements in contexts such as shipyards and port logistics.

The list of suitable parameters for the self-building Digital twin concept was developed during workshops held between ISKRA d. o. o. and DIGITEH d. o. o., where decisions were made regarding the energy producers and co-users, as well as the types of energy that are either generated or consumed. Figure 3 illustrates the three main pillars of input parameters for the Digital twin.

The simulation model was developed based on real production data provided by ISKRA d. o. o. This model is self-building and adaptable, allowing for the analysis of energy consumption and energy spikes (periods of increased and decreased energy usage). By utilizing the collected data on electricity consumption and production, as well as work orders within the same timeframe, an initial overview of energy consumption in relation to production was achieved.

Currently, activities are underway to develop predictive AI algorithms for energy consumption analysis, establish energy management algorithms, implement a bidirectional link between real production and the digital twin, as well as test and validate the foundational algorithms that have already been developed.

The objective of the INNO2MARE project, along with Pilot Project 2, is to advance collaboration between the scientific community and emerging industrial partners within the maritime sector. Additionally, it seeks to facilitate the development and transfer of innovative technologies and processes into industrial settings. This approach enables us to identify and address new challenges while enhancing the efficiency and sustainability of the maritime industry and logistics.

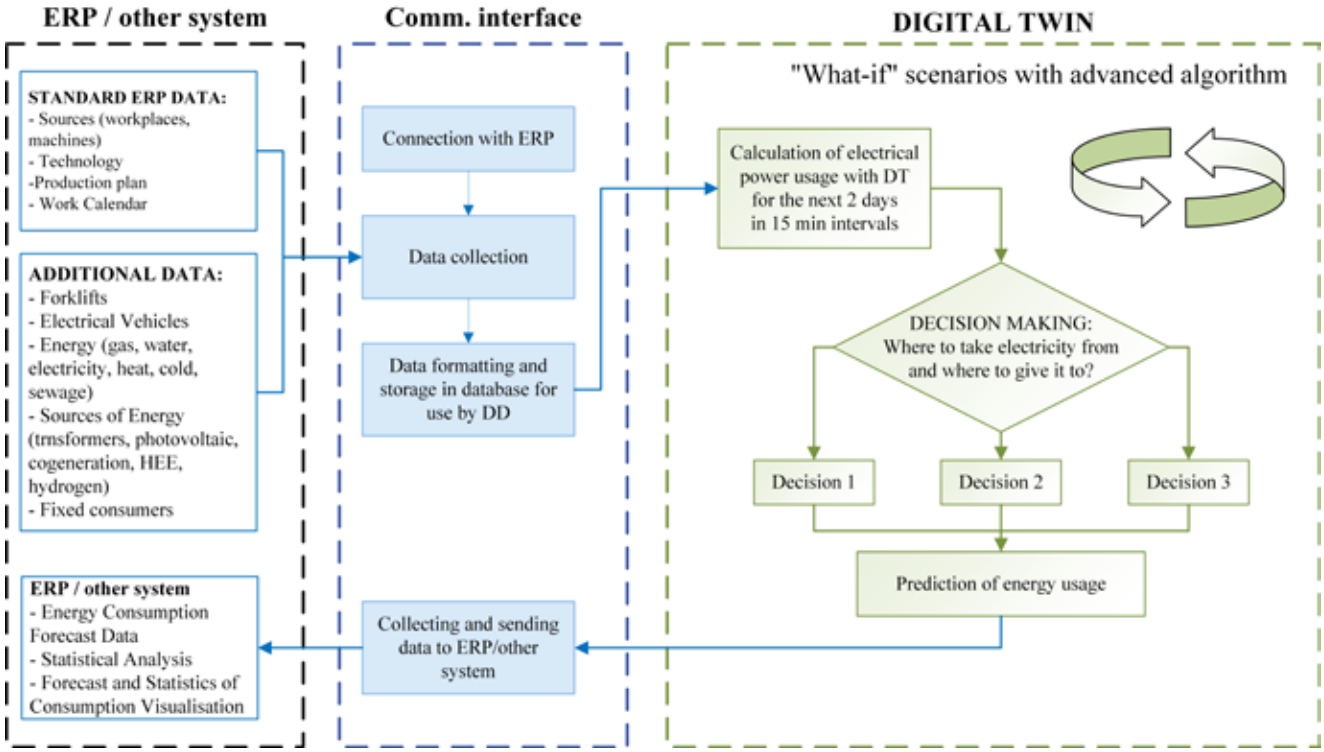

Figure 3 : *Block diagram of working Digital Twin concept.*

Pilot project 3, implemented by the Faculty of Mechanical Engineering from Rijeka (RITEH) and the Faculty of Informatics and Digital Technologies of the University of Rijeka (FIDIT), is studying the use of technologies and the development of methods for the autonomous management of vessels with the support of artificial intelligence (AI). The research work includes the architecture of a model for the automatic detection of small objects on the sea and ocean, as well as the state of the sea in relation to the height of the waves. An accurate assessment and forecast of the state of the sea makes it possible to avoid areas with bad weather conditions, which is important for the safety of navigation and the energy efficiency of maritime transport, as well as the reduction of energy consumption for navigation.

The Faculty of Mechanical Engineering from Rijeka (RITEH) and the Faculty of Informatics and Digital Technologies of the University of Rijeka (FIDIT) are mainly focused on the use of computer vision and deep learning methods on the basis of which they try to recognize complex patterns in images and video recorded with a stationary camera from the left bridge wing of the vessel afforded a panoramic view of the sea and included segments of the ship, the wake, and the distant horizon. The collected images are used to train deep neural network models, to interpret the image and automatically recognize the state of the sea in real time according to the Beaufort scale. The same method is used to detect smaller objects at sea, such as buoys, jet skis and other small vessels. The obtained results demonstrate the exceptional utility of the approach, which can be integrated and supplemented with traditional methods and improve the safety and efficiency of all maritime operations.

Figure 4 illustrates an example of a locally selected image, along with its size and location within the dataset – SeaState-LL (highlighted by the yellow box labelled A). The green boxes labelled B represent some possible locations of objects included in the dataset – SeaState-R, indicating an adaptation of input data and model settings to achieve improved results in recognizing sea state assessments. Given the challenges of obtaining the necessary number of recorded images across different conditions in reality, synthetic images are created for model training, which can simulate various sea surface states and different camera attachment scenarios.

The second approach uses raw time-series data of the ship's pitch as input for the AT-NN (Attention--based Neural Network) to assess sea conditions. These methods allow for the adjustment of input data and model settings to achieve better results in sea state assessment recognition.

The results of this research play a significant role in the development of autonomous vessels (DSS – Dynamic Shipping Services). A fully autonomous vessel, whose system makes decisions independently based on acquired information, without a human crew, must be equipped with the most advanced sensors and developed methods. With the aid of a computer vision model for detecting small

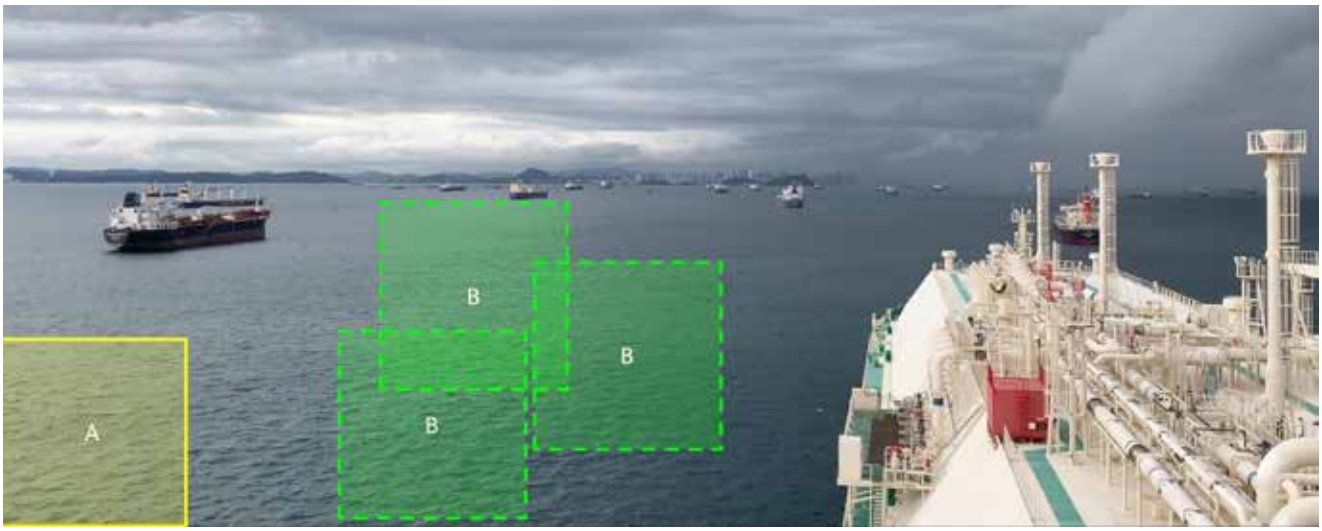

Figure 4 : *Dataset: SeaState-LL (yellow box labelled A), and the green boxes labelled B represent some possible object locations – SeaState-R (green box).*

objects and describing sea conditions, along with developed measurement techniques, it will be possible to ensure smooth and safe navigation in real time, even under adverse weather conditions.

Slovenian and Croatian innovation ecosystems will greatly benefit from the exchange of best practices from the Flemish ecosystem, one of the most developed maritime innovation ecosystems in the world. INNO2MARE will contribute to reducing the innovation gap in Europe in the maritime sector by systematically connecting innovation actors within and between ecosystems and creating synergies in the planning and implementation of investments in research and innovation, thereby fostering the development of a true innovation culture.

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INNO2MARE – Pilotni projekti za krepitev zmogljivosti in znanstvene odličnosti slovenskih in hrvaških inovacijskih ekosistemov

Razširjeni povzetek:
Cilj projekta INNO2MARE je oblikovati skupno strategijo raziskav in inovacij za krepitev odličnosti pomorskih inovacijskih ekosistemov in zmanjšanje vrzeli v znanju na področju pomorskih raziskav z izvajanjem treh pilotnih projektov: (1) izboljšan VR model evakuacije iz strojnice ladje, (2) digitalni dvojček z AI za učinkovito upravljanje energije in (3) tehnologije za avtonomno vodenje plovil s podporo AI. V sklopu pilotnega projekta 1, ki ga vodi Pomorska fakulteta v Reki (PFRI) se razvija izboljšan VR model ladijske strojnice za evakuacijo ob požaru, kar bo povečalo varnost v pomorstvu in podprlo digitalno preobrazbo pomorskega izobraževanja in usposabljanja. VR model in uporabljena tehnologija omogočata realističen prikaz širjenja požara in bo namenjen kot demonstrator in okolje za usposabljanje ljudi pri evakuaciji iz zaprtih prostorov. Pilotni projekt 2, katerega glavni partnerji so ISKRA, DIGITEH, Univerza v Ljubljani s podporo Belgijskih partnerjev, razvija rešitve za digitalne dvojčke podprte z umetno inteligenco za učinkovito upravljanje in rabo energije kot so sončna energija in električna omrežna energija v proizvodnih procesih in logistiki v pomorstvu. V Pilotni projekt 3 so vključeni Fakulteta za strojništvo (RITEH) in Fakulteta za informatiko in digitalne tehnologije (FIDIT) Univerze v Reki. Raziskuje pristope kot so računalniški vid, metode globokega učenja v kombinaciji z drugimi pristopi umetne inteligence, za avtonomno vodenje plovil, prepoznavanje majhnih objektov na morju in oceno stanja morja glede na višino valov.

Slovenski in hrvaški inovacijski ekosistemi bodo pridobili z najboljšimi praksami flamskega ekosistema, enega najrazvitejših na svetu. INNO2MARE bo zmanjšal inovacijsko vrzel v evropskem pomorstvu s povezovanjem akterjev inovacij ter sinergijami pri naložbah v raziskave in inovacije, s čimer bo spodbujal inovacijsko kulturo.

Ključne besede:
INNO2MARE, vozlišče odličnosti, pomorstvo, inovacije, AR/VR, digitalni dvojčki, avtonomna plovba, umetna inteligenca, strojno učenje.