AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping

D.4.3: Results of autonomous tugboat operation simulation

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List of Acronyms

Abbreviation / acronym	Description
EC	European Commission
D1.1	Deliverable number 1 belonging to WP 1
WP	Work Package
AI	Artificial Intelligence
ML	Machine learning
RL	Reinforcement learning
MDP	Markov Decision Process
DQN	Deep Q-Network
MCTS	Monte Carlo tree search
PPO	Proximal Policy Optimisation
SAC	Soft Actor Critic
PFA	Policy function approximation
CFA	Cost function approximation
VFA	Value function approximation
DLA	Direct lookahead approximation
BC	Behavioral Cloning
GAIL	Generative Adversarial Imitation Learning
MA-POCA	MultiAgent Posthumous Credit Assignment
NN	Neural Network
Eq.	Equation
ECR	Empty Container Repositioning
LCG	Longitudinal center of gravity
TCG	Transverse center of gravity
DL	Deep Learning

Executive Summary

This document reports the activities and the outcome of the MOSES Task 4.3: Swarm intelligence algorithm development & simulation, which is part of WP4. In this task, we present the design, development and optimisation of the algorithms that enable intelligence of virtual tugboat agents in order to automate the docking process of a large ship. The main objective of this task is to teach a swarm of autonomous tugboats to establish path-planning, execute sophisticated manoeuvres and ultimately control a large vessel while coordinating actions among the actors of the swarm.

Leveraging both the virtual environment developed in the Unity3D framework under Task 4.2 and the ML-Agents toolkit, we showcase that it is possible to train the behavior of the tugboat agents using the Proximal Policy Optimisation Reinforcement Learning algorithm. During algorithm training, the agents are provided with real-time feedback from the environment and thanks to their own reward functions, they are able to dynamically adapt to its policies and navigation strategy.

The performance evaluation shows that by formulating appropriate reward functions, selecting the correct training strategy, tuning model hyperparameters, and shaping penalties, the agents can successfully learn the desired task and improve the performance and quality of an important maritime operation such as the docking of large ships.

Finally, within this document a Fail-safe operation analysis is presented that provides the foundations for the fail-safe functionality. The latter is intended to be used by the autonomous tugboat swarm to maintain the safety of the manoeuvring operation in case a failure occurs (e.g. connectivity loss, other alarm etc.).