AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping

D.3.3: Create 3D world model for Robotic Container Handling System

Document Identification			
Status	Final	**Due Date**	Thursday, June 30, 2022
Version	1	**Submission Date**	30/06/2022
Related WP	WP3	**Document Reference**	D.3.3
Related Deliverable(s)	D.3.3, D.3.5	**Dissemination Level**	CO
Lead Participant	TNO	**Document Type:**	R
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861678. The content of this document reflects only the authors' view and the Agency is not responsible for any use that may be made of the information it contains.

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Document History			
Version	**Date**	**Change editors**	**Changes**
0.1	13/4/2022	Frank ter Haar	Created outline, structure and template.
0.2	31/5/2022	Team	Chapter 1, 2, 3 content update
0.3	3/6/2022	Team	Chapter 4, 5 content
0.4	7/6/2022	Team	First full version ready for internal team review
0.5	8/6/2022	Team	Final improvements
0.6	9/6/2022	N. van der Stap	Internal review TNO
0.7	10/6/2022	B. van Manen, F.B. ter Haar	Processed review
0.8	12/6/2022	Team	Processed review
0.9	13/6/2022	F.B. ter Haar	Final draft version submitted to external reviewers
1.0	29/6/2022	F.B. ter Haar	**Final version to be submitted**

Quality Control		
Role	**Who (Partner short name)**	**Approval Date**
Deliverable leader	TNO	13/06/2022
Quality manager	NTUA	27/06/2022
Project Coordinator	NTUA	30/06/2022

Table of Contents

List of Figures

List of Acronyms

Abbreviation / acronym	Description
3DVR	3D Virtual Reality (the immersive view of IOSS with 3DWI results)
3DWI	3D World Interpreter
CCU	Crane Control Unit
D3.3	Deliverable number 3 belonging to WP 3
DEM	Digital Elevation Map
EC	European Commission
FOV	Field Of View (of a sensor)
GLE	Wire luffing onboard electric crane
hFOV	Horizontal Field Of View (of a sensor)
MOSES	AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping
IMU	Inertial Measurement Unit
IOSS	Intelligent Operator Support System
PoE	Power over Ethernet
PTU	Pan Tilt Unit
RCHS	Robotic Container-Handling System
RDA	Remote Data Access
RGB	Red Green Blue
ROS	Robot Operating System
SA	Situational Awareness
T3.3	Task number 3 belong to WP 3
TNO	Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek
vFOV	Vertical Field Of View (of a sensor)
VLP16	Velodyne Lidar Puck with 16 lines
VR	Virtual Reality
WP	Work Package

Executive Summary

MOSES aims to significantly enhance the short sea shipping component of the European container supply chain by a constellation of innovations including innovative vessels and the optimization of logistics operations. As part of the innovations a hybrid electric feeder vessel outfitted with a Robotic Container-Handling System (RCHS) is designed and developed. This report describes the innovative sensor suite and 3D World Interpreter (3DWI) system that (1) enables the RCHS to scan and interpret the harbor environment for autonomous operations, and (2) provides situational awareness (SA) for the remote operator to monitor the operation and solve occurring issues.

More specifically, the goal of this task is to create a 3DWI system that creates a virtual 3D world model as the basis for the auto drive and control system of the RCHS. To create this model an optimal sensor suite is co-compiled by TNO and MacGregor for the integration on a GLE crane. Object recognition and 3D reconstruction algorithms are developed and run on the 3DWI system in the crane house. Obstacle avoidance algorithms based on computer vision are implemented for safety during loading and offloading. Safeguarding humans in the vicinity of the crane is guaranteed by person detection algorithms.

The resulting sensor suite comprises of a two LiDAR system, a stereo-camera system, and a gravity-aligned zoom-camera. The LiDARs and stereo-camera are mounted on the rotating crane-base directly under the jib to scan the docks in 2D and 3D. The zoom-camera is mounted on the top of the jib and looks down on and along the spreader and containers. The report elaborates on the design aspects and how the multi-sensory data is captured, calibrated, stored, and replayed in the acquisition part of the 3DWI system.

Algorithms have been developed to (1) fuse the LiDAR and stereo-data into a colorized environment scan, (2) automatically detect 3D containers, (3) determine 3D obstacles as no-go areas for the crane, (4) detect human activity and generic objects, (5) conversion of the 2D/3D detections to a local world coordinate system, (6) streaming of sparse crane and sensor data to a remote operator, (7) 3D virtual reality rendering as a digital twin of the real environment. In particular, our detection of human activity goes beyond existing state of the art AI-models; existing models could not cope with the oblique and top-view camera orientations of our sensor suite.

The sensor suite, capture software and algorithms are combined in the 3DWI framework. In this framework the communication and interaction interface with the Crane Control Unit (CCU) and Intelligent Operator Support System (IOSS) is contained. The interaction-flow is described from a functional level perspective of 3DWI. For instance, when the vessel docks the 3DWI is signaled to perform a dock scan together

with the CCU and then 3DWI shares the locations of the containers and obstacles with both the CCU (for obstacle avoidance in path-planning) and with IOSS (to support the remote operation in gaining SA). Another example; when the CCU needs to pick-up a container, then 3DWI scans for red-alerts and stops the process and asks help from the remote operator. Throughout these different steps and states in the 3DWI framework, the essential data is live transmitted between the CCU, 3DWI, and IOSS.

In a number of experiments with real and simulated data the performance of 3DWI is evaluated. The detection and pose estimation of containers within the reach of the crane is close to perfect. The 2D detection of potential threats has a mAP of 92%. Tests performed int his task show that it detects almost all relevant objects, with only a temporal miss every now and then that 2D tracking can solve. Detections are accurately converted to 3D detections with the use of live and stitched LiDAR point cloud data. The quantitative analysis of cars and persons shows an averaged position error that can increase up to 1m and 0.79m respectively, depending on the distance from the crane base. These numbers are not crucial but need to be taken into account as margins when 3DWI decides the threat level. Altogether, this report comprises the innovative 3D world model software solution and completes deliverable D3.3 of the MOSES project.