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ROBS4CROPS

D2.6 Methodologies to assess the real-time performance of the implements (2)

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Abstract:	The deliverable will represent the progress that has been made for assessing the real-time performance of the smart implements in terms of the implemented hardware as well as software to represent the performance of weeder and sprayer.

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List of Abbreviations and Acronyms	
FC	Farming Controller
VT	Virtual Terminal
ECU	Electronics Control Unit
IBBC	ISOBUS breakaway connector
CAN	Controlled Area Network
WUI	Web User Interface
GUI	Graphical User Interface
PTO	Power Take-Off
PWM	Pulse Width Modulation
VRA	Variable Rate Application
ROS	Robot Operating System

1 . In-field performances of Smart Implements

The aim of this document is to describe the implemented methodologies, hardware, and software to evaluate the in-field performance of the developed smart implements (sprayer and weeder) with work package 2. This will be provided by the following sections 2-5.

Section 2 describes the developed smart sprayer and Section 3 describes the evaluation of the dynamic in-field performance of the smart sprayer. In addition to that, the implemented hardware/developed configurations/setups in the spraying cases will be shortly highlighted. For evaluating the dynamic performance of the sprayer, the parameter to process is the "as-applied" rate resulting from the in-field task application of spraying.

Section 4 describes the developed smart weeder and Section 5 describes the evaluation of the dynamic in-field performance of the smart weeder. In addition to that, the implemented hardware/developed configurations/setups in the weeding cases will be shortly described. For the dynamic performance of the weeder, the parameter to process is the quality of the weeding operation that results from the Analytics software.

2 . Setup for the Smart Sprayer (Greece and Spain)

To enable variable rate application, the sprayer from TEYME has been designed with an electronic control unit (ECU-EPEC). Subsequently, the algorithm for the ISO11783 protocol of ISOBUS has been integrated with the implemented ECU of the Sprayer. The final architecture for the entire setup and components connection can be seen in Fig.1 below.

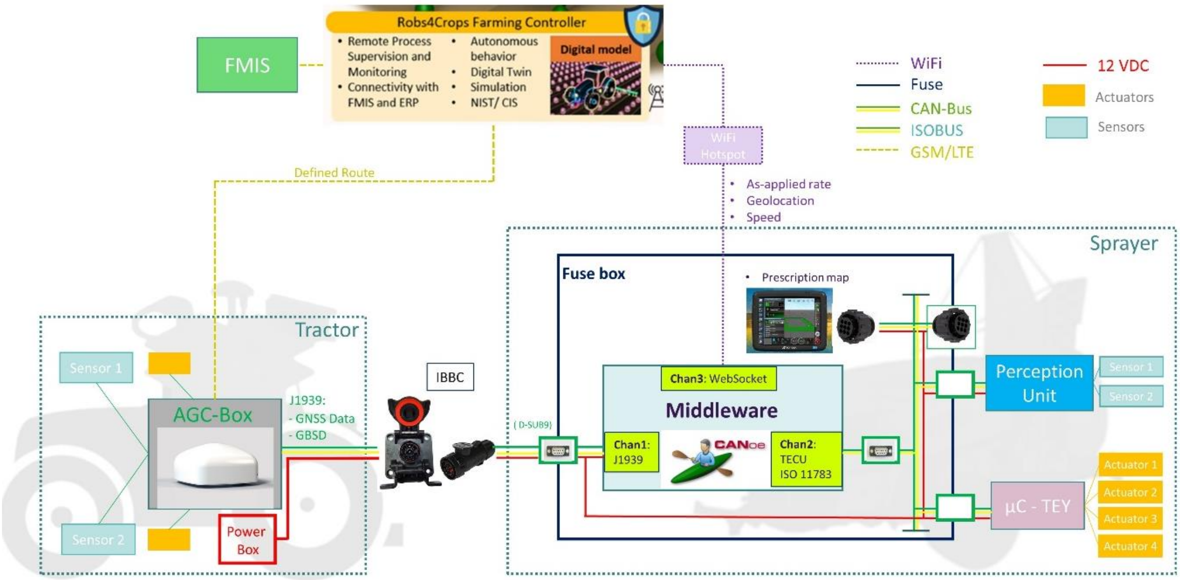

Figure 1. The schematic view for the complete setup of the sprayer in combination with the tractor.

The sprayer that is developed by TEYME, especially for grape and apple orchard applications, is assembled with the sensor system of PWM nozzles for a variable rate of spot-specific phytosanitary application. Besides that, a set of electrohydraulic distributed fan systems that is specific for variable rate application of airflow is implemented. The application rate is combined with the information, such as canopy volume and disease detection, from the perception system. The perception system is developed by AUA. The developed sprayer is connected to the vehicle, in terms of the retrofitted tractor and robot

(CEOL), for different pilot cases. By far, the developed sprayer together with the perception unit, middleware, navigation system and farming controller has been tested only with the tractor. The setup is expected to be tested with the CEOL robot in 2023 in the pilot case in Greece.

The presented setup in the architecture has been tested in the pilot case in Spain as well as Greece. The setup for the pilot case in Greece has not yet been finalized. It is expected to be finalized in November 2022. This needs to be followed to prepare the setup for the connection with the CEOL robot for the season in 2023.

3 . Assessment of the Smart Sprayer Performance

The sprayer is ISOBUS-compliant, in terms of ECU functioning based on the ISO11783 protocol. The setup includes a Virtual Terminal (VT -ANEDO, Germany) that has a task controller functionality of the ISOBUS for the field application. The task controller sends the commands/prescribed rate to the sprayer as well as records the as-applied rate which is defined as the performance of the sprayer. Therefore, the operator is able to observe the performance in real-time. Figure 2 shows the presentation of the as-applied information in real-time on the ISOBUS VT.

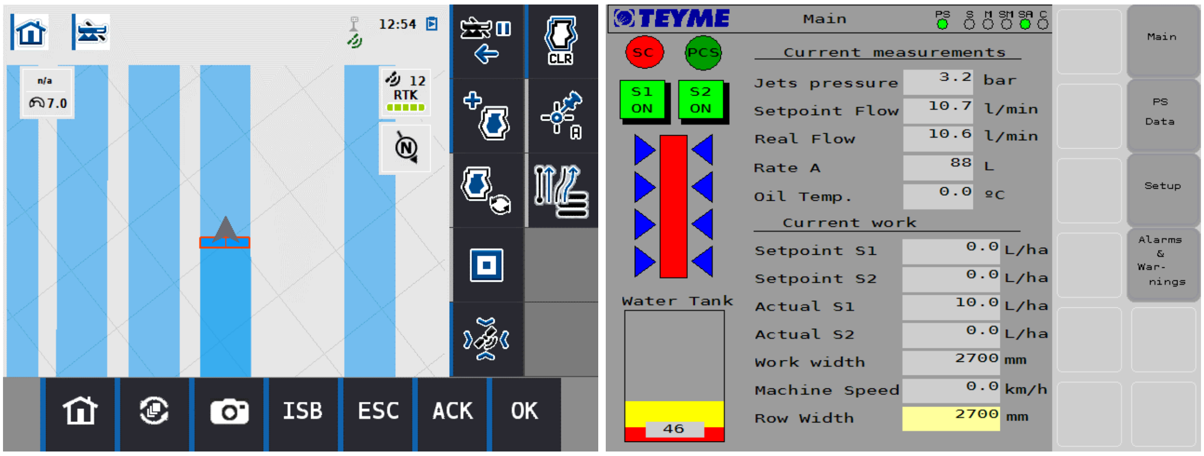

***Figure 2**. Real-time representation of as-applied information on ISOBUS VT*

Simultaneously, the prescribed rate resulting from the perception unit and the as-applied rate is being recorded by the middleware and dispatched to the Farming Controller (FC) using the WebSocket designed on the virtual channel of the middleware. Thus, the FC also represents the as-applied rate in real-time as it is shown in Figure 3.

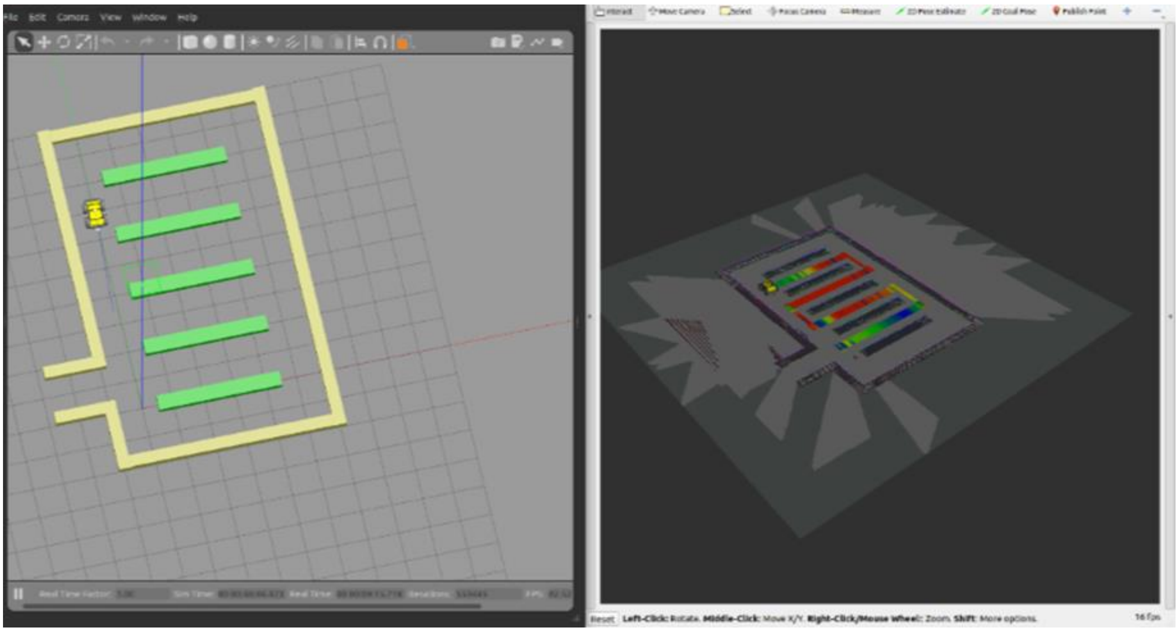

***Figure 3**. The tractor-field simulation (Left) in Gazebo publishes messages, received by the Digital Twin in RVIZ, where the GPS and As-Applied spraying data is visualized.*

Farming controller has been installed in a server in LMS premises and is able to receive data from the external resources through a web socket that is opened by a ROS library, namely ROSBRIDGE server. This library is responsible to serialize ROS2-messages into JSON-based simple text and send them through the socket to the other entity, as well as receive JSON-based text and convert them back to ROS2-messages. In this way, the FC is able to send/receive data from the middleware, such as GPS and/or as-applied spraying data. These messages are published on the ROS2 ecosystem, making them available for representation on the Digital Twin environment for further process. In our case, the simulated robot is running in the virtual environment of the Gazebo, while it publishes messages to the ROSbridge server with GPS and spraying volume data. The ROS2 environment, receives this information and visualizes it in RVIZ environment, updating the Digital Twin with a heatmap layer, where the different colours represent different volumes of spraying.

The description of the task, the current status of the task achieved, and the implemented parameters by each partner involved for evaluating the in-field performance of the sprayer are given and explained in Table 1.

Table 1. Parameters to evaluate the in-field performance of the sprayer

Partner	Description of the Task	Current status of the task	Parameter for the in-field performance
UHOH	Communication based on the ISOBUS with all the necessary components, representing the necessary information, recording the as-applied rate, and sending it to the VT as well as to the Farming Controller	The communication between the middleware and all other components is fully set and functional. The middleware records the as-applied information together with its geo-location as well as other	As-applied rate

		CANBUS data. The prescribed and as-applied rates including the geo-locations are simultaneously transferred to the FC using the WebSocket designed on the middleware.	
TEYME	Communication based on the ISO1783 with the middleware and the perception system. Execution of tasks according to middleware consigns. Receive the required DDI for the prescribed rate from the TC as well as the Perception Unit. Outputting the as-applied information to the TC and the middleware.	The communication between the ECU of the sprayer, the middleware, and the Perception Unit is fully set and functional. The ECU of the sprayer is fully ISOBUS-compliant and properly responding to the prescribed rate coming from the Perception Unit and the TC.	Prescribed and As-applied rates
AUA	Communication with the middleware as well as with the sprayer ECU through the CANBUS based on the ISO 11783 protocol. Defining/correcting the prescribed rate based on the sensor information would be the main function.	The Perception Unit communicates with the middleware through the ISO11783 network and with the ECU through a separate channel using proprietary messages. The prescribed rates based on the integrated agronomic algorithm are dispatched to the ECU of the Sprayer and the middleware.	Prescribed rate based on the agronomic decision resulting from the external sensors
AGC	AGC-Box is responsible for communicating with the middleware and feeding the simulated TECU on the middleware with the necessary data such as position and speed information.	The AGC-Box properly feeds the simulated node of middleware for the TECU functionality with the position and speed information.	GNSS position and speed information
LMS	Communication based on WebSocket through a JSON formatted string will be sent. This file will contain either the ISOBUS data, recording the as-applied rate, or the robot data recording robot status data, and sending it to the Farming Controller	The communication between the WebSocket of the middleware and the FC is fully set and functional. As-applied rates including the geo-location are exchanged.	As-applied rate information from the implement

4 . Setup for the Smart Weeder (France and Netherlands)

In the weeding case, the mechanical weeder is not compliant with ISOBUS because it does not contain a real ECU to implement the ISO11783 protocol. Therefore, the middleware is configured with a simulated ECU for the weeder as well as other ISO11783 network nodes for the TECU and the VT to make the setup compliant with ISOBUS on a software level. The TECU functionality of ISOBUS is simulated on the middleware to make the address-claiming process possible with the robots and to exchange the data as well.

In general, the middleware is configured with three channels. Channel 1 is designed for communication with the robots. So, it is responsible for receiving the position and speed info of the robot from the AGC Box in the case of the CEOL and through the CANBUS in the case of the Robotti, thus feeding the simulated node of the middleware for the TECU on the ISO11783 network. Besides that, this channel is also for feeding the robots with the TIM signals such as emergency stop and hitch position states. Channel 2 contains nodes for communication with the real ISOBUS-compliant component such as the VT as well as to convert signals coming from other channels into ISOBUS-compliant signals. The (virtual) channel 3 is composed of nodes to communicate with the FC and the Analytics software. The communication with the FC is through the WebSocket which is designed in Python. So, both the FC and the Analytics exchange information with the middleware through the virtual channel since they run on the same computer. The schematic view of the data flow and the implemented setup for the weeder with the CEOL robot is represented in Figure 3.

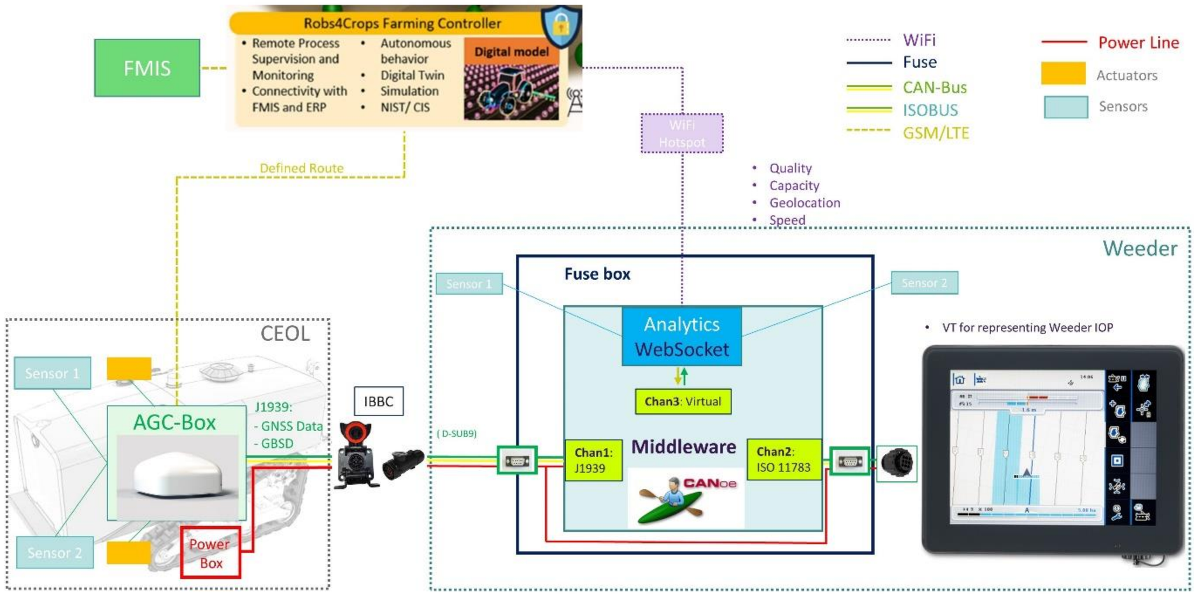

***Figure 4**. The schematic view of the complete setup of the weeder in combination with the CEOL robot*

5 . Assessment of the Smart Weeder Performance

By introducing the ISO 11783 protocol on a software level, the weeder is made ISOBUS compliant. Thus, the performance of the weeder can be introduced in the ISO11783 network of the middleware. In the weeding case, the quality of weeding is defined as the as-applied information which is, in turn, the performance of weeder. The quality of weeding together with the capacity is determined by the algorithm implemented in the Analytics software. The determined value of the quality and capacity are dispatched to the ISO11783 network of the middleware using the virtual channel of the middleware.

The simulated node for the weeder ECU introduces the values of the weeding quality, capacity, and geolocations (GPS and ground-based speed information) to the VT (both the simulated and real VT). The simulated ECU of the weeder utilizes an IOP file that is specifically developed for weeding cases. Simultaneously, the weeding quality including its geolocation is transferred to the FC by the WebSocket that is designed on the Virtual channel of the middleware. The representation of the quality, capacity, speed, and geolocation info on the VT connected to the ISO11783 network of the middleware is shown in Figure 4.

Farming Controller receives and represents the weeding quality in the same way as the spraying implementation. ROSBRIDGE server is utilized to exchange data with the smart implement, using different topic names and namespaces for each case. Representation of the weeding quality is the same to Figure 3. The farmer is able to see the difference only by choosing the respective heatmap layer in his interface.

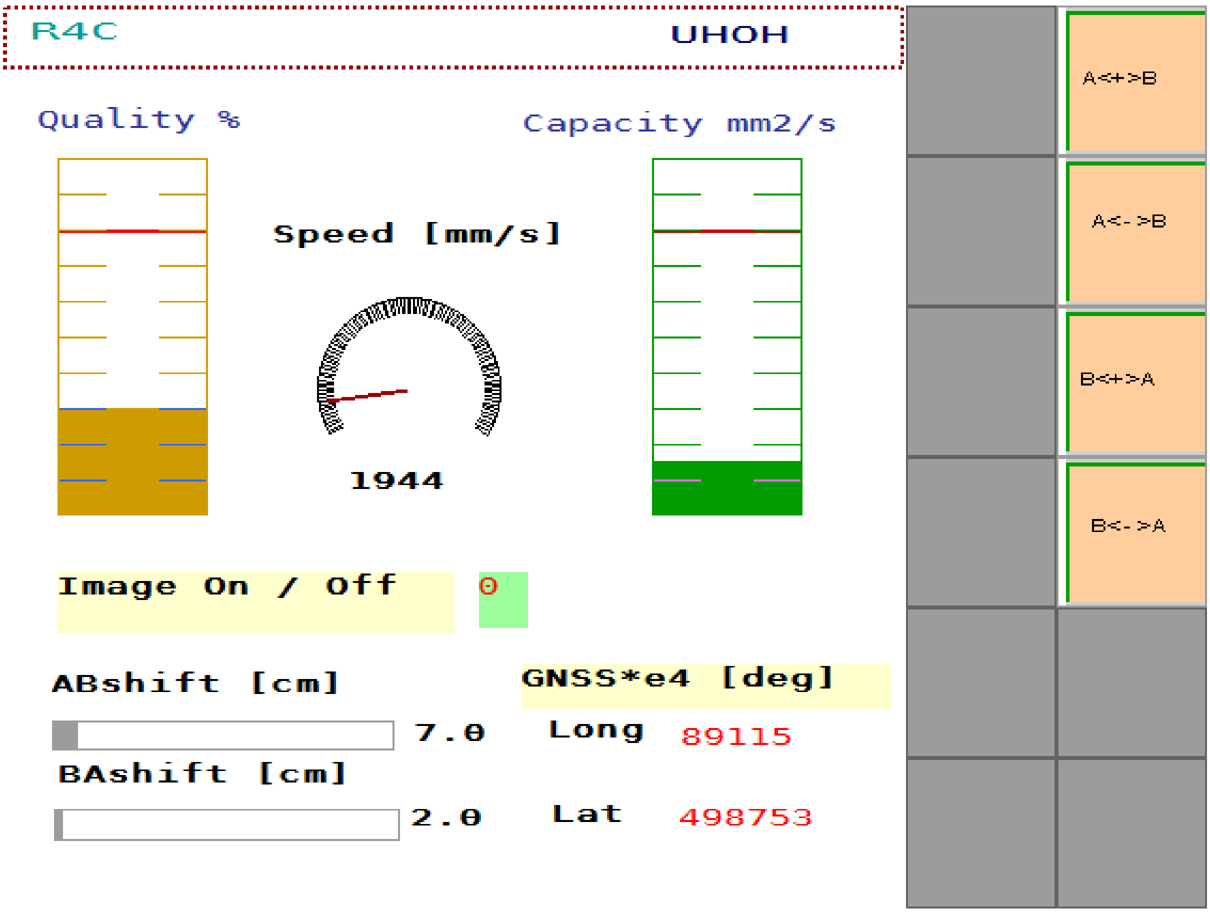

Figure 5. *Representation of the weeder performance on the VT of ISOBUS in real-time*

The description of the task, the current status of the task achieved, and the implemented parameters by each partner involved for evaluating the in-field performance of the weeder are given and explained in Table 1.

Table 2. Parameters to evaluate the in-field performance of the weeder

Partner	Description of Task	Current status of the task	Parameter for in-field performance
UHOH	Communication based on the ISO11783 protocol with all the necessary components, especially with the Analytics of the weeder, representing the necessary information, recording the quality of the weeding, and sending it to the VT. Development of ISOBUS mask for the VT.	The middleware configuration for the communication based on the ISO11783 protocol with the Analytics, VT, FC, and Vehicle is fully set and functional. ISOBUS IOP for representing the weeder performance is developed and integrated with the setup.	Quality and capacity of the weeding including geolocation information
WR	The developed analytics system communicates with the implement (weeder)/middleware through a virtual channel since the middleware and the analytics run on the same computer. The analytics receives sensor/camera data from the Robotti/CEOL or the external sensors from a separate channel to process the weeding quality and machine capacity. The processed information will be shared with the middleware	The Analytics is developed and the communication with the external sensors is set. The stationary test was successful. There is not yet logging data with the French pilot since it wasn't connected to the CEOL robot.	Quality and capacity of the weeding
AGC	AGC-Box should be responsible for communicating with the middleware and feeding the simulated TECU on the middleware with the necessary data such as position and speed information.	The AGC-Box properly feeds the simulated node of middleware for the TECU functionality with the position and speed information.	GNSS position and speed information
AGI	The Robotti should be able to communicate with the developed configuration of the middleware using the ISO11783 protocol	The messages for the ground-based speed info and GPS data are integrated with the Robotti CANBUS system.	GNSS position and speed information

	through the CANBUS systems to send the ground-based speed info of the Robotti and the GPS information.	The communication with the ISOBUS network (one way→ not receiving messages from ISOBUS through) of the middleware is fully set. Two-way communication will be developed in 2023 (TIM)	
LMS	Communication based on WebSocket through which a JSON formatted string will be sent. This file will contain either the ISOBUS data, recording the weeding quality and its geolocations and sending it to the Farming Controller	The communication between the WebSocket of the middleware and the FC is fully set and functional. The weeding quality including the geo-location is being received.	Quality of the weeding including geolocation information