ROBOCON-OCU Kick-off Document

Description

Mobile robots have come a long way both in autonomous functionality and terms of movement capabilities. However, in various scenarios, mobile robots still need humans when it comes to making decisions. These scenarios require operators to control the robots with remote controls. While there are a lot of well established mobile robot platforms, operator control units lag behind a lot. The absence of a robust, secure and practical operator control unit that can stream HD video and transfer control inputs real time over long distances to any robot is still a big, unsolved problem. We aim to solve this problem.

The end product for this project is a standalone Operator Control Unit (OCU) that can be used by field operators that control mobile robots in the field. This unit will consist of two parts: the operator system and the on-board system. Operator system basically will be a remote control that has joysticks, buttons and an LCD screen that designed to be very practical for several field scenarios. The on-board system is the bridge between the operator system and the robot itself with a wired connection between each other. On-board system takes various kinds of state information from the robot such as battery life, operation mode with the video stream from the cameras on the robot and it transfers this information to the operator system. Similarly, the on-board system will transfer control commands received from the operator system to the robot in real time fashion. There will be a robust, secure and reliable wireless connection between these two systems.

Integration of this product is assumed to be done by engineers who have access to robot's codebase. Expected end users are research groups, military personnel and operators of various service robots.

Demonstration of this product will be done by controlling the robot platform(s) with on board cameras and sensors with the Operator Controller Unit while streaming HD video from robot to the operator.

Master Feature List

Below, there is the list of master features of OCU:

MF-1 A portable, wi-fi capable operator system including joystick controls, an LCD display, tactile buttons and other inputs and outputs that may be necessary for particular robot platforms. The operator system is robust and practical for various outdoor field conditions.

MF-2 A portable, robust to physical disturbances, wi-fi capable and GPS embedded on-board system which is mounted on the robot with the camera and other necessary input/output ports, for transferring data between the robot platform and the operator system.

MF-3 Real-time communication between the on-board system and the operator system in order to send/receive control signals and various state information of the robot platform.

MF-4 Soft real-time communication between the on-board system and the operator system for streaming video and audio.

MF-5 Modular software architecture and an API that can be adapted by various robot platforms such as wheeled, legged, and flying robots.

MF-6 Reliable, robust and secure communication of control signals between the operator system and the robot platform because of possible interferences with the operational functionality in field scenarios.

MF-7 Encoding and decoding of the captured video in a soft real-time fashion with best possible compression correlatively with the maximum bandwidth of the wireless connection.

MF-8 A graphical user interface in the operator system which consists of the live video feed and status information such as battery life and operation mode of the robot.

MF-9 Support for controlling and monitoring various sensors and extensions such as cameras, range sensors and IMU that are already connected to the robot platform through the operator system.

MF-10 Location-based features such as last known location, current distance with the built-in GPS module of the on-board system.

Work Packages

WP #	Term	WP Title	Estimated number of person-months
1	491	Project planning and architecture design.	1
2	491	Selection of hardware units.	1
3	491	Create a custom Linux based real-time system using Yocto Project and porting RHexLib and necessary libraries into this custom system.	2
4	491-492	Design and implementation of a robust, real-time network communication software subsystem for sending commands to the robot and receiving state information from the robot.	3
5	491-492	Design and implementation of a soft real-time network communication system for transferring video streams from the on-board system to the operator system.	3
6	492	Building the robot platform(s).	2
7	492	Design and implementation of the software architecture for communication between the robot and on-board system.	4
8	491	Design and manufacturing of the electromechanical components of both parts of the OCU, including a carrying case, CPU and LCD mounts, input devices like buttons and joysticks of the operator system and output ports of both systems.	6
9	491	Design and implementation of the software architecture for I/O operations with input/output	4

		components such as LCD, buttons, and joysticks of the operator system.	
10	492	Overall system integration and scenario tests.	4
BWP 1	492	Supporting additional hardware platforms or frameworks.	-
BWP 2	492	Supporting control of multiple robots from a single operator system.	-
		Total:	**30**

Detailed Descriptions of High-Level Work Packages

WP1 - Project planning and architecture design

In this work package, the following work items will be implemented:

1. Develop the list of master features of the project.
2. Produce a project development plan in accordance with Master Feature List.
3. Design the overall architecture of the project.
4. Analyze risks and make a management plan.

WP2 - Selection of hardware units

In this work package, the following items will be chosen and bought:

1. Single board computers(SBCs) for both the operator system and the on-board system,
2. Microcontroller unit(MCU),
3. Cameras,
4. LCD screen,
5. Buttons, joysticks, switches,
6. Robot platform
7. Wireless communication module and antennas,
8. GPS module,
9. Other necessary peripherals such as cables, cooler fans, power supplies, screws, spacers, and enclosures.

WP3 - Create a custom Linux based real-time system using Yocto Project and porting RHexLib and necessary libraries into this custom system

In this work package, RHexLib and Yocto Project would be examined and ported for our SBCs. The following would be done:

1. Understanding the core structure and functionalities of RHexLib,
2. Understanding the core structure and functionalities of the Yocto Project,
3. Modernizing and porting RHexLib for the SBCs’ of our choice,
4. Creating a custom Linux based real-time system satisfying our needs with the Yocto Project for the SBCs’ of our choice.

WP4 - Design and implementation of a robust, real-time network communication software subsystem for sending commands to the robot and receiving state information from the robot

In this work package, the following will be learned and implemented:

1. Creating message types representing various kinds of information such as the robot state and control signals of the operator system for wireless communication.
2. Transmission of data between two systems that are approximately 2 km apart from each other.
3. A reliable and real-time wireless connection between the on-board system and operator system with appropriate scheduling.
4. A secure connection between the operator system and the on-board system.
5. Testing the connection between the on-board system and the operator system in terms of bandwidth, range, and reliability.

WP5 - Design and implementation of a soft real-time network communication system for transferring video stream from the on-board system to the operator system

In this work package, the following will be learned and implemented:

1. Encoding an HD video in real-time,
2. Decoding an HD video in real-time,
3. Transmission of data from two systems that are approximately 2 km apart from each other in soft real-time,

4. A secure connection between the operator system and the on-board system,
5. Soft real-time video streaming through a wireless connection with appropriate scheduling,
6. Testing the connection between the on-board system and the operator system in terms of bandwidth, range, and reliability.

WP6 - Building the robot platform(s)

In this work package, followings will be done:

1. Building of the robot platform(s) from bought commercial off-the-shelf parts or assembling the unassembled robot kit,
2. Testing the basic functionalities of the robot platform(s) in isolation so that the commands sent by the on-board system can be tested.

WP7 - Design and implementation of the software architecture for communication between the robot and on-board system

In this work package communication interface between the robot and the on-board system will be done:

1. Research and selection of a widely used and practical communication protocol between the on-board system and the robot platform,
2. Design and implementation of the selected communication protocol in a robust fashion,
3. Standardizing the messages between the on-board system and the robot platform and implementing the interface of a communication library for the on-board system which will make the system compatible with different robot platforms,
4. Creating an API that will enable users to make use of OCU in customized ways for their robots' needs,
5. Configuring the OCU API for the robot platform(s),
6. Testing of the communication protocol between the on-board system and the robot platform by checking the robot's response to commands that send by the on-board system.

WP8 - Design and manufacturing of the electromechanical components of both parts of the OCU, including a carrying case, CPU and LCD mounts, input devices like buttons and joysticks of the operator system and output ports of both systems

In this work package, the operator system and the on-board system will be designed and manufactured. The connection of the electromechanical components will be built. The following items will be designed:

1. Buttons and joysticks of the operator system,
2. Carrying case and the general look of the operator system and on-board system,
3. Output ports,
4. The placement of MCU, SBC, LCD screen, buttons, and the wireless communication module of the operator system,
5. The placement of SBC, the wireless communication module, cameras, and LEDs of the on-board system.

The following electrical connections will be designed and built:

1. The connection between MCU and SBC of the operator system,
2. The connection between buttons and the MCU,
3. The connection between the wireless communication module and the SBC of the operator system,
4. The connection between the wireless communication module and the SBC of the on-board system,
5. The connection between the GPS module and the SBC of the on-board system,
6. The connection between the cameras and the SBC of the on-board system.

The following scenarios will be tested:

1. Every component in isolation from other components,
2. Every connection between every unit.

WP9 - Design and implementation of the software architecture for I/O operations with input/output components such as LCD, buttons, and joysticks of the operator system

In this work package, the following will be implemented:

1. An embedded software architecture for MCU to manage the input peripherals such as buttons and joysticks of the operator system,
2. The communication protocol between MCU and SBC,
3. A software architecture for the SBC to transform the input signals gathered from the MCU to commands,
4. A GUI for the LCD screen so that the video from the cameras and the health information of the robot can be seen. The following are included in the GUI:
    a. Display of robot's state information overlaying on the video stream,
    b. Several functionalities that receive input from the touchscreen.
5. Testing the embedded software, the communication between MCU and SBC, the software architecture for SBC, and the GUI's functionalities.

WP10 - Overall system integration and scenario tests

In this work package, the operator system, on-board system, and the robot will be integrated. The integrated system and its connections will be tested with the following scenarios:

1. Overall system integration test,
2. High bandwidth long range test with the robot platform,
3. Low bandwidth long range test with the robot platform,
4. High bandwidth short range test with the robot platform,
5. Low bandwidth short range test with the robot platform.

BWP1 - Supporting additional hardware platforms or frameworks

In this work package, the OCU API would be ported to additional hardware platforms or frameworks in order to support these platforms and frameworks. Following platforms/frameworks will be supported and tested:

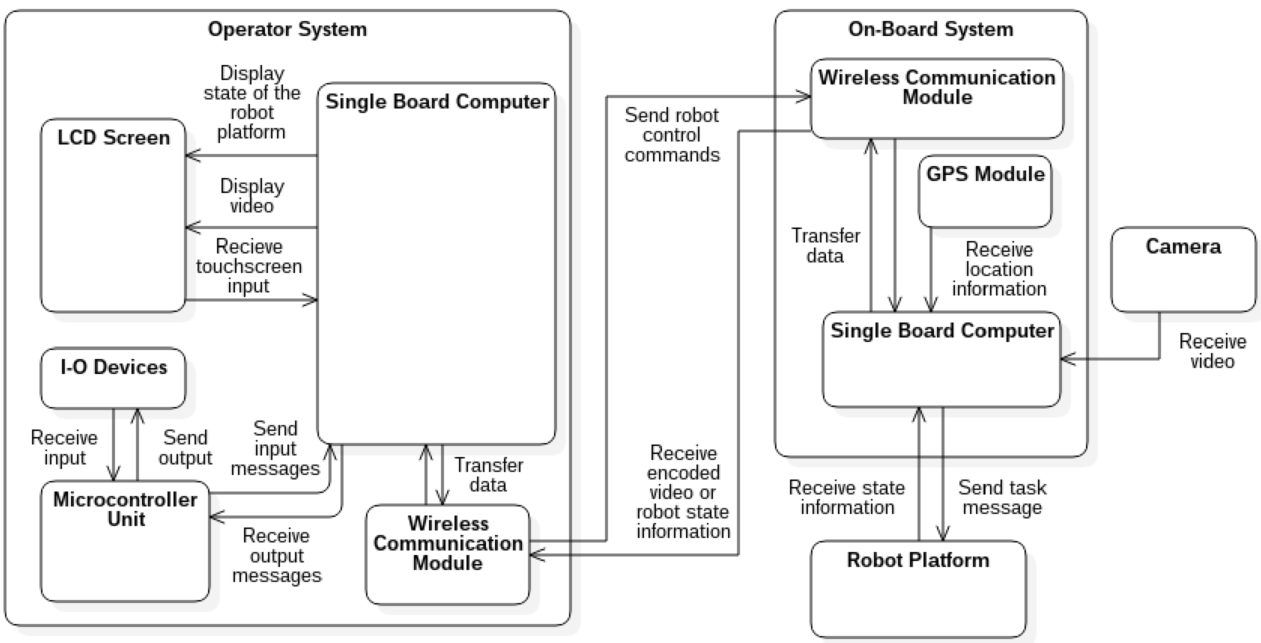
1. ROS, which is a collection of software frameworks for robot software development,
2. Pixhawk, which is a hardware standard for open source autopilots,
3. Arduino, which is an open-source electronics platform based on easy-to-use hardware and software.

BWP2 - Supporting control of multiple robots from a single operator system.

In this work package, the following would be done:

1. Building another on-board system the same as the one used in the project,
2. Building another robot platform,
3. Update and configuration of the OCU API to switch between the on-board systems,
4. Testing the requirements of real-time data transmission from the operator system to several on-board systems and vice versa.

Overall Systems Architecture



Overall systems architecture is planned as above. In this project, there are two main components, which are the operator system and the on-board system.

Operator system will be the remote control unit. Its main use-case is to help field operators control the robot platform and receive various types of information through the on-board system. The data transfer between the two system will be handled by the wireless communication modules, which are both in the operator system and on-board system. When it is necessary, data will be sent by associated SBC to other systems' wireless communication module. When data is received from the latter, it will be sent to corresponding SBC to be processed.

There are two primary components in the operator system. First one is the SBC. Main objects of the SBC module are sending, receiving and processing data. The SBC will be connected with other components through wireless or serial communication to manage this data transfer.

First data transfer will be soft real-time video streaming which will happen through the wireless communication module. When the video came from the on-board system as encoded, SBC of the operator system will decode the video. After that, the video will be displayed on the LCD Screen in soft real-time.

Second data transfer will be the state information of the robot platform which will also come from the on-board system through its wireless communication module and received by the SBC of the operator system. This state information will also be displayed in real time on the LCD Screen with a user-friendly GUI for the operator to keep track of the robot's situation.

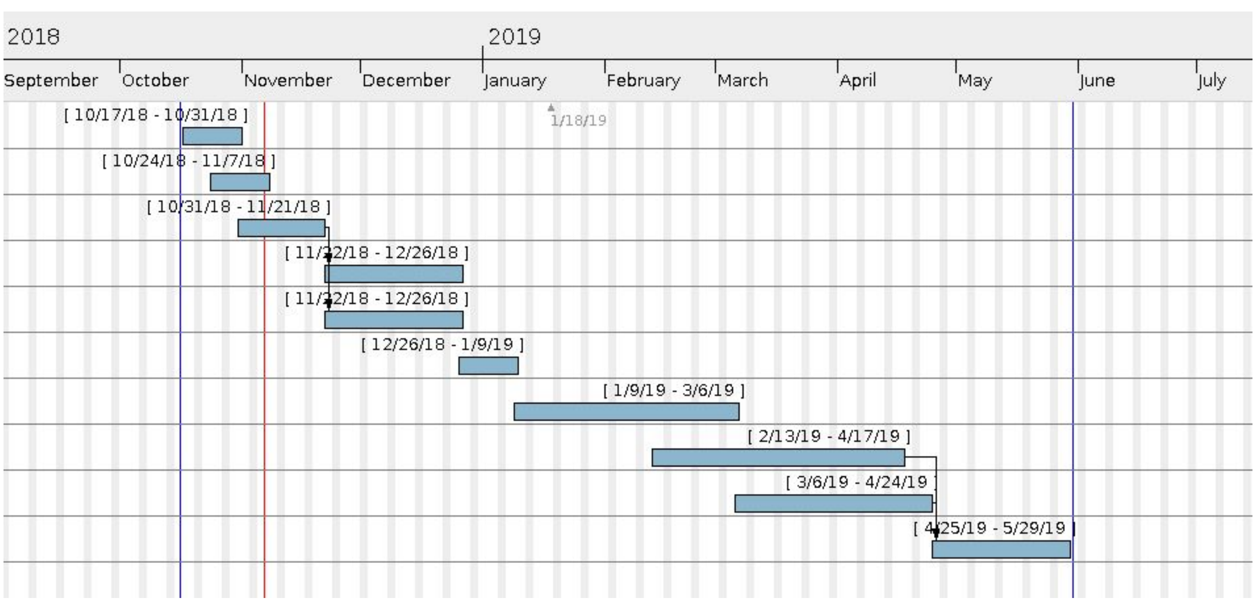
Third data transfer will be from the input devices on the operator system, such as joysticks or buttons or touch screen of LCD Screen. Some of these input signals will be received and processed by an MCU, which is the second primary component of the operator system. Successively, MCU will send the I/O information to the SBC. SBC will process the input data, and send corresponding signals to the on-board system over the wireless communication module. This will be done periodically in the interval where the overall system is in use. The reason why there is an additional controller beside SBC is that an MCU has more I/O ports than an SBC to serve, for multiple input devices such as buttons and joysticks. On the other hand, since LCD Screen will be connected only to SBC, inputs from the touchscreen will be dealt by SBC. Output ports of MCU will be used mostly for the state information changes. To illustrate, a blinking red LED in the case of a connection failure or a green LED when everything is on the way it should be, can be used for visualization purposes.

On-board system will be the unit to be connected with the robot and a camera. Main jobs of the on-board system are receiving the state of the robot from the robot platform, send that information to the operator system, encoding the received video from the camera in real-time and streaming it over wireless communication module to the operator system and receive robot control commands from the operator system. When the video is received, SBC of the on-board system will encode the video and prepare to send it through the wireless module. The on-board system will be connected to the robot platform and will receive robot state information including location information (by its GPS module). Again, the SBC of the on-board system will process the data and send through the wireless communication module to the operator system.

Hardware and software implementation of the robot platform will be out of scope for this project. However, the interface between the on-board system and robot platform will be a crucial issue to deal with.

TimeLine

WP1 - Project Planning and Architecture Design	10/17/18	10/31/18	11
WP2 - Selection of Hardware Units	10/24/18	11/7/18	11
WP3 - Create Yocto Build and Porting RhexLib	10/31/18	11/21/18	16
WP4 - Design and Implementation of a Robust, Real-time Network Communication	11/22/18	12/26/18	25
WP5 - Design and Implementation of a Soft Real-time Network Communication	11/22/18	12/26/18	25
WP6 - Building the Robot Platform(s)	12/26/18	1/9/19	11
WP7 - Design and Implementation of the Software Architecture for Communication between the Robot and On-board System	1/9/19	3/6/19	41
WP8 - Design and Manufacturing of the Electromechanical Components	2/13/19	4/17/19	46
WP9 - Design and Implementation of the Software Architecture for I/O Operations	3/6/19	4/24/19	36
WP10 - Overall System Integration and Scenario Tests	4/25/19	5/29/19	25



Risk Assessment

Risk #	Description	Possible Solution(s)
1	Signal interference or loss during the communication and data transfer through a wireless connection. (WP4-WP5)	To prevent interference more powerful antenna alternatives may be considered.
2	General difficulties in working with physical robot platforms and embedded software. (Related to most of the work packages)	To overcome these difficulties people experienced in robotics such as our supervisor and our team members can be consulted.
3	Not being able to create a high bandwidth wireless connection over long distances between the operator system and the on-board system will limit our ability to stream HD video over desired distances. (WP4-WP5)	To compensate for low data transmission rates we can lessen the quality of the video to a tolerable degree.
4	Lack of heat management for both hardware systems may limit the usability of the OCU dramatically in various field scenarios. (WP10)	To maximize thermal capacity, we can use additional fans, heat sinks etc. Also, new vents can be added to the carrying case to boost airflow.
5	Operator and on-board system may not be as portable as desired. due to the sizes and quantities of internal components. (WP1-WP10)	Several internal components may be replaced with their lighter and smaller alternatives.
6	Electromechanical parts may break down and become unusable. (Can be encountered at any time in the project period)	To avoid such problems, many parts would be ordered with their spare ones.
7	Difficulties in the acquisition and interfacing of various hardware components may be faced. (WP2)	Many of these components were previously acquired by Teknolus and Prof. Uluç Saranlı, so these risks are partially mitigated. Nevertheless, Teknolus has the necessary experience and infrastructure for rapid acquisition of components as well as facilities for mechanical manufacturing.