Roboboat 2023
Technical Design Report

Olivier Lichota (olivier.lichota@solarboat.agh.edu.pl), Robert Koziarski (robert.koziarski@solarboat.agh.edu.pl)

Abstract

Barka is a direct follower of our previous autonomous boat R.O.B.U.R. It is built as an universal platform for executing special tasks during RoboBoat 2023. Barka was designed and manufactured by a group of students from AGH Solar Boat which is student scientific association. After the experience of the previous year competition we decided that we will build a much better autonomous boat in terms of construction design, used composites and implemented systems.
Being part of such a huge project is a great learning opportunity for AGH Solar Boat team members by allowing tchem to dive deep into various modetechnologies.

Software Design

Implemented software is made up of two different systems. These are the low-level system and the high-level system which are able to communicate via CAN bus.

A. *Low-level system*

The embedded system which runs on our custom PCB board is responsible for radio communication allowing us for manual control and ability to use remote kill switch. It is written in C programming language, making it compatible with the ARM64 architecture.

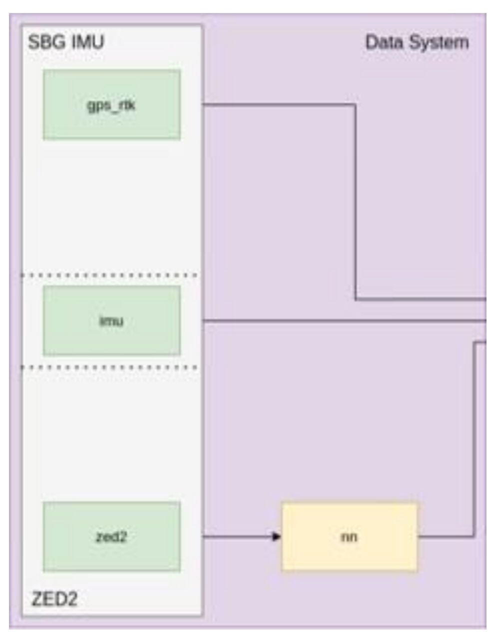
B. High-level system

Most of the work is done by the high-level software that operates on main CPU which is Nvidia Xavier AGX. This system takes care of vessel positioning, motor calculator, obstacle mapping, pathfinding and logging. Similarly to the previous version of our high-level software it has been developed as a network of special modules, each responsible for a various tasks. Thanks to ROS (Robot Operating System) we are able to communicate those modules and create connections beetween tchem is order to send data required for our algorithms. Most of this software is written in Python programming language. High-level system is divided into two smaller subsystems:

- Data system,
- Control system.

I.Data system

This system is responsible for gathering all kind of data from surounded environment. It consists of ROS nodes called gps_rtk, imu and zed2 which is connected to our neural network node.



I.Data system diagram

I.I. Gps_rtk + imu

This is special node implemented in order to handling the SBG Ellipse-D IMU with integrated GPS RTK functionality. We will mainly use the GPS RTK and IMU options for this module in order to get accurate positioning of both the boat and the obstacles on the course. The module (SBG IMU) communicates via CAN, so we realized some integration with the ***motors*** component.

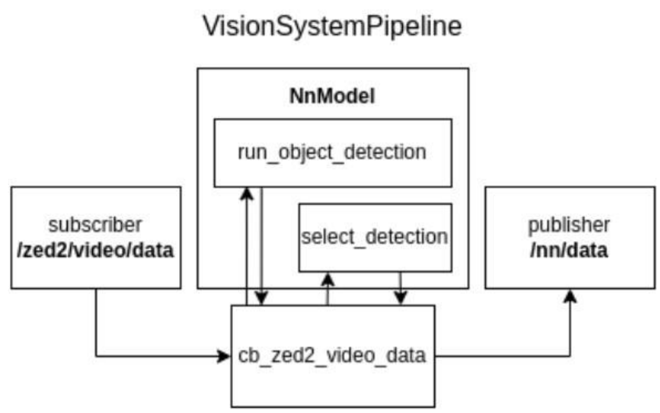
I.II. Zed2

This is component for ZED2i camera control. We use the producer's library, so it's technically just a ROS-enabled wrapper with minimalist functionality for our use. The concrete functionalities are to be decided, but they will include:

- Grabbing stereo video frames including the embedded depth measurement,
- Sending the grabbed frame over ROS with custom defined messages,
- Starting and stopping recording into a file (.svo format, script for conversion not needed – supplied in the SDK),
- Sending IMU data (from the IMU embedded in the camera) over to the ROS network.

I.III. Neural network (nn)

The neural network that produces detection ROS messages (*DetectionData*). This is a ***major*** component, which is our primary focus. The data produced by this neural network will be later used for obstacle avoidance and obstacle mapping in the *core*. This node is responsible for object detection in real time using our pretrained model which is loaded in our module that contains also functions that allow to run detection algorithms on the input images from the Zed2i camera. After inference we are able to select most accurate detections. In order to implement vision system we use tensorflow library and object detection API. The model that we have used for running our neural network module is resnet50 but recently we are working for deployment of new model which is yolov5.



II. Vision system pipeline

II. Control system

This system is required for all autonomous control logic. It is build of two nodes: core and motors which are responsible for getting required data information from collected data.

III. Control system diagram

II.I. Core (algorithms & fsm)

The main high-level vessel control component. It collects inputs from all sensors after they've been properly prepared (filtered, scaled, etc.) and uses it in various algorithms.

II.II. Motors

Component for passing on CAN messages to the **control board** based on ROS *MotorPowerData* messages received from the Core component. This is an interface component between the high-level logic and the embedded control system.

III. + Motors disable command

This component is responsible for stopping our autonomous vessel after it goes out of range from the operator control station. It is checking the connection with gogle dns server every second. If it can't, it sends special motor diable command id (1 to stop). If motors returns the same command id, then it has been executed correctly. If it returns 0, then some failure has occurred.

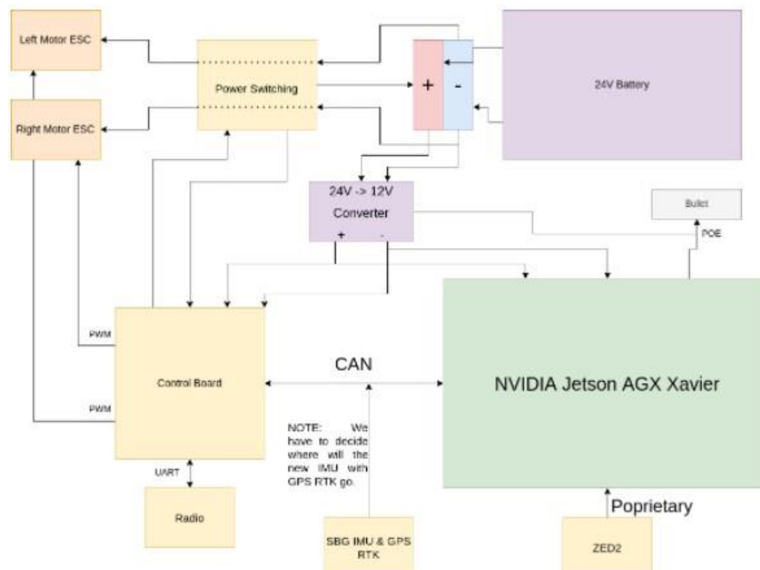
Electronics

The fundamental control setup is made up of custom PCB board, developed by our team members. It has two tasks:

- Relay the control signals calculated by high-level system,
- Safely manage the power supply including safety switches.

The main board with embedded software allows us to generate signal to be passed for ESCs that control the motors. It's main function is to generate an appropriate PWM signal based on data received from system on main CPU and messages received from radio. You can disconnect the power either via remote kill switch or a manual kill switch. The remote kill switch can be triggered via radio, based on LoRa protocol.

The schema below show all hardware management on autonomous boat.



IV. Hardware graphical schema

Hull

The hull is in the form of catamaran with floats connected by ultra-light and durable profiles. This kind of construction allows quick and easy disassembly into component parts which can be fitted into the small luggage. A boat designed for universal research with size that allows for trouble-free transport to any place is a solution needed in the market that will arouse interest in the autonomous vehicle industry. The CAD model has been designed and subjected to numerical simulations CFD to optimize the geometry of the structure in terms of boat hydrodynamic resistance. Then based on the obtained results, an FEM analysis of the resulting stresses and strains was carried out. The floats are created from sandwich composite material. The core of the sandwich consist of a thin layer of polyurethane foam. It ensures good stress transfer between the covers and lightness of the entire structure. Basalt fiber was used in the covers as a reinforcing phase. Currently, it is gaining more and more popular in the industry due to its properties. This kind of fiber has a lot of advantages, it is corrosion resistant, has greater mechanical strength and is very light which is really important in our model. Moreover, it is recyclable material of natural origin. What is also important for construction, basalt is transparent for measuring equipment, so it does not interfere with the operation of the measuring apparatus.

V. Model of autonomous boat Barka

Powertrain

The vessel is propulsed by two underwater thrusters from Blue Robotics model T200, each giving up to 645 [W] of power. The motors are connected to the back of the boat.

Appendix A: Component Specifications

Component	Vendor	Model/Type	Specs	Custom/Purchased	Cost	Year of purchase
ASV Hull Form/Platform	-	-	made of basalt fiber composite	custom	-	2023
Waterproof Connectors	KSS Wiring	-	-	purchased	25$	2022
Propulsion	Blue Robotics	T200	-	purchased	donated	2022
Power System	Zeee	4S Lipo Battery	-	purchased	150$	
Motor Controls	Blue Robotics	Basic ESC	-	purchased	donated	2022
CPU	Nvidia	Xavier AGX	-	purchased	1308$	2022
Teleoperation	Tbs	Crossfire rx		purchased	30$	2023
Compass	-	-	-	-	-	-
Inertial Measurement Unit (IMU)	SBG Systems	Ellipse-D	-	purchased	3358$	2022
Doppler Velocity Logger (DVL)	-	-	-	-	-	-
Camera(s)	Stereo Labs	Zed2i	-	purchased	589$	2022
Controlling PCB	-	-	-	custom	50$	2022
Hydrophones	-	-	-	-	-	-
Algorithms	-	-	-	custom	-	-
Vision	-	Neural network	Bouya detection	custom	-	2023
Localization and Mapping	-	-	-	custom	-	-
Autonomy	-	-	-	custom	-	-
Open-Source Software	-	-	-	custom	-	-