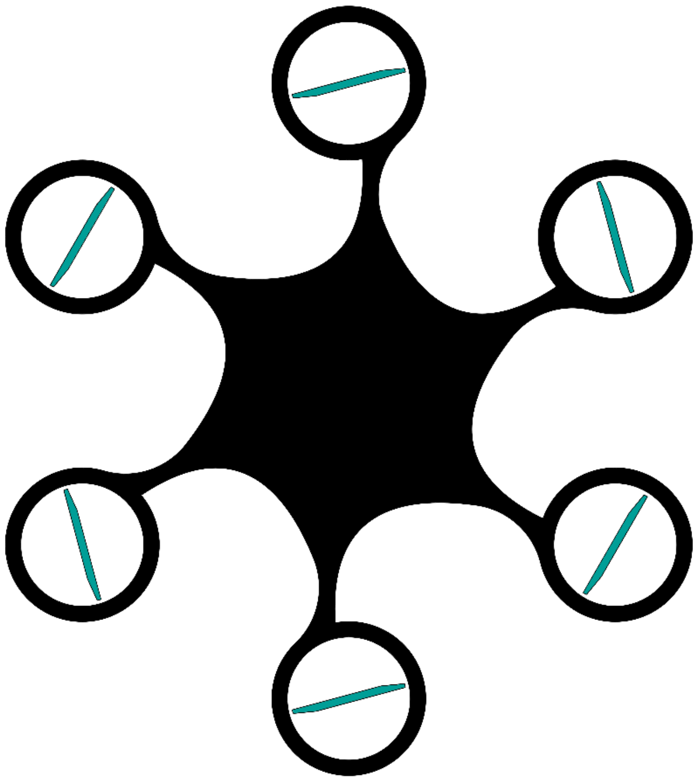
Competition Drone

Technical documentation



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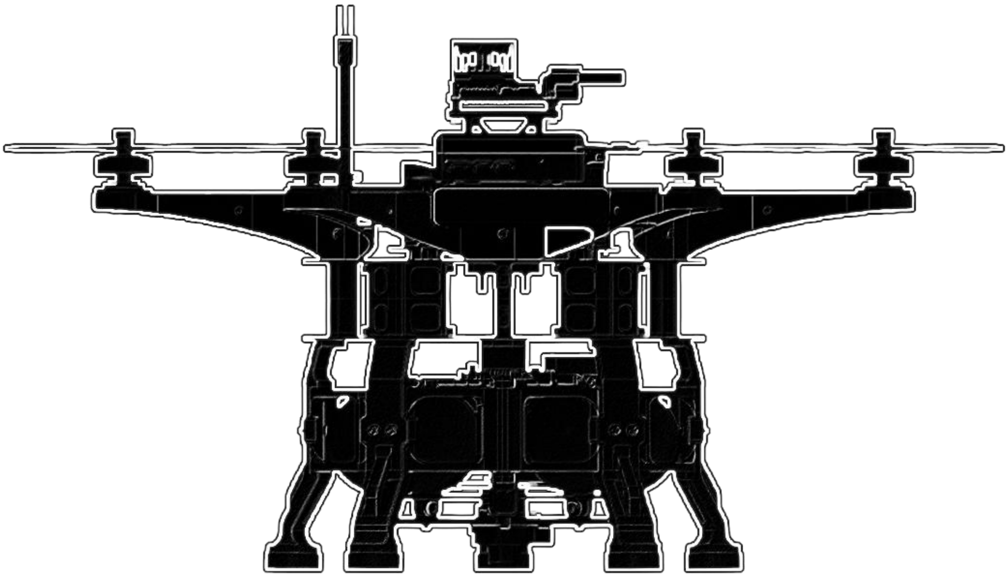

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This technical documentation deals with the description of a competition drone of the VŠB-TUO Department of Robotics, which is designed to participate in a competition held at TDTU in Vietnam, where its main task is to drop balls on designated targets with maximum accuracy. This drone is equipped with several key subsystems that ensure its full autonomy, its ability to detect targets and deliver balls accurately to these targets.

The competition drone is divided into several subsystems, each of which performs a specific function to ensure efficient and accurate operation.

Locomotion subsystem: Contains six motors that provide stable and dynamic movement of the drone in all axes. It allows flexible and precise control of speed and position in the air.

Action subsystem: This subsystem is responsible for dropping the balls on the marked targets. The mechanism is designed to allow fast and accurate ball release.

Control and communication subsystem: Includes the Pixhawk 6C flight controller, which provides flight stability and overall control of the drone. The RealSense T265 camera is integrated for navigation and precise position detection of the drone. This subsystem also includes communication between the drone and the controllers, either for manual or autonomous control.

Vision subsystem: For image data processing, the drone is equipped with a Raspberry HQ camera to detect targets, analyze the pad and assist in guiding the drone to the right place to drop the balls.

Power Supply Subsystem: provides power to all drone components, including motors, controllers and camera systems.

The drone is able to operate in two modes of operation: manual control, where the pilot uses a remote control to control the drone's movement, and autonomous mode, where the drone fully automates its movements and performs the tasks assigned without direct human intervention.

This documentation also describes the development of this drone, including the team set-up and the definition of key technical requirements. The team consists of software, mechanical and electronics experts who together designed the kinematic scheme of the drone and implemented key algorithms for its autonomous control. We used a variety of software tools for efficient development, including simulators for autonomy testing, design software for 3D modeling, and development environments for algorithm implementation.

1 DESCRIPTION OF THE DRONE

Competition drone of the Department of Robotics, see Fig. 1.1, is an autonomous flying robot developed by students of the University of Mining Engineering in Ostrava, who are working on its development and their own improvement. The drone was developed primarily for the *"International Drone Competition"* held in November 2024 at TDT University in Vietnam.

In addition to the above mentioned competition, the drone is also designed to participate in other international competitions. Based on the rules of the competition, the drone always needs to be modified, develop the necessary module, change the design, program new software, etc.

The drone is equipped with advanced sensors and technologies that allow it to perform autonomous flight, data collection and remote control. The design and software is continuously improved by students of bachelor, master and doctoral programs, who strive to achieve the best possible results during the tasks at each competition.

During the development of the system, high emphasis was placed on reliability, durability, light weight and modularity. Thanks to these features, the system can be quickly maintained and serviced.

To control the robot in autonomous mode, at least one operator is needed to supervise the task remotely from the control computer, check data from individual sensors, and possibly terminate the service task and call the drone back. In the case of manual control, a minimum of three operators are needed. One of the operators controls the drone using a remote RC controller the second operator uses the camera images to aim the target into which the tennis ball needs to be launched and the third operator performs quick service and maintenance in case the drone needs to make any changes to the system during the task.

Fig. 1.1 Competition drone

1.1 Drone parameters

In the picture below, see Fig. 1.2, shows the basic dimensions of the robotics department's competition drone. At Fig. 1.3 depicts the various subsystems of the competition drone, and in the table on the next page, see Tab. 1.1, more detailed parameters of the proposed flying system are listed.

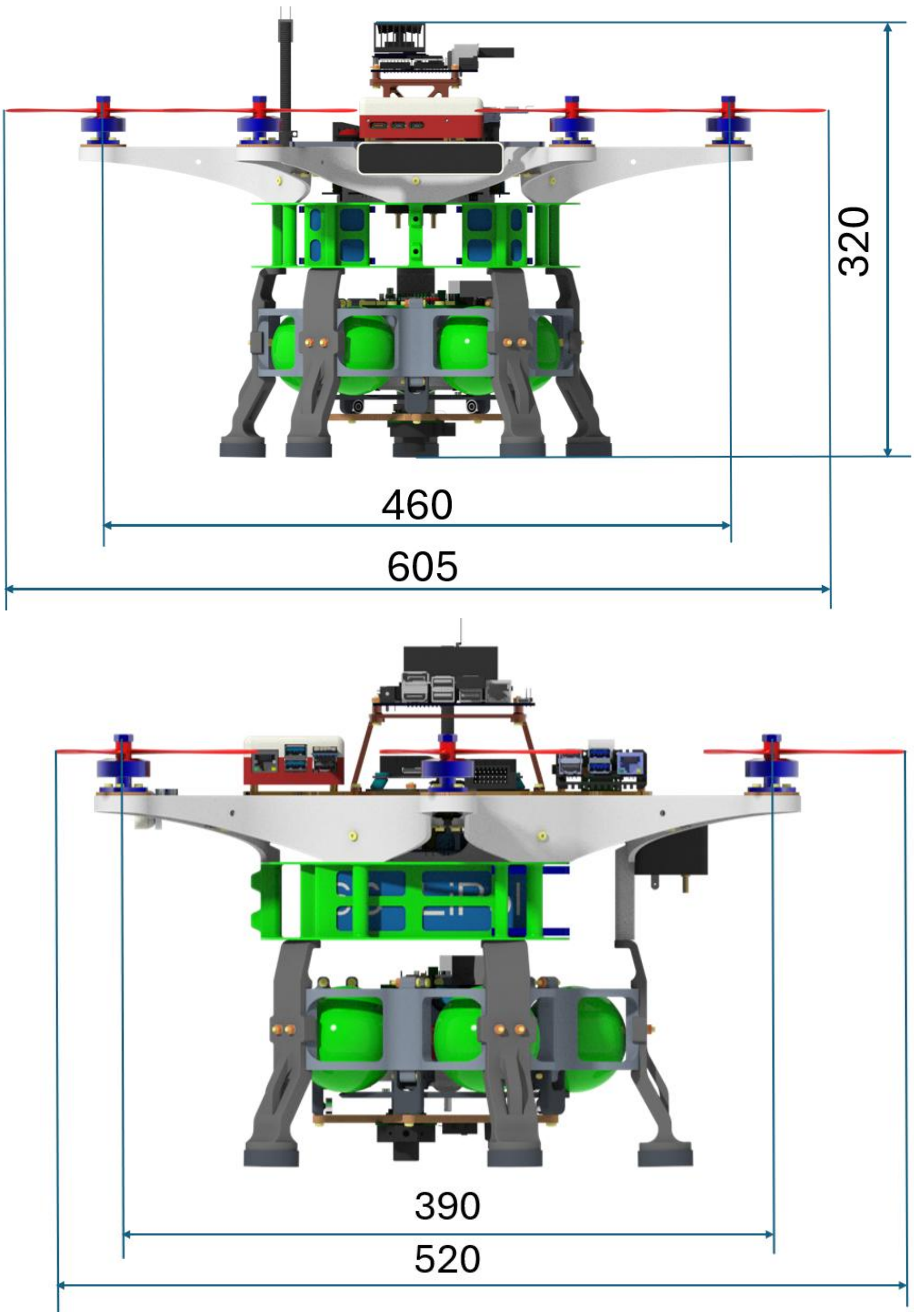
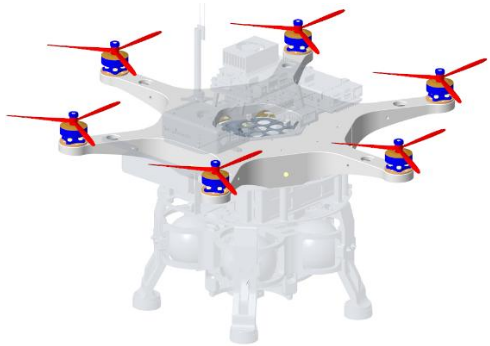
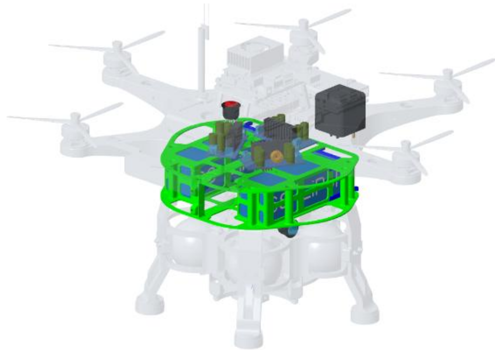


Fig. 1.2 Basic dimensions of the competition drone



Locomotion subsystem



Energy security subsystem

Control and communication subsystem

Action subsystem

Vision subsystem

Fig. 1.3 Subsystems of the competition drone

Tab. 1.1 Parameters of the competition drone

Parameter	Value
Maximum dimensions	605 × 520 × 320 mm
Number of motors (propellers)	6 (6)
Total weight	5 kg
Weight without action subsystem	3,6 kg
Maximum flight time	10 minutes
Number of accumulators	2
Battery type	Lithium-Polymer
Nominal battery voltage	22,2 V
Flight controller	Pixhawk 6C
Number of balls in the action subsystem	5

1.2 Operating states

This subsection describes the drone operational conditions that team members encounter during the use of the system. It is important to follow the texts that are given for each state. Failure to follow the specified procedures can result not only in damage to the system, but also in personal injury. It is always necessary to read the text below that corresponds to a given operational condition before the operational condition.

1.2.1 Development

When developing a drone, there are usually several people working on it at the same time, and it must be taken into account that some of the drone's subsystems will not behave as described in this document. During development, the safety switches on the system must be in the off position and the system must not be connected to batteries. During the development phase, the system is usually unenclosed and may cause cuts or other personal injury, and the use of protective equipment is commanded during this operating condition. Use caution when handling electronics and avoid damaging wiring.

WARNING

During development, work in software that is used within the team and has shared storage. Shared storage makes it more efficient to share newly created designs for a subsystem.

1.2.2 Testing

Before testing the system, it is necessary to check whether the wiring of the hardware components corresponds to the wiring diagrams of the individual subsystems of the drone. No cables shall protrude from the system. In case it is not possible to remove these cables, it is necessary to ensure that they do not interfere with the movement of the system and to isolate the ends of the cabling or to blind the unused connectors.

Before testing, check that there are fire extinguishers nearby in the test facility. Then check that the safety switches are in the off position. Put on protective equipment and connect the batteries to the system. You can now put the safety switches in the on position. If the system shows signs of unwanted behaviour, immediately switch the safety switches to the off position and disconnect the batteries.

WARNING

In the case of testing the system or any of its subsystems, it is necessary to take extra care, the system may behave non-standardly. Protective equipment such as gloves and goggles must also be used during testing.

1.2.3 Transportation

If the drone needs to be transported, the batteries must be removed from the drone. Failure to remove the batteries could result in a short circuit and damage to the system. The batteries must always be transported separately in a safe place away from the system. When transporting by air, please follow the airline's instructions, these are Li-Pol batteries and some airlines may not allow the transport of these batteries. When transporting, the drone must be secured in such a way that it does not move spontaneously during transport, spontaneous movement could cause mechanical damage to the system. The loose ends of the wiring must be insulated or the connectors must be blinded to prevent damage.

If any of the cables protrude from the structure, the cable must be glued to the structure so that they are not loose and prevent free movement. Once the transportation of the drone is complete and the drone is outside of the transportation facility, the batteries can be reconnected to the system.

⚠	**WARNING**
In the case of both local and global transport of the system, it is necessary that the batteries are disconnected from the system, while at the same time the batteries must not be connected in parallel with each other using cabling that allows this connection.	

1.2.4 Operation

Before operating the drone, you should first check that the appearance of the system corresponds to the pictures in this document. Next, the wiring of the hardware components should be checked to see if the wiring corresponds to the wiring diagrams shown in this document. If any part of the system does not correspond to the information given in this document, the part needs to be rectified. It is also necessary to check individual algorithms to see if the algorithm matches the information in this document. In the event that the above check has been carried out, batteries need to be inserted into the system that are charged to the maximum level. Once the batteries have been inserted into the system, the system needs to be switched on using the safety button, after which the system is ready for operation. The operator has the option of selecting manual or autonomous mode.

⚠	**WARNING**
It is forbidden to approach the drone or any of its parts during operation, as personal injury and damage to any part of the system may result. During operation, the operator and the other team members must be at a distance that ensures that in the event of a malfunction, no harm will be caused to the participating team members.	

1.2.5 Maintenance

Before maintenance, the batteries must be removed and the system secured against movement. The system must be cleaned of any coarse dirt that may have been deposited on the system during operation, e.g. leaves, airborne dirt. When using water-based cleaners, areas with electronics must be avoided, as irreversible damage to the hardware component may occur. Clean these areas using compressed air spray. Use the compressed air spray in accordance with the instructions included with the selected compressed air spray.

⚠	**WARNING**
If maintenance is carried out on mechanical components, protective equipment such as gloves and safety glasses must be used. In the case of maintenance on hardware components, the batteries need to be removed from the system and the safety button needs to be in the off position.	

1.2.6 Service

In the event of non-standard system behaviour (such as that not specified in this document), the system must be switched off by using the safety buttons and switching them to the off position. The next step is to remove the batteries. Then carry out the necessary servicing. Servicing should always be carried out with safety equipment such as goggles and protective gloves to avoid personal injury. Once servicing is complete, testing should be carried out.

⚠	**WARNING**
When handling individual parts, use caution and do not use sharp tools that may damage or destroy mechanical or electrical parts of the system. When using tools, be aware of your safety and wear protective equipment.	

1.2.7 Charging

Before charging the batteries, the batteries must first be removed from the system. The batteries must never be charged when they are placed in the system. Furthermore, they must not be charged if the batteries are visibly damaged and do not correspond in appearance to the pictures shown in this document. Charge the battery with the supplied multi-function charger. Always check that all batteries are charged to the same and maximum level before inserting them back into the system.

⚠	**WARNING**
Do not use a third-party charger. Do not leave the battery unattended while charging and if there are problems, stop the charging cycle immediately. The battery may heat up to a higher temperature during charging. The battery should be kept in a protective case during charging.	

⚠	**WARNING**
Use caution when handling the battery in any way. Do not use sharp tools, water or other cleaning agents. If the battery is short-circuited or otherwise damaged (mechanical, chemical), there is a risk of explosion, ignition, etc.	

⚠	**WARNING**
Before carrying out maintenance, the module must be disconnected from the power supply, i.e. disconnect the power and communication cabling of the module, there is a risk of electric shock.	

2 DRONE DEVELOPMENT

This chapter deals with the development of our drone solution for the "Internation Drone Competition". In the first subsection, the team and its members are first described, along with their specialization in the drone subsystem. This is followed by the application of the service scenario methodology to the defined problem. This subchapter describes the objectives of each task that needs to be accomplished with the drone and also how these objectives are achieved. Next, a general requirement list was established based on the competition rules and our capabilities. The development continues with the creation of the functional, organ and structural structure of the drone. Based on these structures, a kinematic diagram of the mechanism is also created.

2.1 Team

Team Drone VSB-TUO consists of 7 members in total, each member is responsible for a specific part related to the drone. The team consists of members from bachelor, master and doctoral studies. The picture below shows the pictures of the team members, their names and their specialization in that area.

Ing. Tomáš Drastik
Team leader and autonomous driving specialist

Bc. Jindřich Třaskoš
Control and communication specialist

Bc. Radomír Nový
Control and communication specialist

Ing. Daniel Hartmann
Documentation specialist

Bc. Matyáš Machalla
Locomotion subsystem specialist

Matěj Papežík
Action subsystem specialist

Bc. Ondřej Binar
Specialist of vision subsystem

2.2 Software tools used within the team

During the development of the system, a large amount of data is created, such as CAD models, drawings, electronics wiring diagrams, algorithms, etc. In order to share the data comfortably between the members, a suitable platform had to be selected for each type of data.

Communication and division of tasks and between team members

The team holds regular weekly meetings where all members come together and present progress in the area being addressed, and other members can ask questions and make comments. The Teams app is used for online communication. With this application, it is possible to assign tasks to individual members in a given area, check the completion of tasks, share files, or hold online meetings. A record of each meeting is also created, describing the points discussed and recording attendance.

Sharing and creating CAD files

The team uses PTC Creo Parametric 10 CAD software to create 3D CAD models and drawings. To share the 3D models and drawings between users, the team uses PTC's Windchill PLM system. This tool allows the files created in the Creo CAD system to be shared over the network, and it is also possible to see who is currently editing the files and who has made the latest changes.

Sharing and creating electronics and PCB wiring diagrams

The team uses the online tool EasyEDA to create electronics wiring diagrams and design PCBs. The advantage of this tool is that it is an online application that can be used in a browser, so there is no need to download software to a computer. Sharing of the created schematics and PCBs is handled through a common project within EasyEDA, which all team members have access to.

Sharing and creating diagrams

The team uses the online tool DrawIO to create flowcharts, swimlane and other types of diagrams. This tool can be linked to a shared storage within Google drive. The tool also has the advantage of selecting from a large number of pre-made diagrams that can be customised by individual team members to suit their needs. These diagrams can also be used to explain algorithms to other team members who are not as experienced in programming.

Sharing and creating algorithms

In order for individual team members to have access to the algorithms created for each subsystem of the drone, the team uses Git and GitHub. With these tools, it is not only possible to share the algorithms created, but also to go back to previous versions of each algorithm.

Sharing and creating text documentation

Text documentation is created and shared within the team in Word and shared using OneDrive. Ideas and thoughts can be written by individual team members in OneNote, and the resulting documentation is then continuously expanded upon based on these ideas and thoughts. Documentation is divided into internal and external within the team. External documentation is submitted to the judges, describing the proposed flying system, its subsystems, controls, etc. Internal documentation is for team members only and is used to gain a deeper understanding of the issues related to the proposed system, and also describes previous versions of the subsystem.

System simulation

In order to test the individual designs before implementation, a simulation is created in the CoppeliaSim EDU simulation environment. This tool allows testing not only the proposed design, but also the algorithms for autonomous and manual operation of the system.

Purchases within the team

Purchases are recorded within the team in an application created in Excel. In the application, the individual components purchased are assigned to a given subsystem, so it is possible to determine how much money was spent on each subsystem. The application also includes a graphical representation of the ratio between expenditure and remaining funds for component purchases.

Documentation of 3D printing production

Within the development team we use 3D printing as the main technology for production. Each printed part is recorded in an Excel application, where the necessary information for the part, such as the weight of the material used, the cost of electricity, the type of printer, the number of pieces, etc. Based on these parameters, the application calculates the price of one piece of the part and the price for all pieces. The application also calculates the total price and weight of the material used as well as the total electricity consumed. A graphical representation of the selected parameters is also included.

Inventory of components

In order for all team members to keep track of the components that have been purchased, manufactured or borrowed from the robotics department for the development of the drone, an Excel application is created where all these components are sent. For each component, the price, the total number of pieces, how many of the component is used, or if any of the components have been discarded. Thanks to this application, we know whether we need to reorder any of the components or whether we have them available on the shop floor.

Task planning

In order to graphically present the completion and setting of new tasks within the team, a gantt chart is created in Excel. The chart is used to record all the tasks that need to be completed, the time it is expected to take to complete the tasks, and then the actual completion time once the task is completed. Thanks to this tool, we have an overview of which tasks have already been completed and how long it took to complete them, so optimization can occur when completing a similar task.

2.3 Application of the service scenario methodology to the defined problem

Chronologically arranges the events and processes related to the activities and operation of the service robotic system in the execution of the required service task, including their links. The result is a comprehensive formulation of the technical requirements for the service technology and the means of its implementation, for the SR itself, as well as for the operation and maintenance of the entire service robotic system by the user.

Product

The drone produces flight in autonomous and manual mode. Autonomous flight is produced based on data from individual sensors. The minimum flight height is 5 meters. This value is provided by the barometric altimeter. Thanks to this sensor it is also possible to maintain a constant flight altitude. Furthermore, the drone produces a move to the desired location where the ball is placed. The movement is enabled based on the navigation algorithm. The desired location is determined based on the algorithm that processes the data from the vision sensor. In the manual mode, movement is provided based on a controller held by the operator. The data from each sensor is available to the operator to adapt the control as much as possible to the actual service conditions in the environment.

Process

The whole process of the drone's working cycle consists in the autonomous mode in flying up to a height of more than 5 meters, then it is necessary to maintain this height with a sufficient reserve. Next, it is necessary to use sensors and algorithms to find the first target into which the ball from the action body is launched. Next, the search for other targets and the launching of balls is carried out. Once all balls are launched at the targets, the drone's service task is complete. In the case of manual control, the process of the service task is controlled by the operator through the controller. The drone moves based on commands from the controller.

Technology

In order to achieve the above product and process, the drone needs to contain the appropriate technologies. To achieve the take-off and movement in the air, the drone is equipped with a locomotion subsystem that contains a total of four BLDC motors with three-bladed propellers. In order to be controlled by an operator, the drone includes a single board computer and a controller for the motors. The power supply is provided by four batteries. The system also includes an IMU sensor and a barometric altimeter. The ball-launching action attachment is controlled via a single-board computer. The release of individual balls is provided by a stepper motor and a rotary mechanism. The drone is also equipped with the necessary vision sensors that sense the surrounding environment, the visual data is then processed and evaluated.

Environment

The drone is developed based on the environment that is set by the rules of the competition. It is therefore designed for the indoor gym environment. It is necessary to take into account that smoke or water vapor may occur in the environment, so it is necessary to take into account these aggravating conditions and at the same time it is necessary to protect the vulnerable parts of the system from the ambient conditions.

Client

Operation of the drone with the action body is carried out via Wi-Fi or with a controller using a radio signal, thanks to this communication it is possible to control the status of the drone, the height at which it is currently located, images from cameras, etc. Regular maintenance of the whole system including the action body is required, i.e. checking of propellers, wiring, electronics, screw and clamp connections. Operation of the robot should always start with fully charged batteries and all batteries should be replaced with charged batteries after each service task is completed. Maintenance is always performed after each round of competition to prevent unexpected failures.

Operator

Control of the drone is performed using the software completely autonomously. The operator will receive live information about the current position of the robot, image data from the cameras, the height at which it is located, the number of dropped and remaining balls, etc. In the case of manual control, the operator uses a controller. It is important that the operator has experience in operating similar devices, a pilot's license of the required level and sufficient feedback from the system.

2.4 Requirement sheet V3

On the basis of the competition rules, the research of the individual subsystems and the team's capabilities, a requirement sheet was drawn up, see Tab. 2.1.

Tab. 2.1 Requirement sheet for the development of a competition drone

Category	Request	Value	Note
Construction	Weight of the whole system	5 kg	
	Action subsystem mass	1 kg	
	Weight of vision subsystem	0,5 kg	
	Number of balls in the action sub.	5 pcs.	
	Max. drone dimensions	0,5 × 0,5 × 0,5 m	width × length × height
	Max. dimensions of action sub.	0,45 × 0,45 × 0,5 m	width × length × height
	Number of propellers and type	6 pcs. GEMFAN FLASH 7040	Trifoliate
	Frame	PETG	3D printing
	Wings	PETG	3D printing
	Action subsystem	PETG	3D printing
Electronics	Locomotive motor	AOS SUPERNOVA 2807 1400KV	6 pcs.
	Flight controller	Pixhawk 6X Standard	
	ESC	ESC Flycolor X-Cross 2 50A 3-6S	
	Computer for driving	Raspberry Pi 5	
	Optical flow sensor	ESC Flycolor X-Cross 2 50A 3-6S	
	Action subsystem motor	17HS13-0404S	Stepper motor
	Action subsystem controller	Arduino nano	
	Motor driver action sub.	A4988 Pro Reprap	
	Computer for vision	Raspberry Pi 4	
	Camera	RaspberryPi HQ camera	Interchangeable lens
	Battery capacity	18.4 Ah/22.2 VDC	LiPol
Working environment	Service task environment	Gym	
	Temperature	20 ÷ 50 °C	Estimated
	Humidity without condensation	5 ÷ 95 %	Estimated
Buoyancy parameters	Lift at 50% power	7,5 kg	
	Lift at 100% power	15 kg	
Service	Data from the system	Wi-Fi	
	Operator control	2.4 GHz	Radiomaster Boxer ELRS
	Switching the system on/off	ON/OFF button	Relay 24 V 120 A

2.5 Functional structure of the mechanism

This subsection describes the main, assisting and called functions of the whole system. Main functions are those functions that characterize the system under development, assisting functions are those functions that assist the main functions of the system. Invoked functions are those functions that serve to invoke the two aforementioned functions.

Main functions

The main function of this system is to take off, maintain the prescribed flight altitude and then navigate to the desired location where the balls are placed. It is necessary to detect the altitude level, detect the position of the system on the competition area and control the launched balls. There is also a need to detect targets where balls need to be dropped and also obstacles that overlap the targets.

Assisting functions

The assisting function for take-off and holding the flight level are the motors together with the propellers, also included is a barometric sensor that detects the flight altitude. The assisting function is furthermore the holders for the action subsystem, which allow the transmission of the subsystem together with the drone to the desired location where the balls are placed. In order to check the main functions, LEDs are placed on the drone to indicate the performance of the main ones for assistance.

Called functions

To invoke the above functions, the drone is equipped with a control system and controller together with a motor driver, which is designed to control the motors and communicate with the control system. The control system also invokes the assisting function of the LEDs. To invoke the target detection function, the drone includes a vision subsystem. In order to release the balls on the target, a rotary mechanism is included in the subsystem to trigger the ball release. To invoke the overall behavior of the system, the operator uses an RC controller.

2.6 Organ structure

This subchapter is divided into two subchapters for clarity. The first subchapter deals with the organ structure of the drone without the action subsystem. The different organs are described, which generally represent the different parts of the proposed drone. The second subchapter deals with the organ structure of the action subsystem, where the individual organs are described similarly to the drone.

2.6.1 Drone organ structure without action subsystem

In this subsection, the individual organs of the drone's locomotion system are depicted in a diagram, see Fig. 2.1 a Tab. 2.2. This is actually the first general design of the whole system, where the different important parts (organs) that are on the drone are depicted.

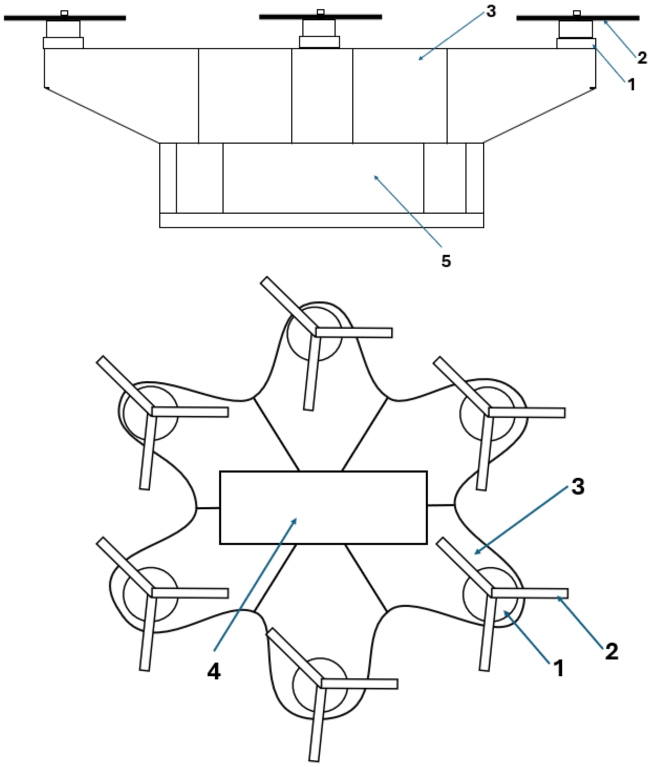


Fig. 2.1 Organ structure of drone without action subsystem

Tab. 2.2 Drone organ structure components without action subsystem

Number	Authority
1	Propeller drive organ
2	Authority to create buoyancy
3	Drone drives and frame holder
4	Authority for positioning control electronics
5	Authority for placement of accumulators

2.6.2 Organ structure of the action subsystem

In this subsection, the individual organs of the action subsystem are depicted in a diagram, see Fig. 2.2 a Tab. 2.3. This is actually the first general design of the whole subsystem, showing the different important parts (organs) that are present on the action subsystem.

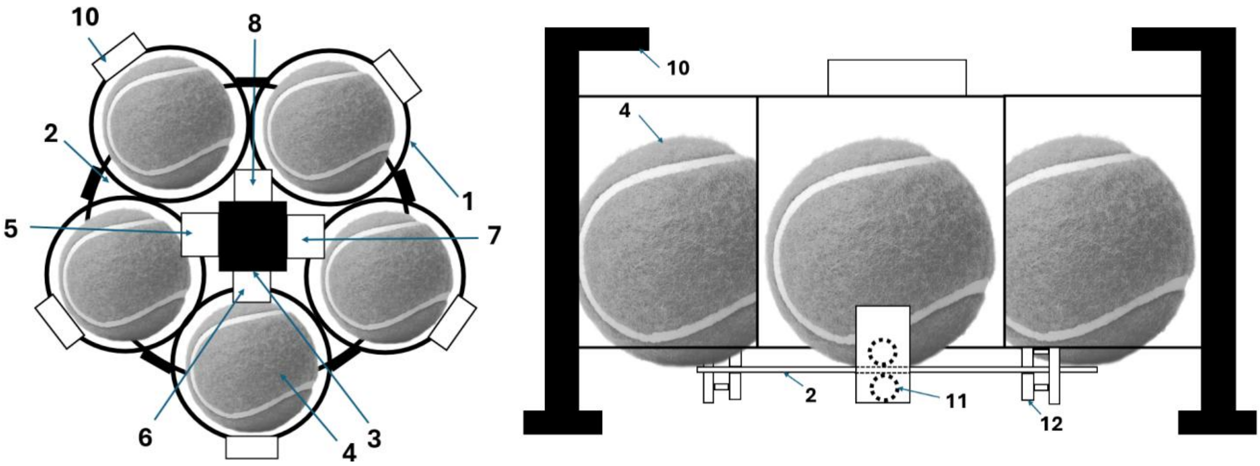


Fig. 2.2 Organ structure of the action subsystem

Tab. 2.3 Components of the organ structure of the action subsystem

Number	Authority
1	Organ tray for balls
2	Ball launching authority
3	Ball launching actuator
4	The body of the ball
5	Subsystem Management Body
6	Drive control authority
7	Authority of voltage change
8	Authority to switch off and on the action subsystem
9	The organ of Hall feedback probes
10	Action subsystem attachment body to the drone
11	Authority of the bearings
12	Authority of the bearings

2.7 Building structure

This chapter, like the previous one, is divided into two subchapters for the sake of clarity. The first subchapter deals with the structure of the drone without the action subsystem. The building structure is tightly coupled to the organ structure from which it is essentially based. The second subchapter deals with the organ structure of the action subsystem, where, similarly to the drone, the individual organs of this subsystem are described.

2.7.1 Drone structure without action subsystem

In this subsection, a diagram shows the structure of the drone without the action subsystem, see Fig. 2.3 a Tab. 2.4. The building structure already describes the specific components that will be part of the system including their location in the structure.

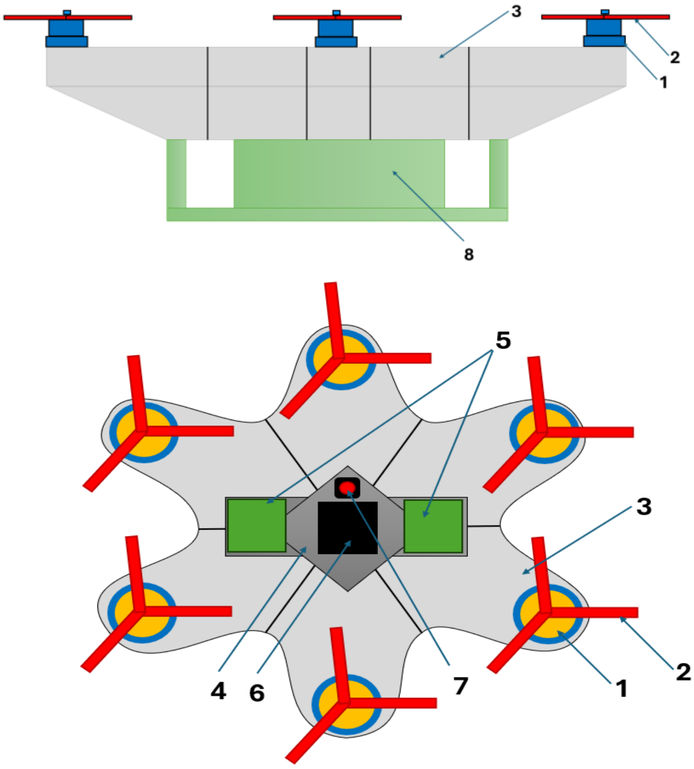


Fig. 2.3 Building structure of drone without action subsystem

Tab. 2.4 Components of the drone structure without action subsystem

Number	Component
1	High speed motors
2	Three-bladed propeller
3	PETG wings
4	Control electronics holder
5	Mini computers
6	Flight controller
7	ON/OFF button
8	Battery holder

2.7.2 Building structure of the action subsystem

In this subsection, the individual structures of the drone's action subsystem are illustrated in a diagram, see Fig. 2.4 a Tab. 2.5. The building structure already describes the specific components that will be part of the system including their location in the structure.

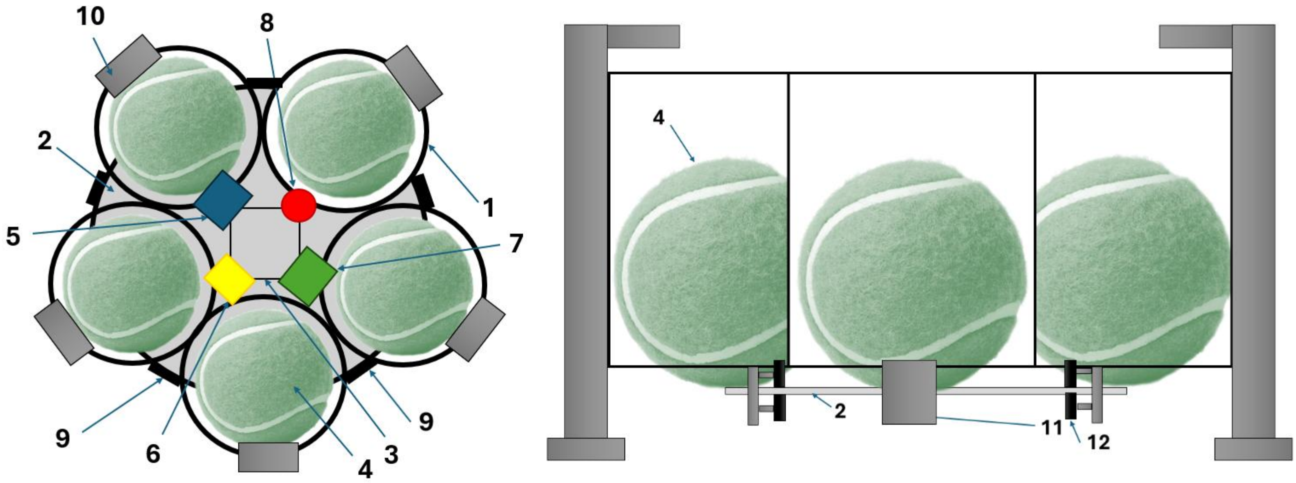


Fig. 2.4 Structure of the action subsystem

Tab. 2.5 Components of the building structure of the action subsystem

Number	Component
1	Tray for PETG balls
2	Rotating surface made of PETG
3	Stepper motor
4	Ball
5	Control system
6	Step-Down Converter
7	Motor driver
8	ON/OFF switch
9	Hall probes
10	Legs and brackets for attaching to the drone
11	Bearing holder
12	Bearing pivot surfaces

2.8 Kinematic diagram of the mechanism

This chapter is divided into several subchapters for clarity. The first subsection shows the kinematic diagram of the locomotion subsystem. The second subchapter shows the kinematic diagram of the action subsystem.

2.8.1 Kinematic diagram of a drone without action subsystem

In this subsection, the figure Fig. 2.5 shows the kinematic diagram of a drone without action subsystem

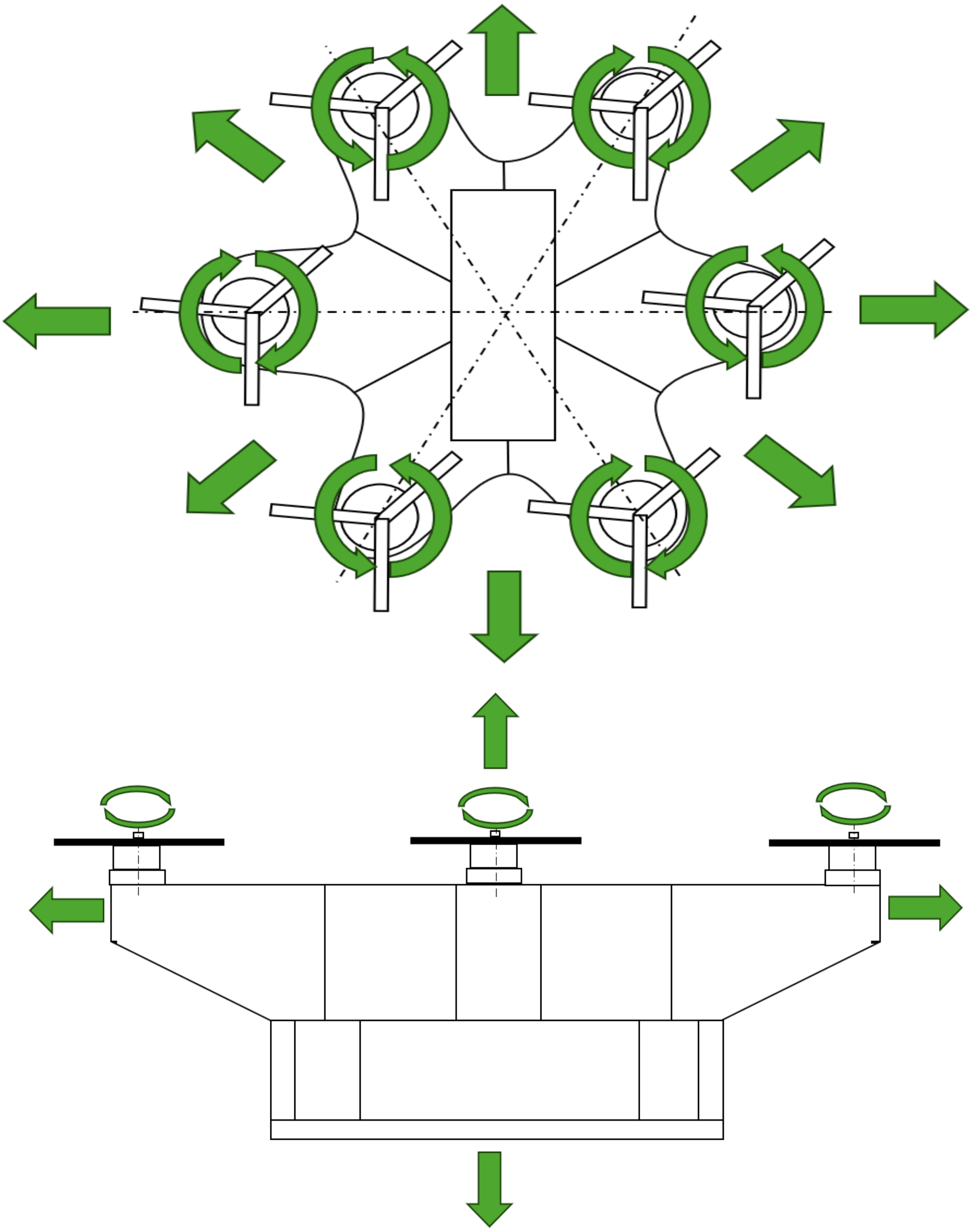


Fig. 2.5 Kinematic diagram of drone without action subsystem

2.8.2 Kinematic diagram of the action subsystem

In this subsection, the figure Fig. 2.7 shows the kinematic diagram of the action subsystem.

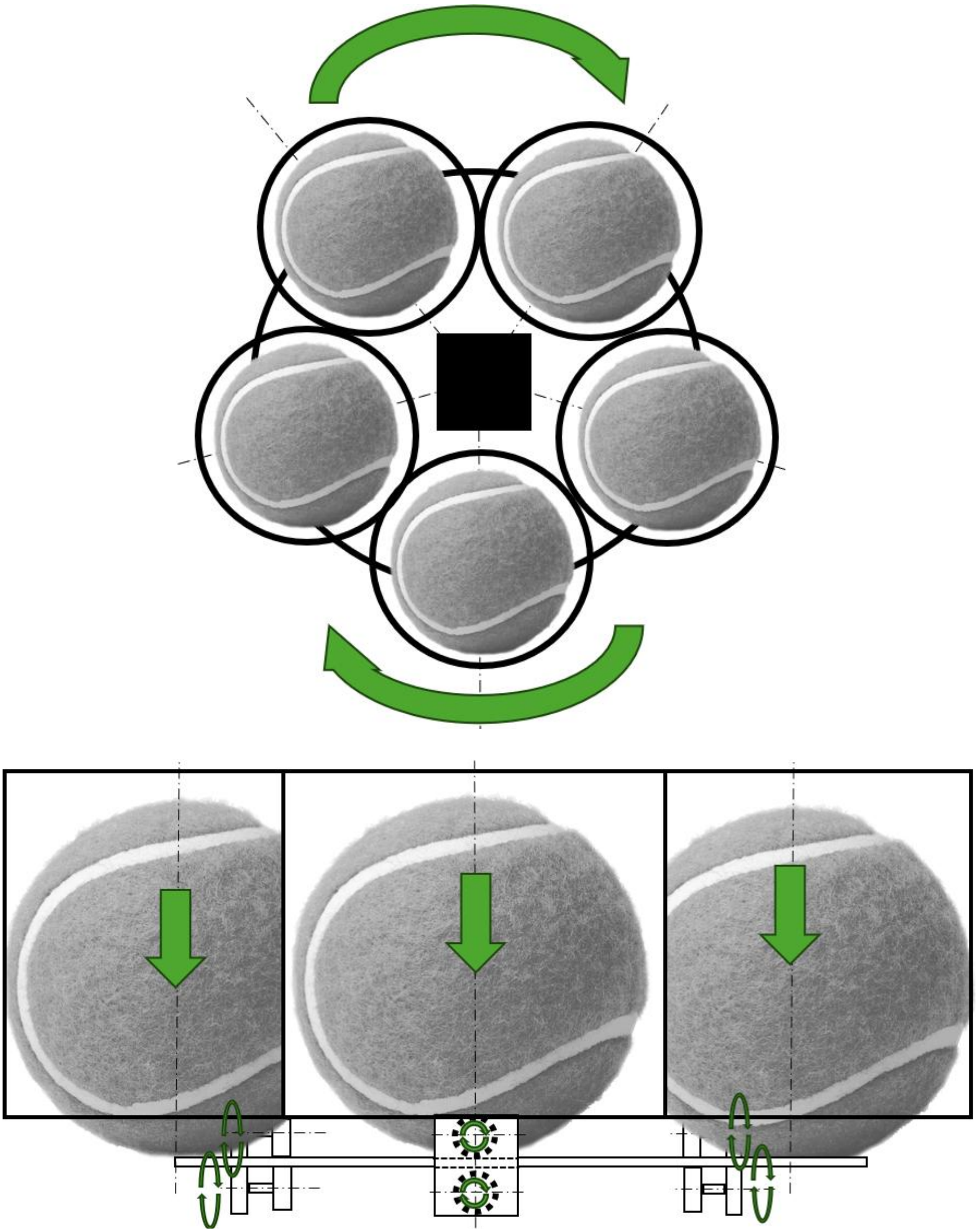


Fig. 2.7 Kinematic diagram of the action subsystem

3 LOCOMOTION SUBSYSTEM

The locomotion subsystem is made mainly by 3D printing from PETG material. The locomotion subsystem is equipped with a total of 6 motors and it is basically the basis of the whole drone.

3.1.1 Basic description of the subsystem

The mechanical part consists mainly of 3D printed parts made of PETG material. The mechanical part includes high-speed BLDC motors. There are 6 motors in total, so there are. The design of the subsystem was designed to make the parts interchangeable, while also keeping the weight low. The CAD model of the locomotive subsystem is shown on Fig. 3.1.

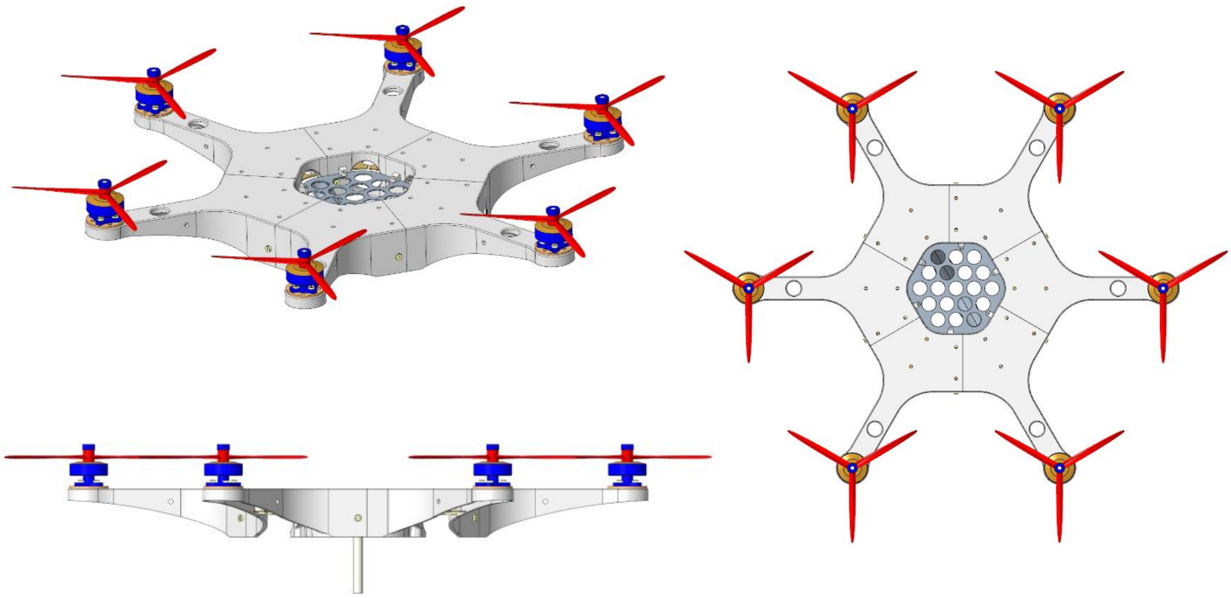


Fig. 3.1 CAD model of the locomotion subsystem

Parameters of the locomotion subsystem

At Fig. 3.2 shows the basic dimensions of the locomotion subsystem, the Tab. 3.1 other essential parameters related to this subsystem are listed.

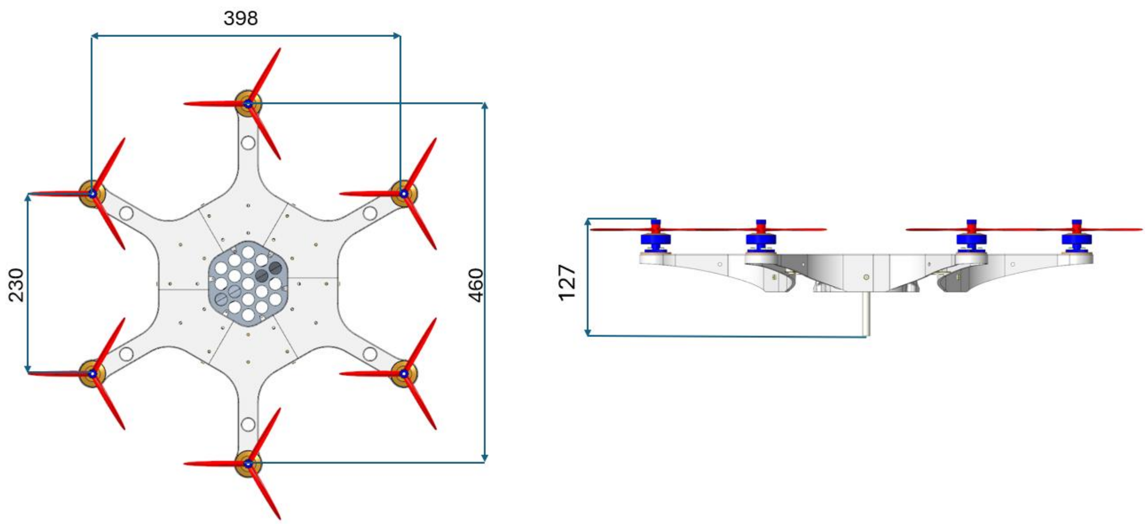


Fig. 3.2 Basic dimensions of the locomotion subsystem

Table 1 Basic parameters of the locomotion subsystem

Parameter	Value
Dimensions	460 × 398 × 127 mm
Weight	2,6 kg
Material of prints	PETG
Number of motors	6

Inventory of components

In the table below, see Tab. 3.1, all components that are present in the CAD model of the locomotion subsystem are listed. Based on the numbers in the table, the Fig. 3.3 indicates the component in question. The bolded part in the name of a given component is the commercial designation of that component. Each component name is also accompanied by the corresponding CAD model name.

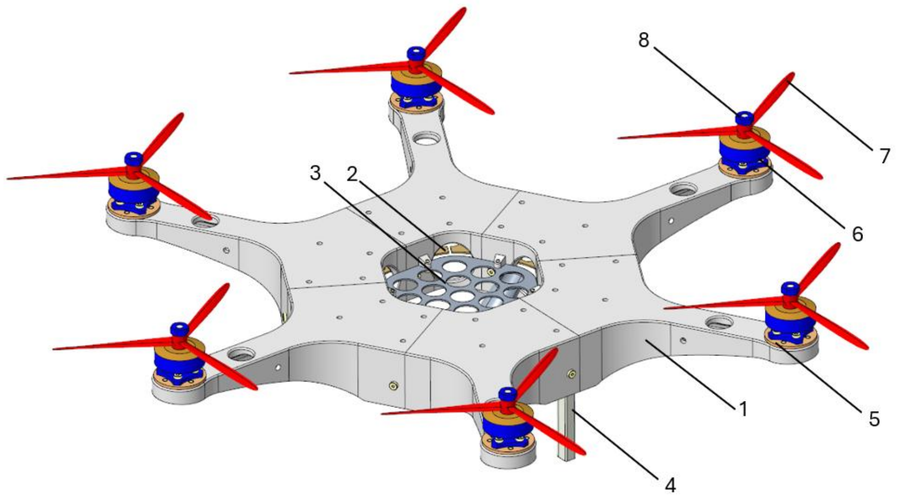


Fig. 3.3 Location of the components of the locomotion subsystem

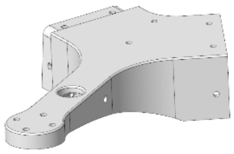
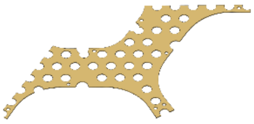
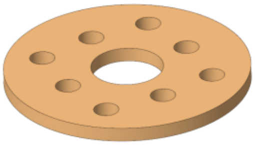
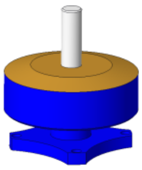
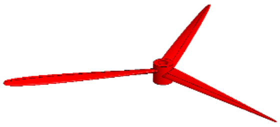
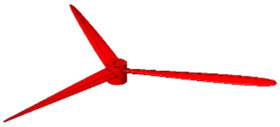
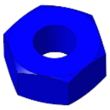
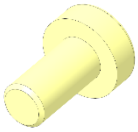
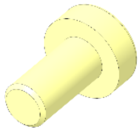
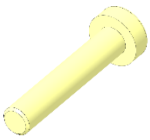
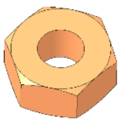
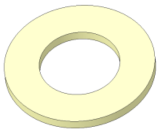
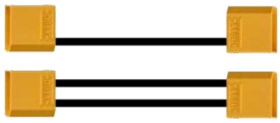
Tab. 3.1 Inventory of components of the locomotion subsystem

Number	Ks.	Component	CAD model
1	6	Drone wing	MAIN_STRUCTURE.PRT
2	3	Electronics board under the wings	CHEESE_PART.PRT
3	1	Electronics board in the middle	MIDDLE_PLATE.PRT
4	1	Tube for attaching the action subsystem	PILLAR_WASHER.PRT
5	6	Wooden pad for motor	MOTOR_PLATE.PRT
6	6	**AOS SUPERNOVA 2807 1400KV** motor	MOTOR.PRT
7	6	Three-blade propeller **Gemfan Flash 7040**	PROP.PRT
8	6	Motor nut	NUT_MOTOR.PRT

3.1.2 Assembly instructions

To build a locomotion subsystem you need to have all the components shown below, see Tab. 3.2.

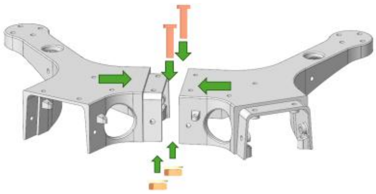
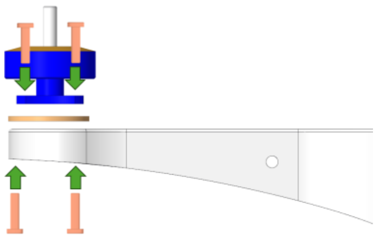
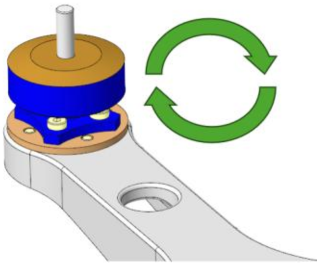
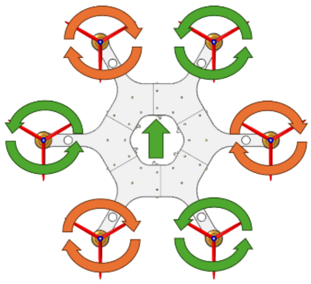
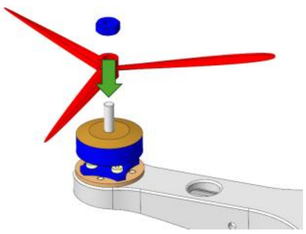
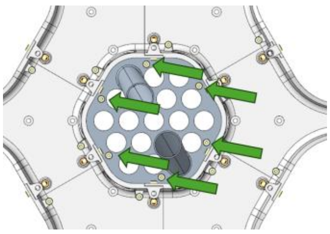
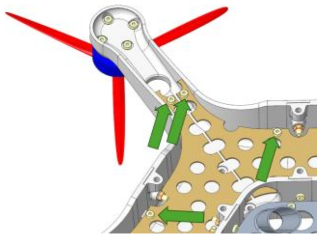
Tab. 3.2 Components needed to assemble the locomotion subsystem

			
Drone Wing ***1***	Electronics board 1 ***2***	Electronics board 2 ***3***	Trumpet of action sub. ***4***
6x	3x	1x	1x
			
Motor washer ***5***	Motor ***6***	Three-bladed propeller CCW ***7***	Three-bladed propeller CW ***8***
6x	6x	3x	3x
			
Motor nut ***12***	Threaded insert M3 ***9***	DIN7984 M3×5 ***10***	DIN7984 M3×10 ***11***
6x	36x	6x	72x
			
DIN7984 M3×16 ***12***	ISO4032 M3×6 ***13***	ISO7092 4 ***14***	Motor wiring ***15***
12x	44x	72x	6x

Assembly of the locomotion subsystem

In the table below, see Tab. 3.3, a pictorial and verbal description for the assembly of the locomotion subsystem is shown. During the assembly of the subsystem, it is necessary to have the appropriate equipment and tools available at all times, at the same time it is necessary that the assembly is carried out by the person responsible for the subsystem, in case the assembly is carried out by a person who is not responsible for the subsystem, it is necessary that the responsible person supervises the person carrying out the assembly.

Tab. 3.3 Instructions for setting up the locomotion subsystem

		
Step 1 - Connect the two wings of drone ***1*** using 2 screws ***12***, nuts ***13*** and washers ***14***.	Step 2 - Repeat step 1 for the remaining wings ***1***.	Step 3 - After completing step 2, the resulting assembly should match the image above.
		
Step 4 - Attach the motor pad ***5*** and motor ***6*** to the wings of drone ***1*** using 8 screws ***11***.	Step 5 - Repeat Step 4 for the remaining motor ***5*** and motor ***6*** pads.	Step 6 - The figure above describes the correct propeller turning directions when using 6 motors.
		
Step 7 - Based on the picture shown in the previous step, mount the correct propellers ***7*** and ***8*** on the motors ***5***, secure the propellers with nut ***12.***	Step 8 - Using the screws, attach the center electronics plate ***3*** with 6 screws ***10***.	Step 7 - Using the screws, attach the center electronics board ***2*** with 6 screws ***10***.

For the correct connection of the electrical components - motors **6** and motor wiring **15**, it is necessary to follow the electronics wiring diagram in the following subsection see 3.1.3.

3.1.3 Preparation for operation

In order to make the locomotive subsystem ready for operation, it is necessary to follow the assembly instructions of the previous subchapter and to have assembled all the subsystems that were described in the documentation before this subsystem. It is also necessary to wire the electrical components as prescribed in the wiring diagrams shown in this subchapter.

Electronics wiring diagram

In the picture below, see Fig. 3.4, shows the wiring diagram of the individual electrical components contained in the locomotion subsystem. The diagram contains all the electrical components used, including the names of the components and the correct interconnections between

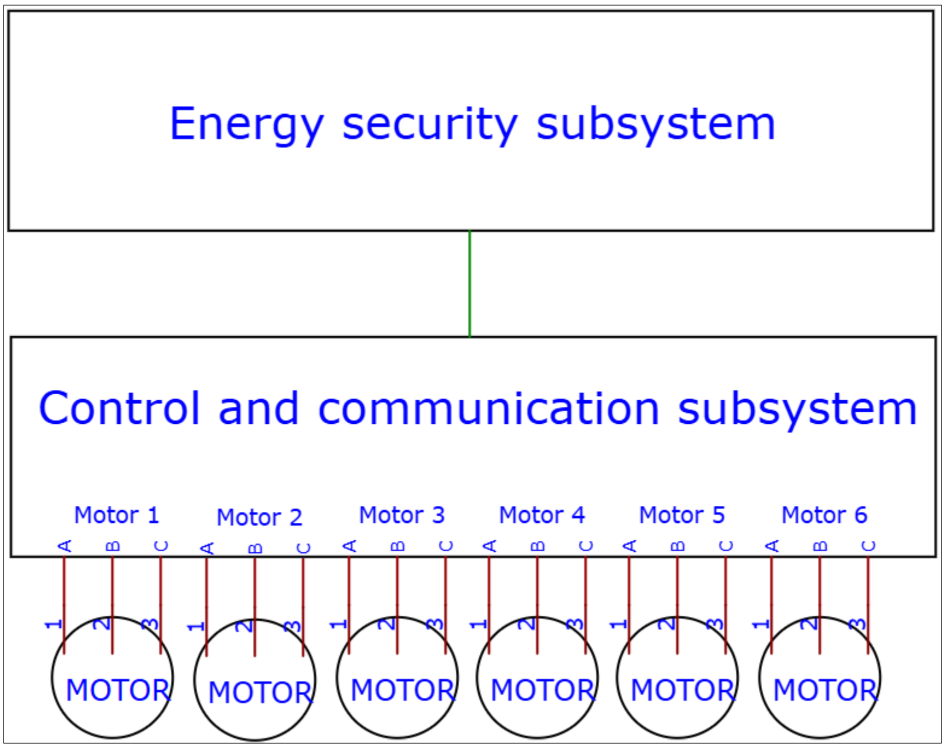


Fig. 3.4 Wiring diagram of the locomotion subsystem electronics

them.

⚠	**WARNING**
Before commissioning, all switches must be in the off position, i.e. "0". Failure to do so may result in a short circuit and subsequent damage to any of the electrical components of the subsystem.	

⚠	**WARNING**
Take extra care before commissioning to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, take care for your safety and use protective equipment	

Block diagram

In the picture below, see Fig. 3.5, a block diagram of the locomotion subsystem is shown. This diagram shows the interconnection of the individual components as well as any communication that takes place between the components.

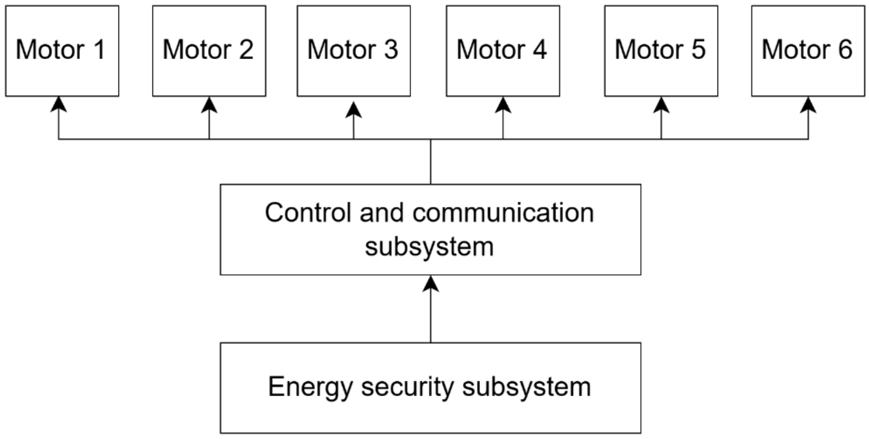


Fig. 3.5 Block diagram of the locomotion subsystem

WARNING

Before commissioning, all switches must be in the off position, i.e. "0". Failure to do so may result in a short circuit and subsequent damage to any of the electrical components of the subsystem.

WARNING

Take extra care before commissioning to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, take care for your safety and use protective equipment

3.1.4 Maintenance

Before maintenance, it is necessary to ensure that the locomotive subsystem is not connected to the power or communication cabling, and it is also necessary to secure the subsystem against movement. In case the subsystem is dirty, it is necessary to remove these impurities so as not to damage any of the mechanical or electrical components. When using water-based cleaners, avoid areas with electronics, as irreversible destruction of the subsystem may occur. Clean these areas using compressed air spray. In the event that a part of the subsystem must be removed for maintenance, always follow the instructions in this document.

WARNING

Before carrying out maintenance, it is necessary that the batteries are disconnected from the wiring, ensuring that the batteries are connected in parallel.

WARNING

Take extra care during maintenance to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, take care for your safety and use protective equipment

3.1.5 Service

In the event of non-standard behaviour of the locomotion subsystem, design repair or electrical circuit burnout, the module must not be connected to the drone with a power or communication cable. Subsequently, perform the necessary servicing. Servicing shall only be performed by the person responsible for the subsystem. In the event that servicing is performed by a person who is not responsible for that subsystem, it is necessary that the responsible person supervise the person performing the servicing. After the servicing is completed, the previous sub-sections, such as the assembly and commissioning instructions, must be followed.

WARNING

When handling individual parts, use caution and do not use sharp tools that may damage or destroy mechanical or electrical parts of the system. When using tools, be aware of your safety and wear protective equipment.

WARNING

Before carrying out a service operation, it is necessary to disconnect the subsystem from the power supply, i.e., the power supply subsystem, to prevent a short circuit and subsequent damage to any of the subsystem's electrical components.

4 ACTION SUBSYSTEM

The action subsystem is made by 3D printing from PETG material. It holds a total of 5 balls and is controlled by an Arduino NANO control system. The drive is provided by a stepper motor together with a motor driver. The feedback from the spin is obtained using hall effect probes.

4.1.1 Basic description of the subsystem

The mechanical part consists mainly of 3D printed parts made of PETG material. The mechanical part also includes a stepper motor. The mechanical part consists of five ball trays, which consists of two parts and a rotating surface. This surface is in the shape of an incomplete circle, this circle also includes a hole for a magnet which is located at the location of the Hall probe at each rotation. In order to release the ball from the action subsystem, the circle must be rotated by means of a stepper motor so that the incomplete part is located in the area of the ball, thus releasing it from the subsystem. The subsystem also includes an area for placing the sensors of the control and communication subsystem and the vision subsystem. The CAD model of the action subsystem is shown in Fig. 4.1.

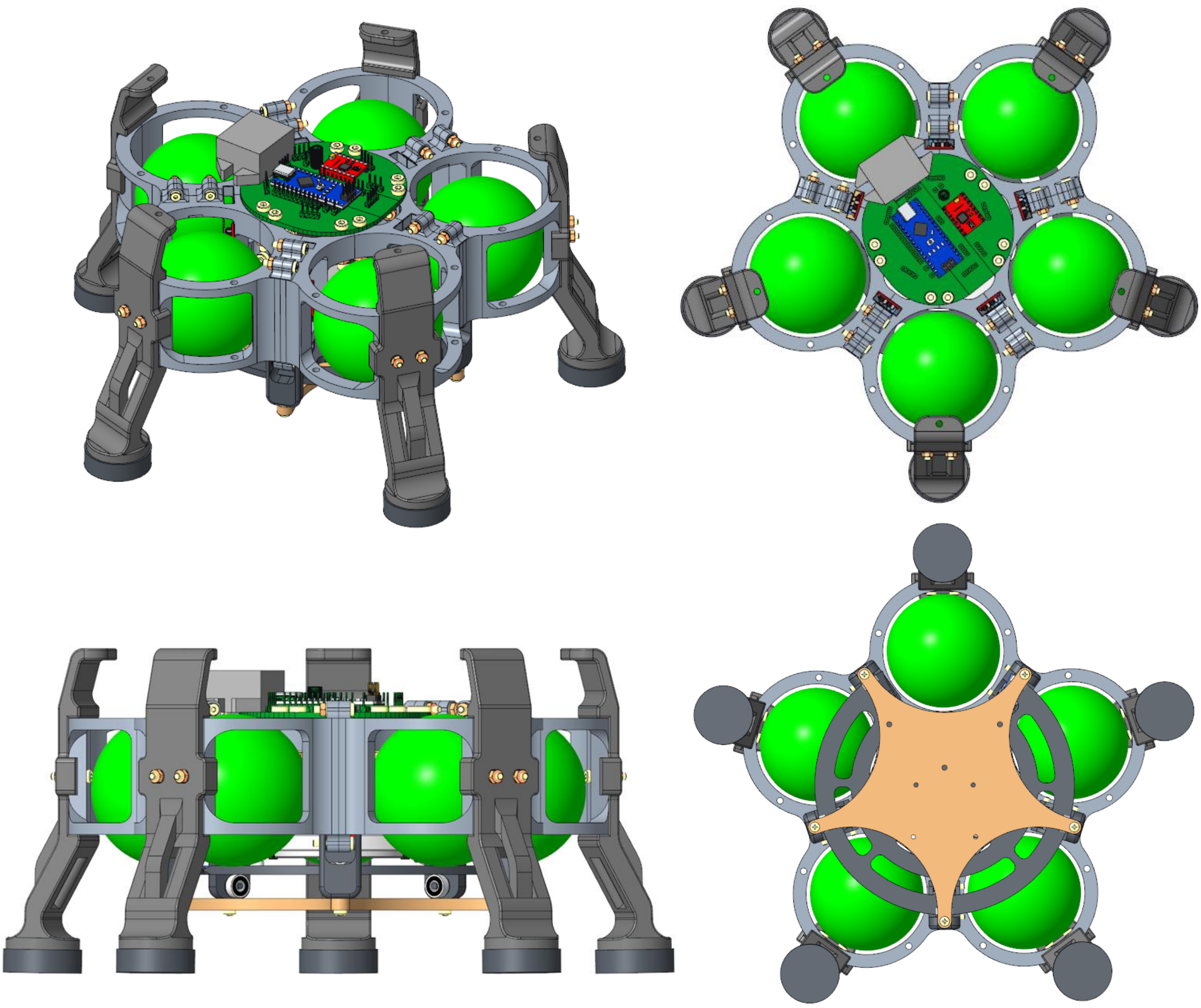


Fig. 4.1 CAD model of the action subsystem

Subsystem action parameters

At Fig. 4.2 shows the basic dimensions of the action subsystem, the Tab. 4.1 other essential parameters related to this subsystem are listed.

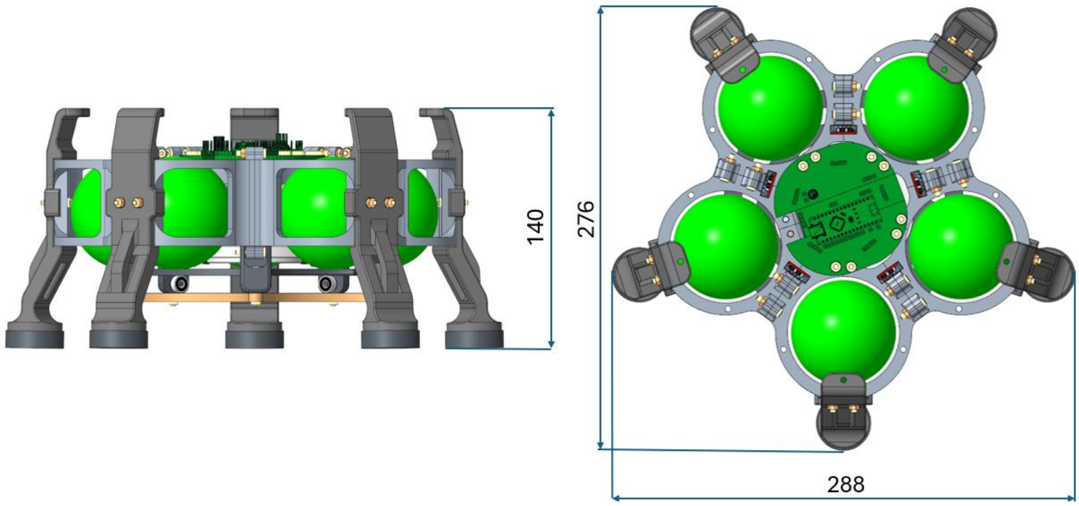


Fig. 4.2 Basic dimensions of the action subsystem

Tab. 4.1 Basic parameters of the action subsystem

Parameter	Value
Dimensions	288 × 276 × 140 mm
Number of places for balls	5
Weight including balls	1,15 kg
Material of prints	PETG

Inventory of components

In the table on the next page, see Tab. 4.2, all components that are present in the CAD model of the locomotion subsystem are listed. Based on the numbers in the table, the Fig. 4.3 indicates the component in question. The bolded part in the name of a given component is the commercial designation of that component. Each component name is also accompanied by the corresponding CAD

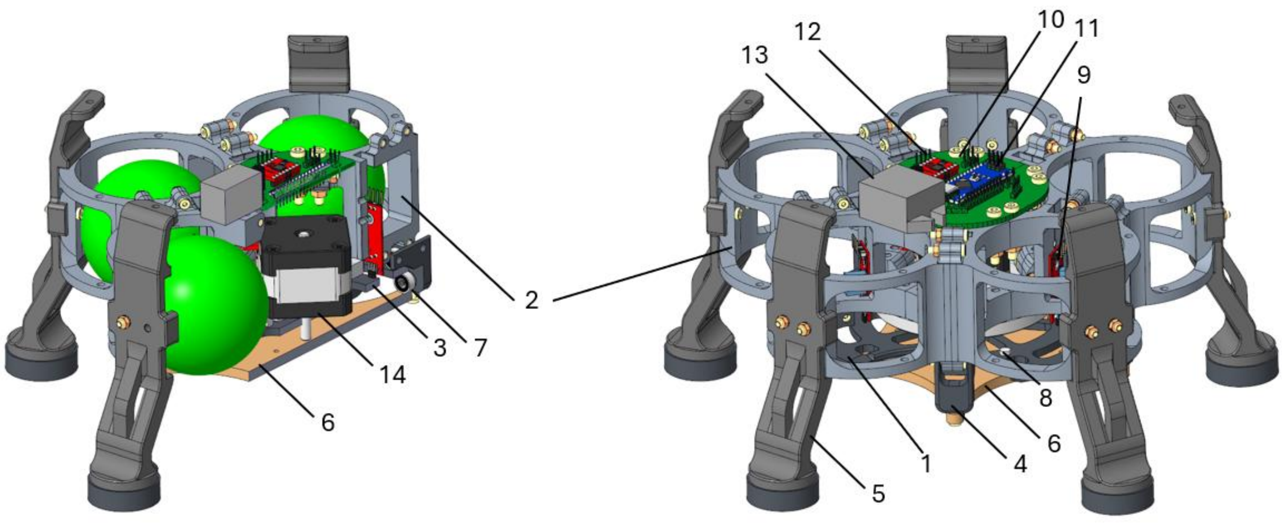


Fig. 4.3 Component layout on the action subsystem

model name.

Tab. 4.2 Inventory of action subsystem components

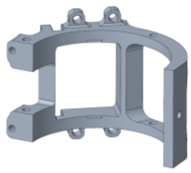
Number	Ks.	Component	CAD model
1	1	Rotating ball release area	OTOCNA_PLOCHA_3.PRT
2	10	Half of the basket for ball retention	POLOVINA_VALCE.PRT
3	1	Motor flange	PRIRUBA_MOTORU.PRT
4	5	Radial bearing holder	DRZAK_LOZIS.PRT
5	5	Legs with silent blocks	LEG.PRT
6	1	Sensor holder	DRZAK_SENZORU.PRT
7	5	Radial bearings **Bearing 623 2RSR KINEX**	LOZISKO.ASM
8	10	**Neodymium magnet disc 5x3 mm**	MAGNET.PRT
9	1	**Hall sensor module KY-024** for magnet detection	HALL_SONDA.PRT
10	1	PCB subsystem action	AN_V3_PCB.PRT
11	5	**Arduino Nano** control system	ARDUINO_NANO.PRT
12	1	Motor driver **A4988**	DRIVER.PRT
13	1	Inverter **Step Down Wire 24VDC 12VDC 3A 36W**	STEP_DOWN_AN.PRT
14	1	Stepper motor **17HS13-0404S**	17HS13-0404S.PRT

4.1.2 Assembly instructions

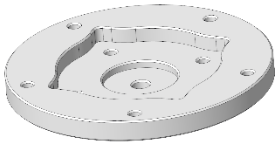
To build an action subsystem you need to have all the components shown below, see Tab. 4.3. At the same time, the locomotion subsystem needs to be assembled and ready as the action subsystem is attached to the locomotion subsystem.

Tab. 4.3 Components needed to build the action subsystem

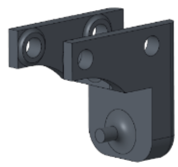
Turning area ***1***
1x



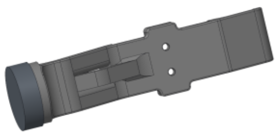
Half a basket ***2***
10x



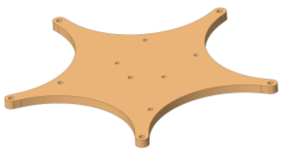
Motor flange ***3***
1x



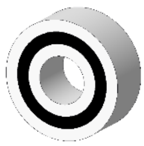
Bearing holder ***4***
5x



Leg ***5***
5x

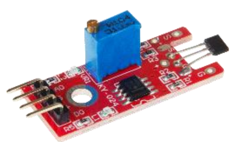


Sensor holder ***6***
1x

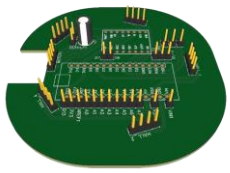


Radial bearing ***7***
10x

Neodymium magnet ***8***
1x



Hall Probe ***9***
5x



PCB ***10***
1x

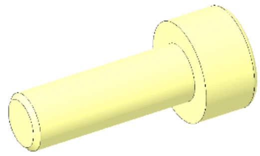
Arduino NANO ***11***
1x

Motor driver ***12***
1x

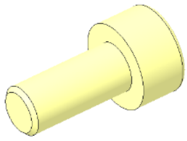
Step-Down Converter ***13***
1x

Stepper motor ***14***
1x

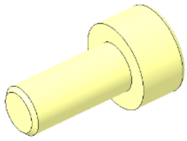
Hall cabling ***15***
5x



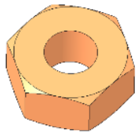
ISO4762 M3×16 8.8 ***16***
38x



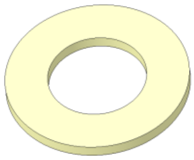
ISO4762 M4×20 8.8 ***17***
4x



ISO7045 M3×12 4.8 ***18***
5x



ISO4032 M3×6 ***19***
38x

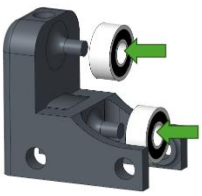


ISO7092 4 ***20***
42x

Instructions for setting up the action subsystem

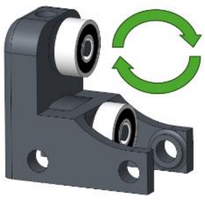
In the table below, see Tab. 4.4, a pictorial and verbal description for the assembly of the action subsystem is shown. During the assembly of the subsystem, it is necessary to have the appropriate equipment and tools available at all times, at the same time it is necessary that the assembly is carried out by the person responsible for the subsystem, in case the assembly is carried out by a person who is not responsible for the subsystem, it is necessary that the responsible person supervises the person carrying out the assembly.

Tab. 4.4 Instructions for setting up the action subsystem

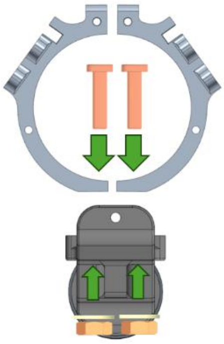


Step 1 - Insert the two bearings ***7*** into the bearing holder ***4.***

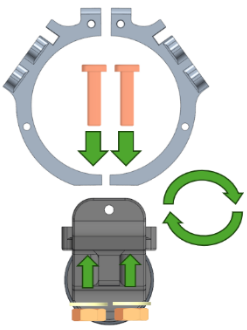
Step 2 - Test that the bearings in the holder rotate freely.



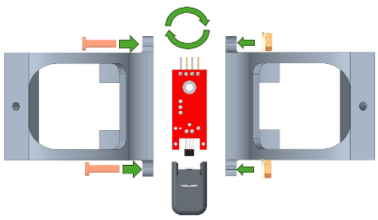
Step 3 - Repeat steps 1 and 2 for all 5 bearing holders ***4***.



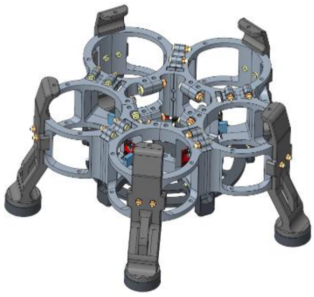
Step 4 - Using 2 bolts ***16***, nuts ***19*** and washers ***20***, attach leg ***5*** to the two halves of basket ***2***.



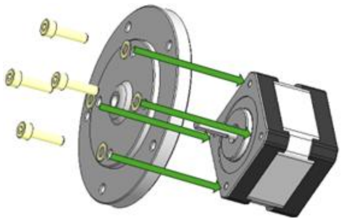
Step 5 - Repeat step 4 for the remaining halves of basket ***2*** and leg ***5***.



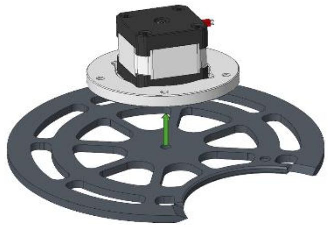
Step 6 - Connect the 2 assemblies from step 4/5 with bolts ***16***, nuts ***19*** and washers ***20***. Repeat step.



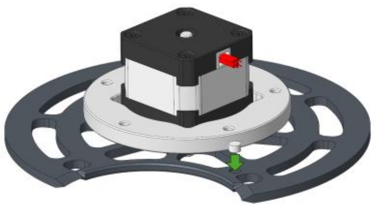
Step 7 - After completing step 6, the resulting assembly should match the image above.



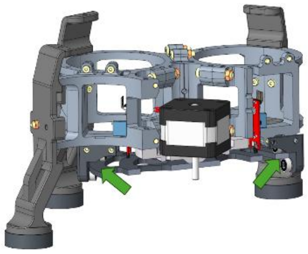
Step 8 - Attach the motor flange ***3*** to the motor ***14*** using the 4 bolts ***17*** washers ***20***.



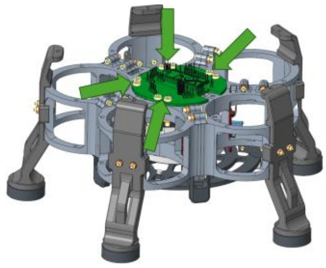
Step 8 - Slide the swivel plate ***1*** onto the motor shaft ***14***.



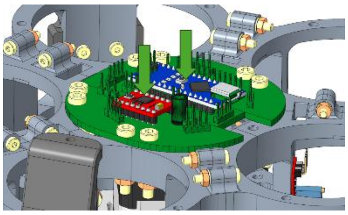
Step 7 - Insert the Neodymium magnet ***8*** into the hole on the rotating surface ***1***.



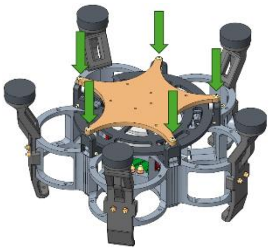
Step 8 - Insert the rotating surface ***1*** together with the motor ***14*** into the bearing holders.



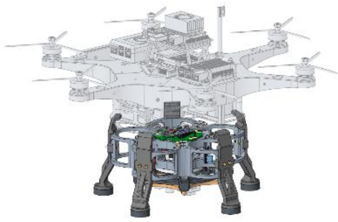
Step 9 - Attach PCB **10** to the assembly from step 8 using 8 screws ***16***, nuts ***19*** and washers ***20.***



Step 10 - Insert the Arduino NANO control system ***11*** and motor driver ***12*** into PCB ***8***.



Step 11 - Attach the sensor bracket ***6 to*** the assemblies from step 3 using 5 screws ***18***.



Step 12* - Attach the action subsystem to the power security subsystem.

* Perform this step after the power supply subsystem is attached to the locomotion subsystem.

4.1.3 Preparation for operation

In order to make the action subsystem ready for operation, it is necessary to follow the assembly instructions of the previous subchapter and to have assembled all the subsystems that were described in the documentation before this subsystem. It is also necessary to wire the electrical components as prescribed by the wiring diagrams illustrated in this subchapter.

Electronics wiring diagram

In the picture below, see Fig. 4.4, shows the wiring diagram of the individual electrical components contained in the action subsystem. The diagram contains all the electrical components used, including the names of the components and the correct interconnections between them. This wiring diagram is identical to the wiring diagram for testing the pivot positions.

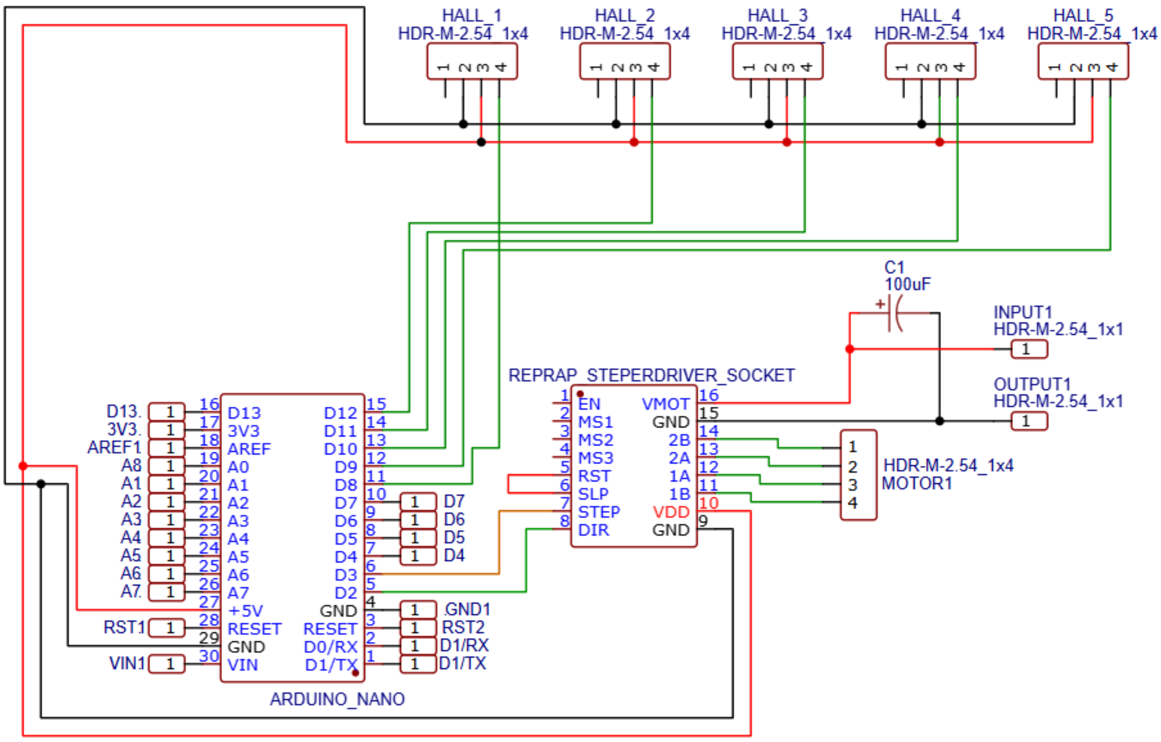


Fig. 4.4 Wiring diagram of the action subsystem electronics

⚠	**WARNING**
Before commissioning, all switches must be in the off position, i.e. "0". Failure to do so may result in a short circuit and subsequent damage to any of the electrical components of the subsystem.	

⚠	**WARNING**
Take extra care before commissioning to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, take care for your safety and use protective equipment	

Electronics wiring diagram - stepper motor testing

In the picture below, see Fig. 4.5, shows the wiring diagram of the individual electrical components, for testing the stepper motor, extra care must be taken during the test.

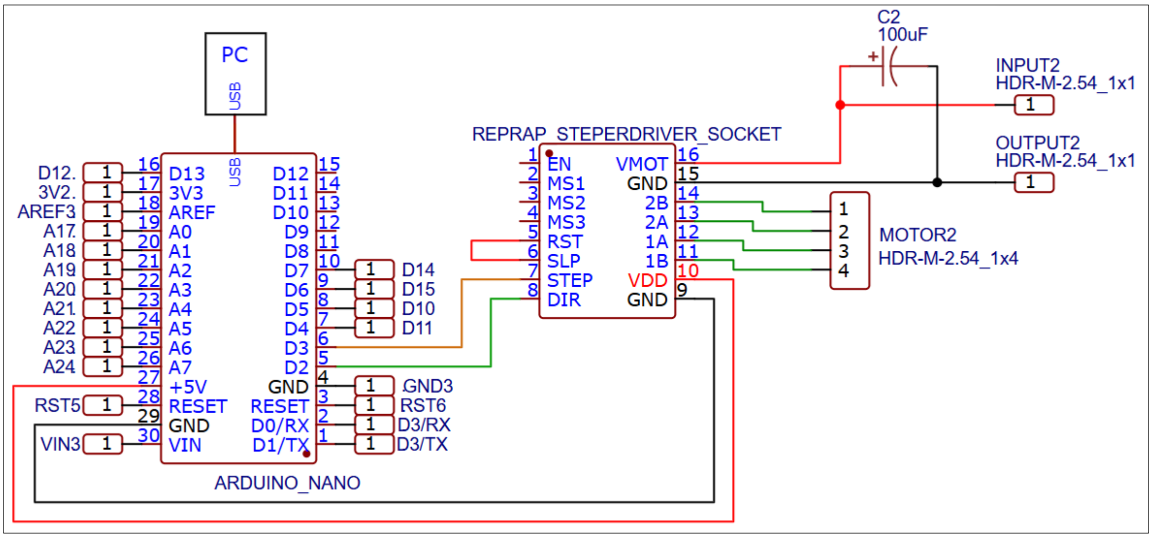


Fig. 4.5 Wiring diagram of the action subsystem electronics - stepper motor testing

Wiring diagram of electronics - Hall probe testing

In the picture below, see Fig. 4.6, shows the wiring diagram of the various electrical components, for testing the Hall probe, during the test a sufficiently strong magent is needed, which the probe will detect.

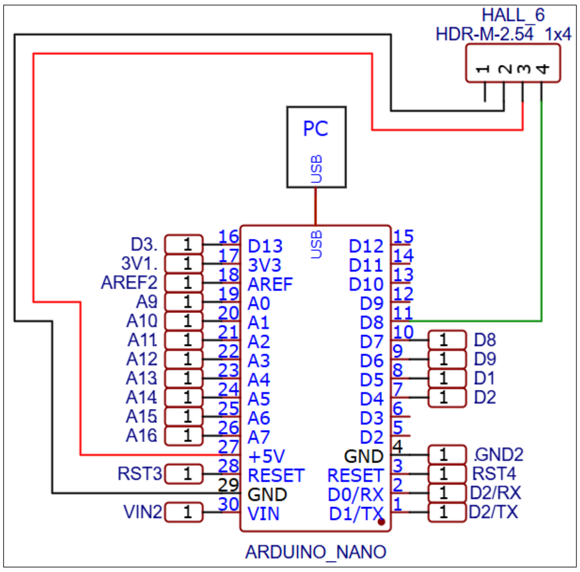


Fig. 4.6 Wiring diagram of the action subsystem electronics - Hall probe testing

Block diagram

In the picture below, see Fig. 4.7, a block diagram of the action subsystem is shown. This diagram shows the interconnection of the individual components as well as any communication that takes place between the components.

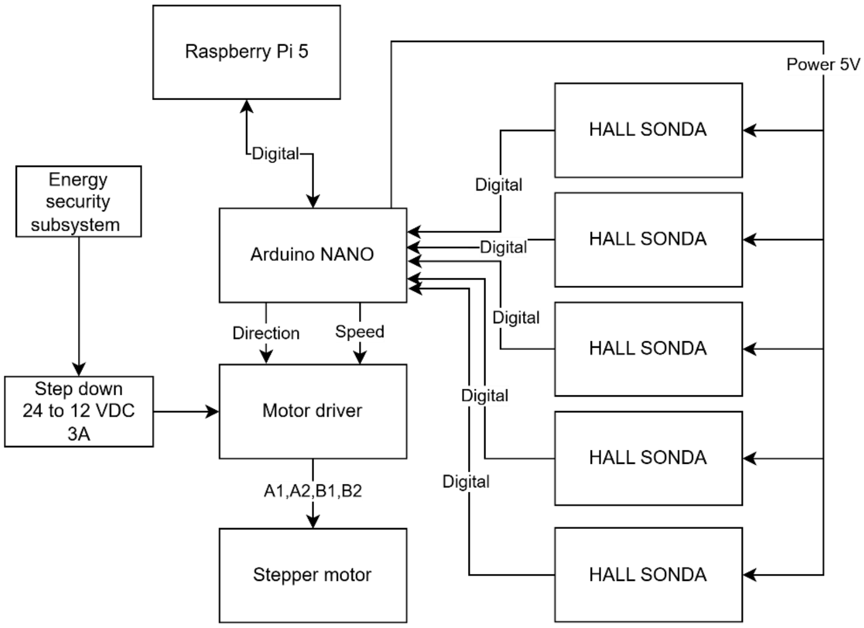


Fig. 4.7 Block diagram of the action subsystem

FlowChart diagram - subsystem operation

In the picture below, see Fig. 4.8, a flowchart diagram of the action subsystem is shown. This flowchart is used to help understand the operation of the action subsystem algorithm.

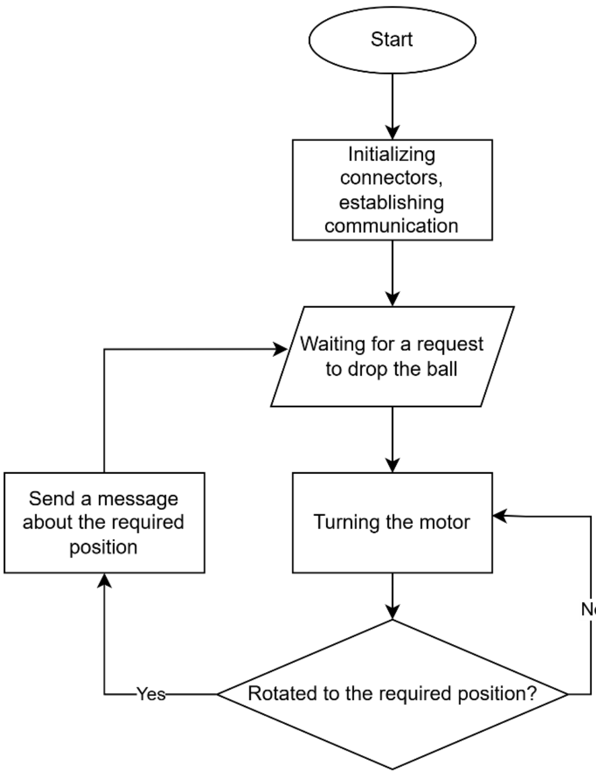


Fig. 4.8 Flowchart diagram of the action subsystem

FlowChart diagram - Hall probe testing

In the picture below, see Fig. 4.9, a flowchart diagram of the action subsystem for Hall probe testing is shown. This flowchart is used to help understand the operation of the algorithm.

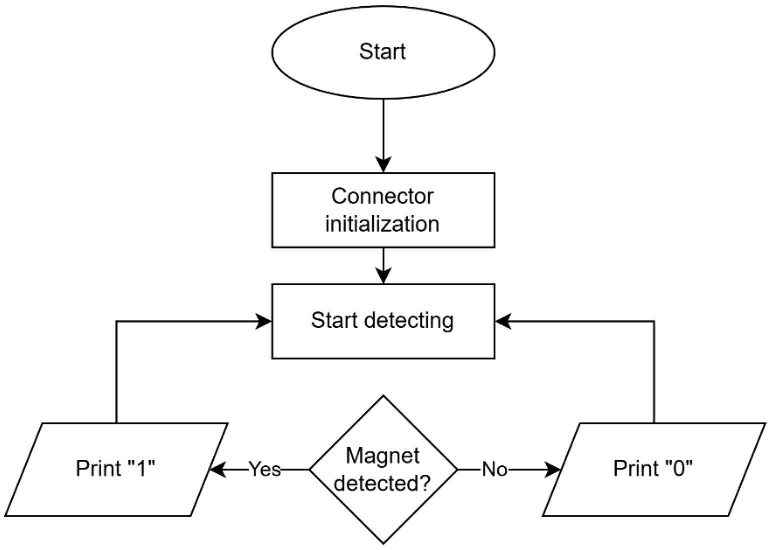


Fig. 4.9 FlowChart diagram of the action subsystem

FlowChart diagram - stepper motor testing

In the picture below, see Fig. 4.10, a flowchart diagram of the action subsystem for stepper motor testing is shown. This flowchart is used to help understand the operation of the algorithm.

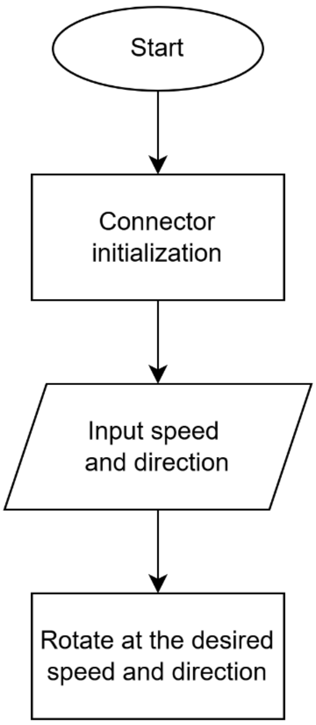


Fig. 4.10 FlowChart diagram of the action subsystem

FlowChart diagram - testing positions

In the picture below, see Fig. 4.11, shows a flowchart diagram of the action subsystem for testing individual rotation positions of the rotating surface. This flowchart is used to make the algorithm easier to understand.

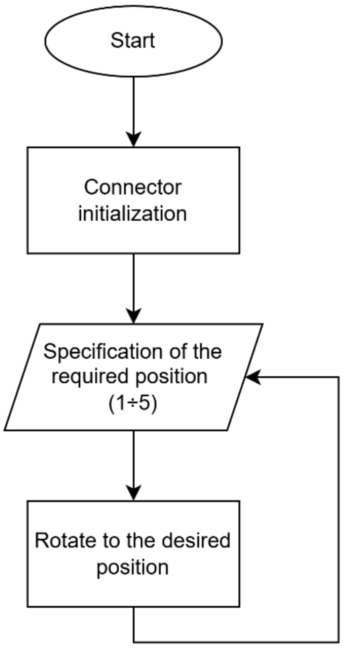


Fig. 4.11 FlowChart diagram of the action subsystem

4.1.4 Maintenance

Prior to maintenance, the action subsystem must not be mechanically attached to the drone, the subsystem must not be connected to power or communication cables, and the subsystem must be secured against movement. In case the subsystem is dirty, it is necessary to remove such dirt so as not to damage any of the mechanical or electrical components. When using water-based cleaners, avoid areas with electronics, as irreversible destruction of the subsystem may occur. Clean these areas using compressed air spray. In the event that a part of the subsystem must be removed for maintenance, always follow the instructions in this document.

WARNING

Before carrying out maintenance, it is necessary that the batteries are disconnected from the wiring, ensuring that the batteries are connected in parallel.

WARNING

Take extra care during maintenance to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, take care for your safety and use protective equipment

4.1.5 Service

In the event of non-standard behaviour of the action subsystem, design repair or electrical circuit burnout, the module must not be connected to the drone with a power or communication cable. Subsequently, perform the necessary servicing. Servicing shall only be performed by the person responsible for the subsystem. In the event that servicing is performed by a person who is not responsible for that subsystem, it is necessary that the responsible person supervise the person performing the servicing. After the servicing is completed, the previous sub-sections, such as the assembly and commissioning instructions, must be followed.

WARNING

When handling individual parts, use caution and do not use sharp tools that may damage or destroy mechanical or electrical parts of the system. When using tools, be aware of your safety and wear protective equipment.

WARNING

Before carrying out a service operation, it is necessary to disconnect the subsystem from the power supply, i.e., the power supply subsystem, to prevent a short circuit and subsequent damage to any of the subsystem's electrical components.

5 CONTROL AND COMMUNICATION SUBSYSTEM

This chapter describes the control and communication subsystem of the drone. This subsystem provides both the communication between the individual hardware elements, i.e. control systems, controllers, subsystems, etc., and at the same time it handles the control of the system itself, either autonomous or manual control, based on the data from these individual communications. The main part of this subsystem is a flight controller and two mini computers. To accommodate all these components in the structure, customized brackets were created.

5.1.1 Basic description of the subsystem

The hardware components of this subsystem, together with the programs developed, provide autonomous and manual control of the system. The main hardware component is the flight controller, other components include a radio signal receiver, two mini computers, optical flow, LiDAR and a tracking camera. The communication between the flight controller and the mini-computer is done via UART. The CAD model with the individual hardware elements is shown in Fig. 5.1.

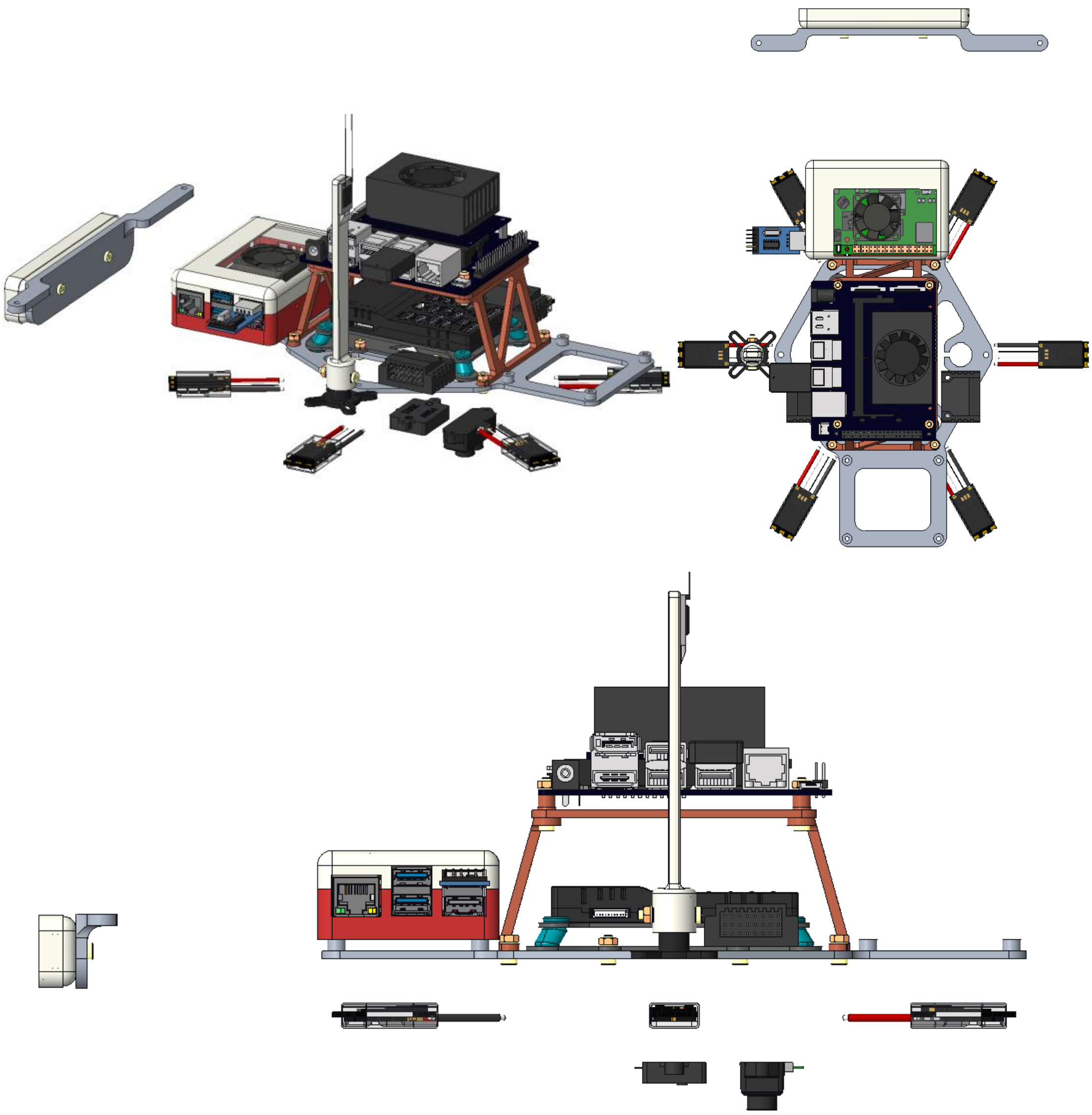


Fig. 5.1 CAD model of the control and communication subsystem

Control and communication subsystem parameters,

At Fig. 5.2 shows the basic dimensions of the control and communication subsystem, the Tab. 5.1 other essential parameters related to this subsystem are listed.

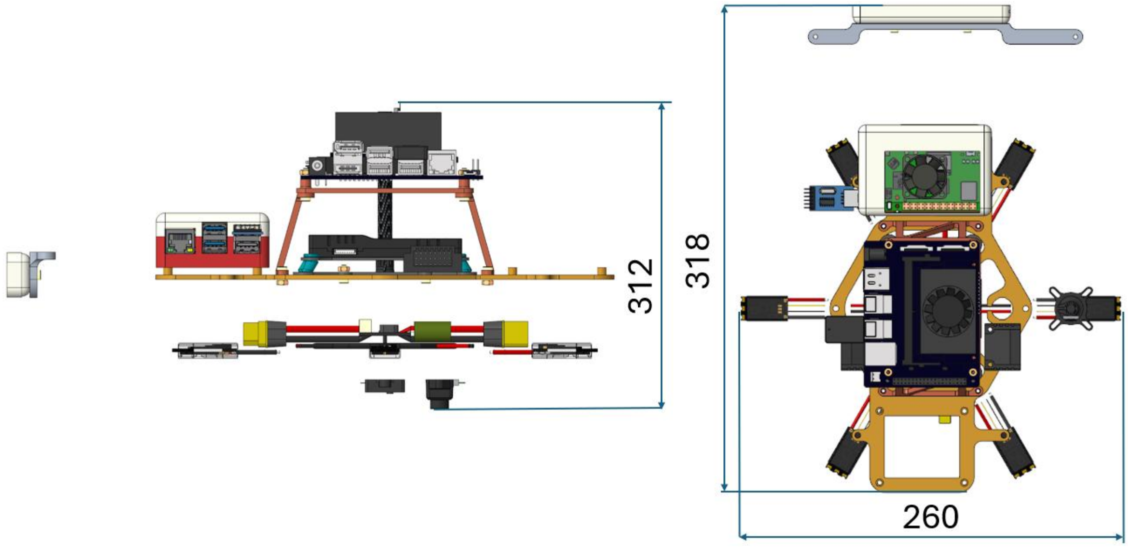


Fig. 5.2 Basic dimensions of the control and communication subsystem

Tab. 5.1 Basic parameters of the control and communication subsystem

Parameter	Value
Dimensions	318 × 260 × 312 mm
Flight controller	Pixhawk 6c
ESC	Flycolor X-Cross 2 50A 3-6S
Radio receiver	Receiver RadioMaster R81 V2
Computer for autonomous dri-ving	Raspberry Pi 5
Computer for surveillance ca-mera	Nvidia Jetson Nano
LiDAR	TFmini-S LiDARoptical flow p
Optical flow	PMW3901
Tracking camera	Intel Realsense T265
TTL UART converter	USB-TTL HV597
Material of holders	PETG

Inventory of components

In the table below, see Tab. 5.2, all components that are present in the CAD model of the control and communication subsystem are listed. Based on the numbers in the table, the Fig. 5.4 indicates the component in question. The bolded part in the name of a given component is the trade name of that component. Each component name is also accompanied by the corresponding CAD model name.

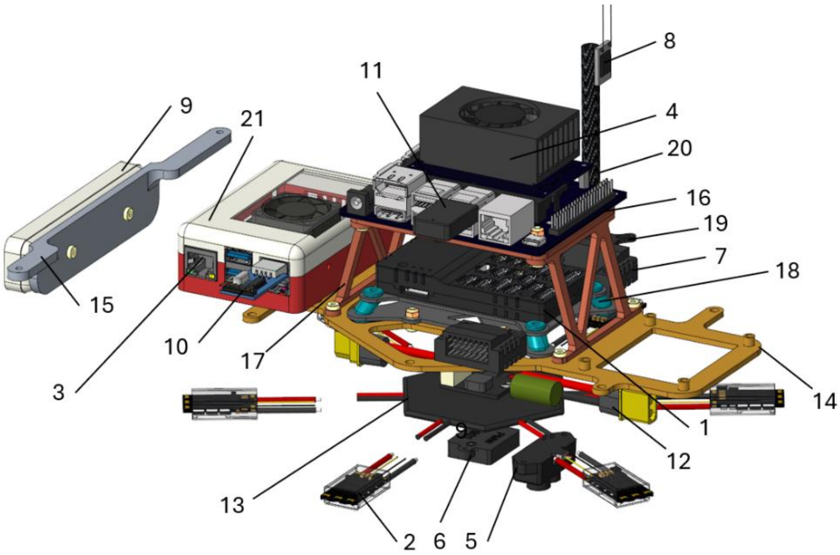


Fig. 5.3 Component layout on the control and communication subsystem

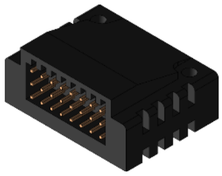
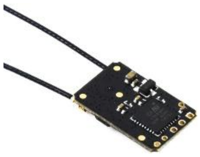
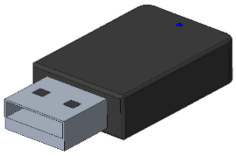
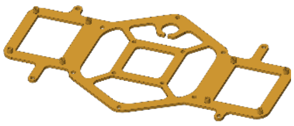
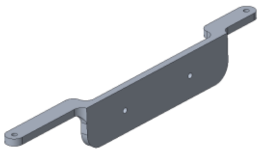
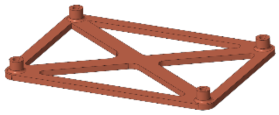
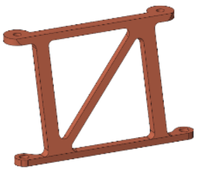
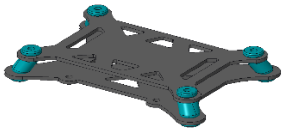
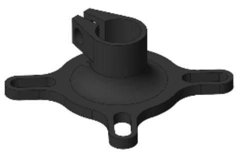
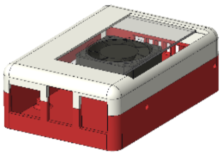
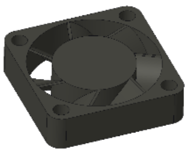
Tab. 5.2 Inventory of control and communication subsystem components

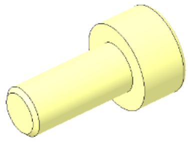
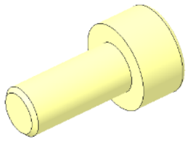
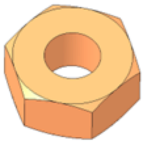
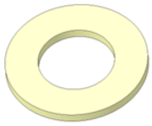
Number	Ks.	Component	CAD model
1	1	Flight controller **Pixhawk 6c**	PIXHAWK6C.PRT
2	6	ESC **Flycolor x-cross 2 50a 3-6s**	ESC.PRT
3	1	**Raspberry Pi 4** mini computer	RASPBERRY_PI_5.PRT
4	1	**Nvidia Jetson Nano** mini computer	LIDAR.PRT
5	1	**TFmini-S LiDAR** laser distance sensor	IMU_LSM303.PRT
6	1	Optical flow **PMW 3901**	OPTICAL_FLOW.PRT
7	2	Pixhawk **PWM module**	PIXHAWK_PWM.PRT
8	1	Radio receiver **Receiver RadioMaster R81 V2**	RC_RECEIVER.PRT
9	1	**Intel Realsense** T265 surveillance camera	REALSENSE_T265.PRT
10	1	TTL USB converter **CP2102**	USB_TTL.PRT
11	1	Wi-Fi adapter **TENDA U9**	WI-FI_MODUL.PRT
12	1	Power Module **PM02 V3**	PM02V3.PRT
13	1	**Tarot Quadcopter Hub PDB**	TARO.HUB.PRT
14	1	Control electronics holder	DRIVER_PLATE.PRT
15	1	Surveillance camera holder	DRZAK_T265.PRT
16	1	Jetson computer holder	DRZAK_JETSON_1.PRT
17	2	Jetson computer holder leg	DRZAK_JETSON_2.PRT
18	1	Pixhawk holder **Anti-Vibration Pixhawk plate**	PIXHAWK_BASE.PRT
19	1	Base for RC receiver holder	ZAKLADNA_RC.PRT
20	1	RC receiver holder column	SLOUPEK.RC.PRT
21	1	Box for Raspberry Pi	RASPBERRY_CASE.PRT

5.1.2 Assembly instructions

To build the control and communication subsystem, you need to have all the components shown below, see Tab. 5.3.

Tab. 5.3 Components needed to build the control and communication subsystem

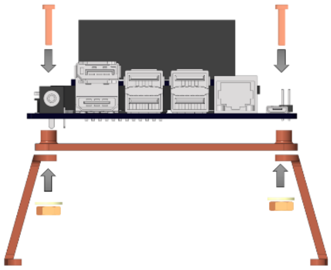
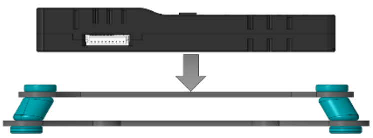
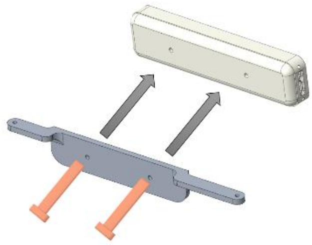
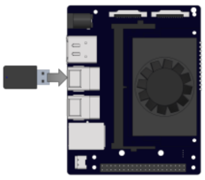
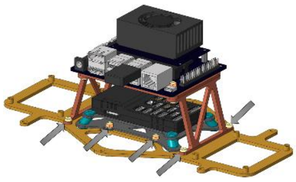
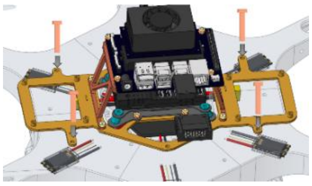
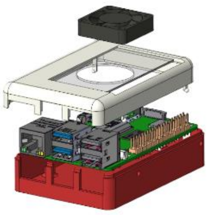
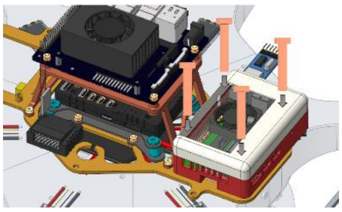
			
Flight controller ***1*** 1x	ESC ***2*** 6x	Raspberry Pi 4 ***3*** 1x	Nvidia Jetson Nano ***4*** 1x
			
LiDAR ***5*** 1x	Optical Flow ***6*** 1x	PWM module ***7*** 2x	RC receiver ***8*** 1x
			
Surveillance camera ***9*** 1x	USB-TTL converter ***10*** 1x	Wi-Fi adapter ***11*** 1x	Power Module ***12*** 1x
			
Manifold ***13*** 1x	Electronics holder ***14*** 1x	Camera holder ***15*** 1x	Jetson ***16*** holder 2x
			
Legs Jetson ***17***	Pixhawk ***18*** holder	Holder RC base ***19*** 1x	RC post holder ***20*** 1x
			
Raspberry ***21*** box 1x	Jetson ***22*** fan 1x	Tightening tape ***23*** 1x	USB-A microUSB-B ***24*** 1x

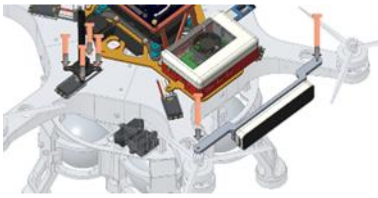
			
ISO4762 M3×9 8.8 ***25***	ISO4762 M3×14 8.8 ***26***	ISO4032 M3×6 ***27***	ISO7092 3 ***28***
13x	12x	12x	24x

Setting up the control and communication subsystem

In the table below, see Tab. 5.4, a pictorial and verbal description for the assembly of the control and communication subsystem is shown. During the assembly of the subsystem, it is necessary to have the appropriate equipment and tools available at all times, at the same time it is necessary that the assembly is carried out by the person responsible for the subsystem, in case the assembly is carried out by a person who is not responsible for the subsystem, it is necessary that the responsible person supervises the person carrying out the assembly.

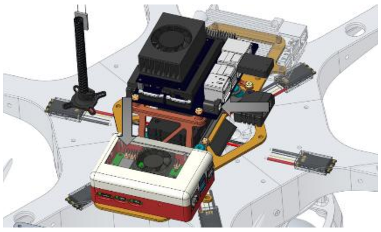
Tab. 5.4 Instructions for setting up the control and communication subsystem

		
Step 1 - Place the Jetson Nano ***4*** into the bracket ***16***, then connect to the legs ***17*** using the 4 screws ***25***, washers ***28*** and nuts ***27***.	Step 2 - Secure Flight Controller ***1*** to Controller Bracket ***18*** with the included tape.	Step 3 - Secure the camera **9** to the bracket **15** using the two screws **25**.
		
Step 4 - Plug the Jetson Nano ***4*** Wi-Fi Adapter into the USB port ***11***.	Step 5 - Place the assembly from step 1 and 2 onto the bracket ***14*** using the 8 screws ***26***, washers ***28*** and nuts ***27***.	Step 6 - Place the assembly from the previous step onto the locomotive subsystem using the 4 screws ***26***.
		
Step 7 - Place the Raspberry Pi 5 ***3*** in the box ***21***, connect the TTL USB converter ***10*** to the USB.	Step 8 - Place the assembly from the previous step onto the bracket **14** using the 4 screws ***25***.	Step 9 - Insert the RC post ***20*** into the RC base ***19***, secure the assembly with the bolt ***25*** washer ***28*** and nut ***27***.



Step 10 - Attach the assemblies from steps 3 and 8 to the bracket **14** using 6 screws ***25***.

Step 11 - Secure the RC receiver ***8*** to the RC post ***20*** using the tape ***23***.



Step 12 - Connect Raspberry Pi 4 (GPIO) ***1*** and Nvidia Jetson Nano (power jack) ***4*** to the power supply.

* Perform this step only after the energy security subsystem has been successfully commissioned.

5.1.3 Preparation for operation

The ArduPilot software is required to commission the control and communication subsystem. In addition, the flight controller needs to be connected to the computer via USB cable before commissioning, as the controller needs to be set up and the sensors need to be calibrated.

Electronics wiring diagram

In the picture below, see Fig. 5.4, shows the wiring diagram of the various electrical components that the control and communication subsystem contains. The diagram contains all the electrical components used, including the names of the components and the correct interconnections between them. The subsystem can then be put into operation following the instructions in chapter "*Manual control*" a "*Autonomous control*".

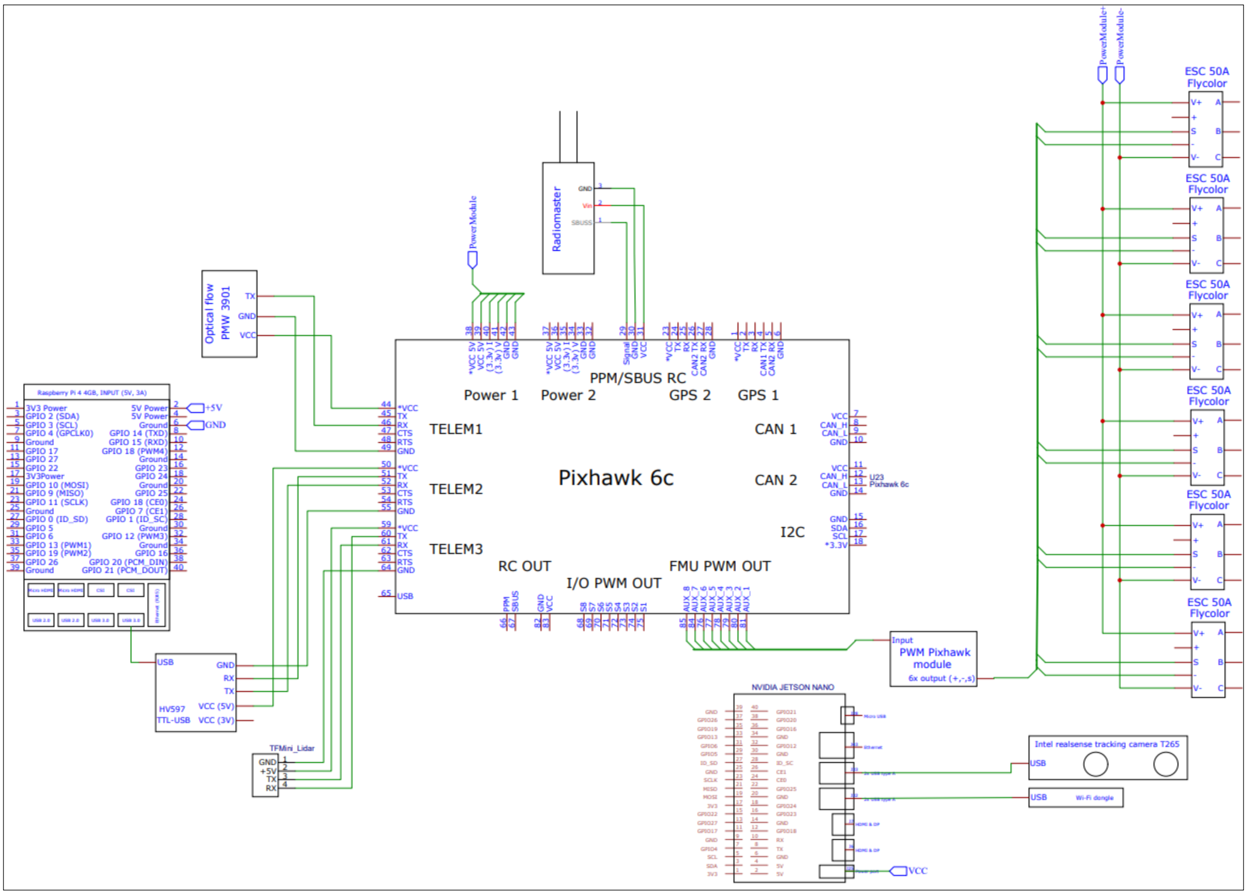


Fig. 5.4 Wiring diagram of the control and communication subsystem electronics

⚠	**WARNING**
Before commissioning, all switches must be in the off position, i.e. "0". Failure to do so may result in a short circuit and subsequent damage to any of the electrical components of the subsystem.	

⚠	**WARNING**
Take extra care before commissioning to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, take care for your safety and use protective equipment	

Block diagram

In the picture below, see Fig. 5.5, shows a block diagram of the control and communication subsystem. This diagram shows the interconnection of the individual components as well as any communication that takes place between the components.

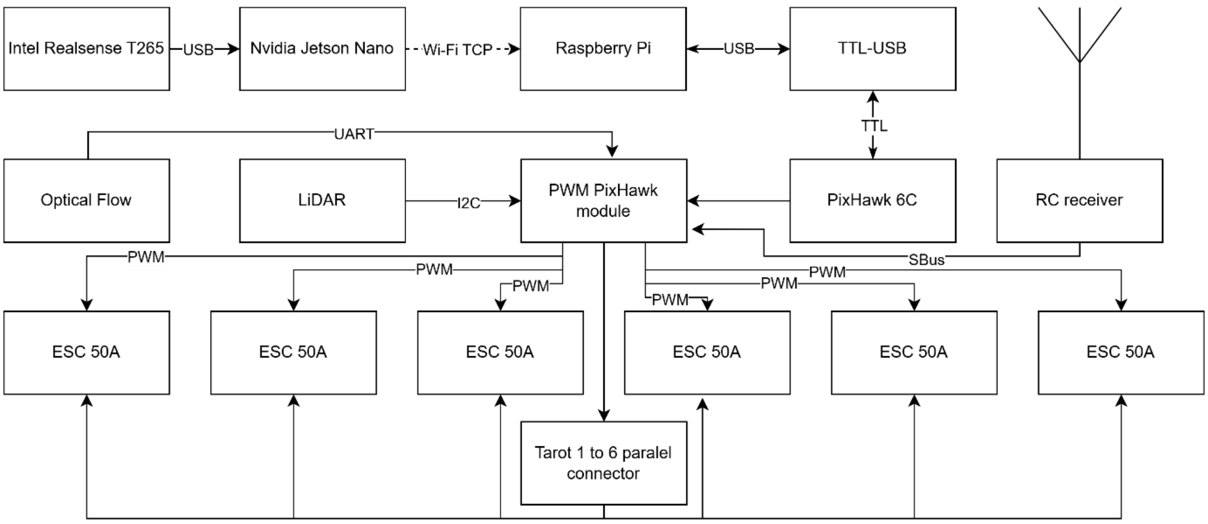


Fig. 5.5 Control and communication subsystem

5.1.4 Maintenance

Before the actual maintenance, it is necessary to ensure that the control and communication subsystem is not connected to the power or communication cabling, and it is also necessary to secure the subsystem against movement. In the event that the subsystem is dirty, it is necessary to remove such dirt so as not to damage any of the mechanical or electrical components. When using water-based cleaners, avoid areas with electronics, as irreversible destruction of the subsystem may occur. Clean these areas using compressed air spray. In the event that a part of the subsystem must be removed for maintenance, always follow the instructions in this document.

⚠	**WARNING**
Before carrying out maintenance, it is necessary that the batteries are disconnected from the wiring, ensuring that the batteries are connected in parallel.	

⚠	**WARNING**
Take extra care during maintenance to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, be aware of your safety and use protective equipment	

5.1.5 Service

In the event of non-standard behaviour of the control and communication subsystem, design repair or electrical circuit burnout, the module must not be connected to the power or communication cable. Subsequently, perform the necessary servicing. Servicing shall only be carried out by the person responsible for the subsystem. If servicing is carried out by a person who is not responsible for the subsystem, it is necessary that the responsible person supervises the person carrying out the servicing. After the servicing is completed, the previous sub-sections, such as the assembly and commissioning instructions, must be followed.

⚠	**WARNING**
When handling individual parts, use caution and do not use sharp tools that may damage or destroy mechanical or electrical parts of the system. When using tools, be aware of your safety and wear protective equipment.	

⚠	**WARNING**
Before carrying out a service operation, it is necessary to disconnect the subsystem from the power supply, i.e., the power supply subsystem, to prevent a short circuit and subsequent damage to any of the subsystem's electrical components.	

6 VISION SUBSYSTEM

This chapter describes the vision subsystem that is used for target detection. The subsystem is located on the underside of the drone and detects colored targets on the pad. Based on the detected targets, balls are released from the action subsystem. The vision subsystem consists of a single board computer along with a camera and a frame, for placing the camera on the bottom of the drone on the action subsystem. The control system of this subsystem is then placed in the electronics holder of the control and communication subsystem.

6.1.1 Basic description of the subsystem

The control system of the subsystem is a single board computer Raspberry Pi 4. For target detection, the subsystem is equipped with a Raspberry Pi HQ Camera. This camera has the possibility of interchangeable lenses, which presents the possibility of optimization during the tests of this subsystem. For the detection of already captured targets through the camera, the computer uses the OpenCV library together with a kernel filter. An application has also been created that processes the data obtained from the image and forwards it to the main control system. The camera is placed on the underside of the drone and the image is sent to the control system using CSI and HDMI cable. The CAD model of the vision subsystem is shown in Fig. 6.1.

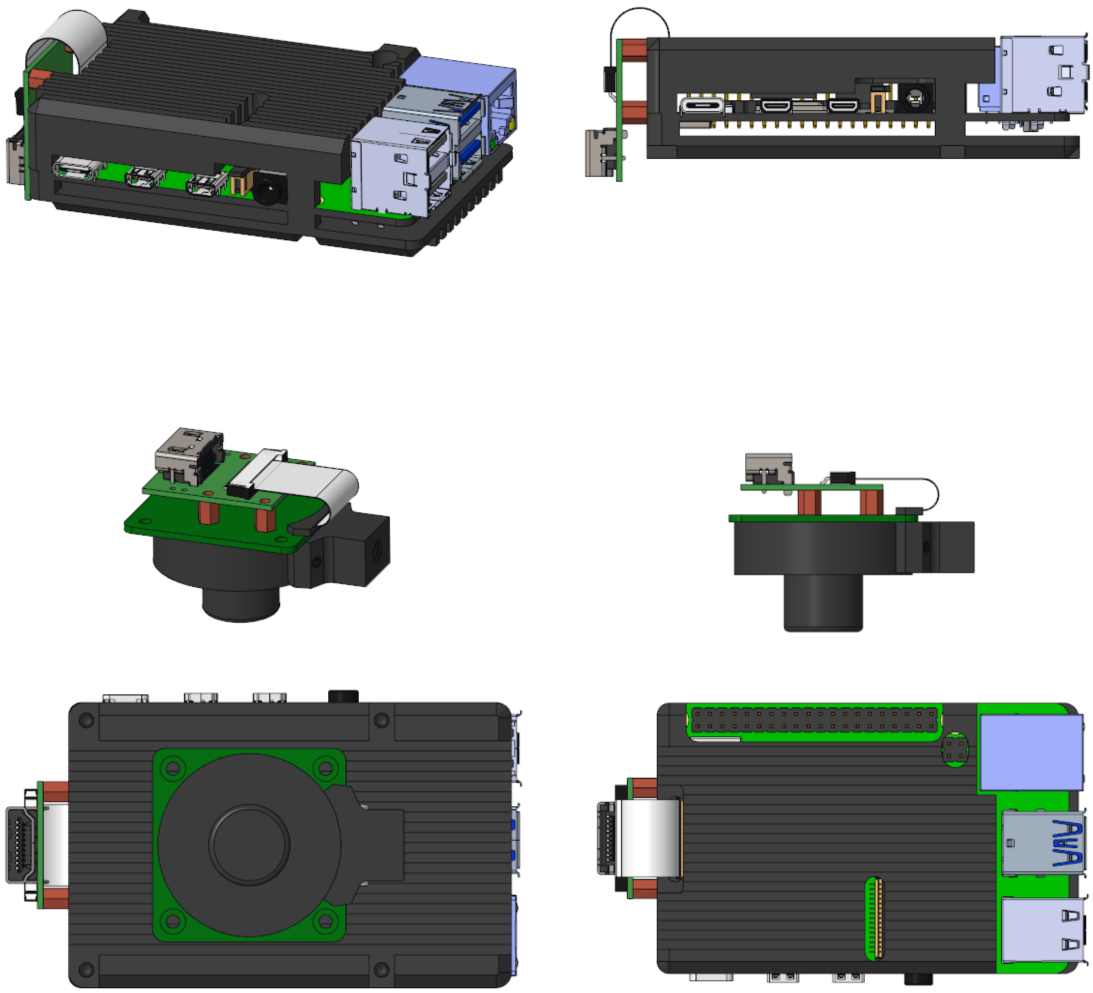


Fig. 6.1 CAD model of the vision subsystem

Basic parameters of the subsystem

At Fig. 6.2 shows the basic dimensions of the vision subsystem, then the Tab. 6.1 other essential parameters related to this subsystem are listed.

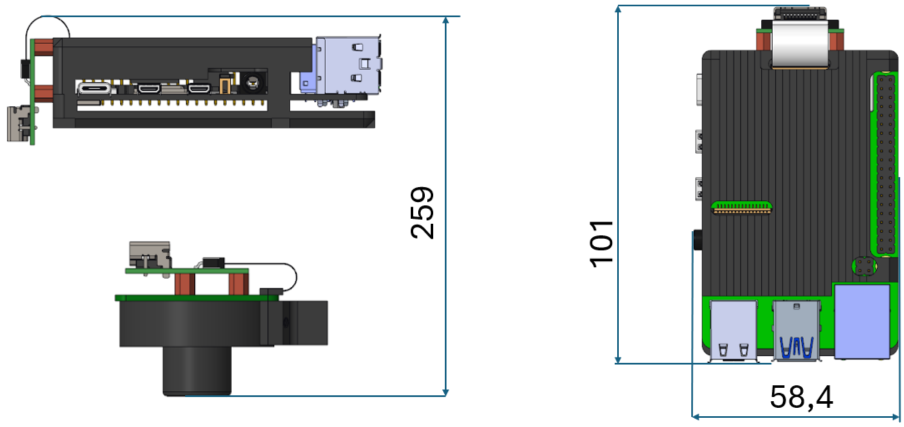


Fig. 6.2 Basic dimensions of the vision subsystem

Tab. 6.1 Basic parameters of the vision subsystem

Parameter	Value
Subsystem dimensions	101 × 167 × 259 mm
Control system	Raspberry Pi 4
Camera	Raspberry Pi HQ Camera
Interconnection cabling	CSI and HDMI
Camera mount material	PETG

Inventory of components

In the table on the next page, see Tab. 6.2, all components that are present in the CAD model of the vision subsystem are listed. Based on the numbers in the table, the Fig. 6.3 indicates the component in question. The bolded part in the name of a given component is the trade name of that component. Each component name is also accompanied by the corresponding CAD model name.

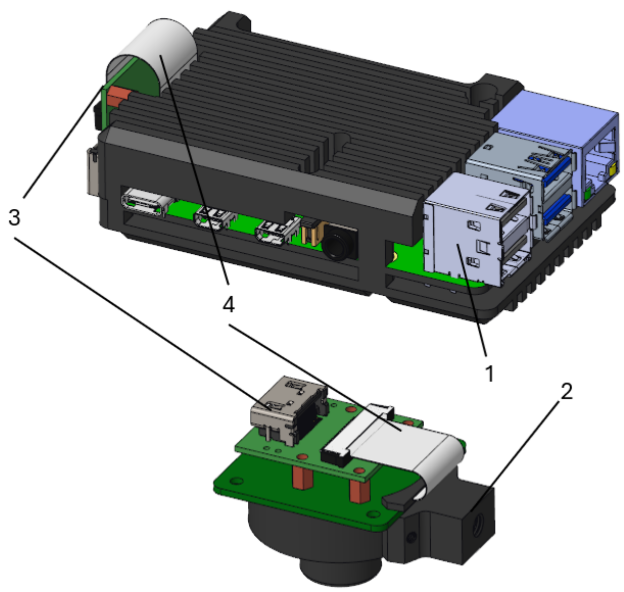


Fig. 6.3 Layout of the vision subsystem components

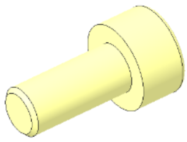
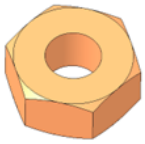
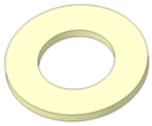
Tab. 6.2 Inventory of vision subsystem components

Number	Ks.	Component	CAD model
1	1	**Raspberry Pi 4** control system	RPI4_B.PRT
2	1	**Raspberry Pi HQ Camera** subsystem	RP_HQ_CAMERA.PRT
3	1	**CSI to HDMI** converter **for Raspberry Pi camera**	CSI_HDMI.PRT
4	1	Interconnecting cable **CSI cable**	CSI_KABEL.PRT

6.1.2 Assembly instructions

To build a vision subsystem you need to have all the components shown below, see Tab. 6.3. At the same time, the action, locomotion and control and communication subsystems need to be assembled and ready, as some components are attached to the mentioned subsystems.

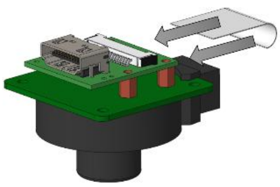
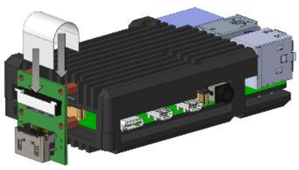
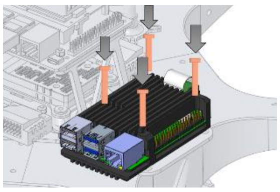
Tab. 6.3 Components needed to assemble the locomotion subsystem

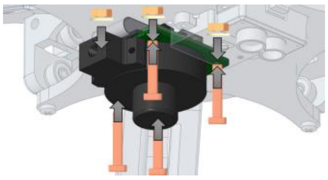
			
Raspberry Pi 4 ***1*** 1x	Camera HQ ***2*** 1x	CSI HDMI converter ***3*** 1x	CSI cable ***4*** 1x
			
HDMI cable ***5*** 1x	ISO4762 M3×12 8.8 ***6*** 8x	ISO4032 M3×6 ***7*** 12x	ISO7092 3 ***8*** 24x

Instructions for building the vision subsystem

In the table below, see Tab. 6.4, a pictorial and verbal description for the vision subsystem build is shown. During the assembly of the subsystem, it is necessary to have the appropriate equipment and tools available at all times, at the same time it is necessary that the assembly is carried out by the person responsible for the subsystem, in case the assembly is carried out by a person who is not responsible for the subsystem, it is necessary that the responsible person supervises the person carrying out the assembly

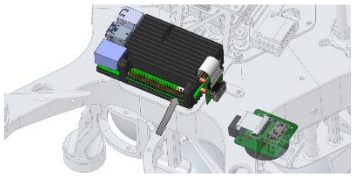
Tab. 6.4 Instructions for setting up the vision subsystem

		
Step 1 - Connect one end of the CSI cable ***4*** to the CSI connector of the camera ***2***, connect the other end to the converter ***3***.	Step 2 - Connect one end of the CSI cable ***4*** to the CSI connector of the Raspberry Pi 4 ***1***, connect the other end to the converter	Step 3 - Attach the Raspberry Pi 4 ***1*** to the control electronics bracket of the control and communication sub. using the



Step 4 - Attach the assembly from step 1 to the action subsystem sensor bracket using the four screws ***6***, nuts ***7*** and washers ***8***.

Step 5 - Connect both converters ***3*** using HDMI cable ***5.***



Step 6* - Connect the Raspberry Pi 4 ***1*** to power via the GPIO pins to the power supply subsystem.

* Perform this step only after the energy security subsystem has been successfully commissioned.

6.1.3 Preparation for operation

To make the vision subsystem ready for operation, it is necessary to follow the assembly instructions of the previous subchapter and to have assembled all the subsystems that were described in the documentation before this subsystem. It is also necessary to wire the electrical components as prescribed by the wiring diagrams illustrated in this subchapter.

Electronics wiring diagram

In the picture below, see Fig. 6.4, shows the wiring diagram of the individual electrical components contained in the vision subsystem.

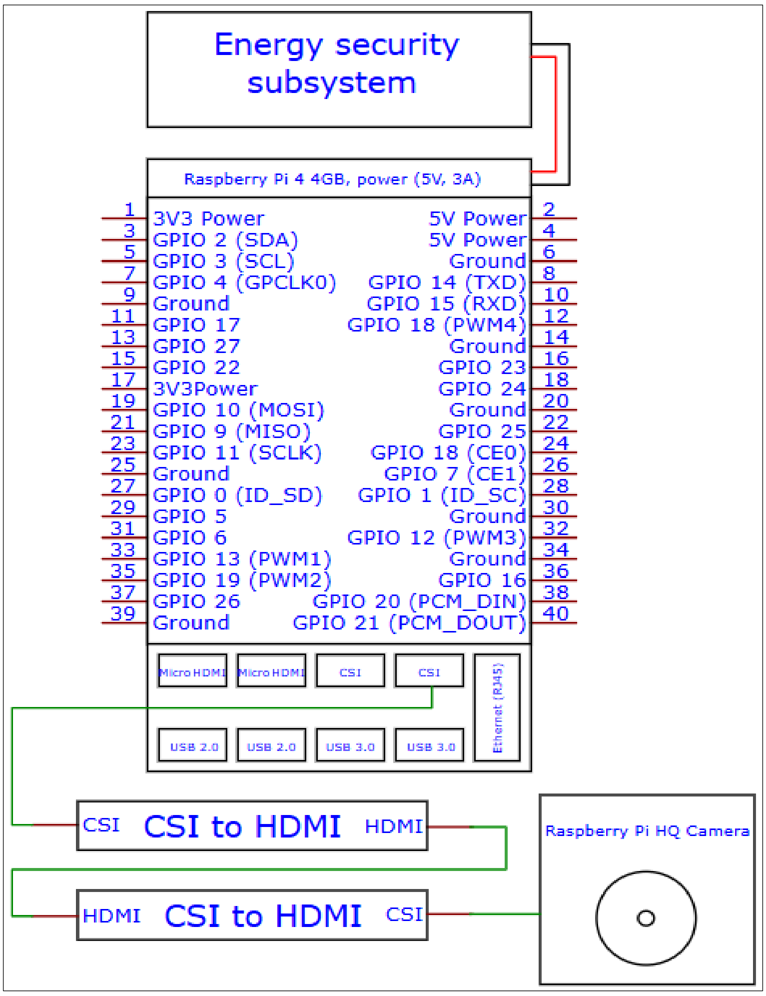


Fig. 6.4 Wiring diagram of the vision subsystem electronics

⚠	**WARNING**
Before commissioning, all switches must be in the off position, i.e. "0". Failure to do so may result in a short circuit and subsequent damage to any of the electrical components of the subsystem.	

⚠	**WARNING**
Take extra care before commissioning to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, take care for your safety and use protective equipment	

Block diagram of wiring

In the picture below, see Fig. 6.5, a block diagram of the vision subsystem is shown. This diagram shows the interconnection of the individual components as well as any communication that takes place between the components.

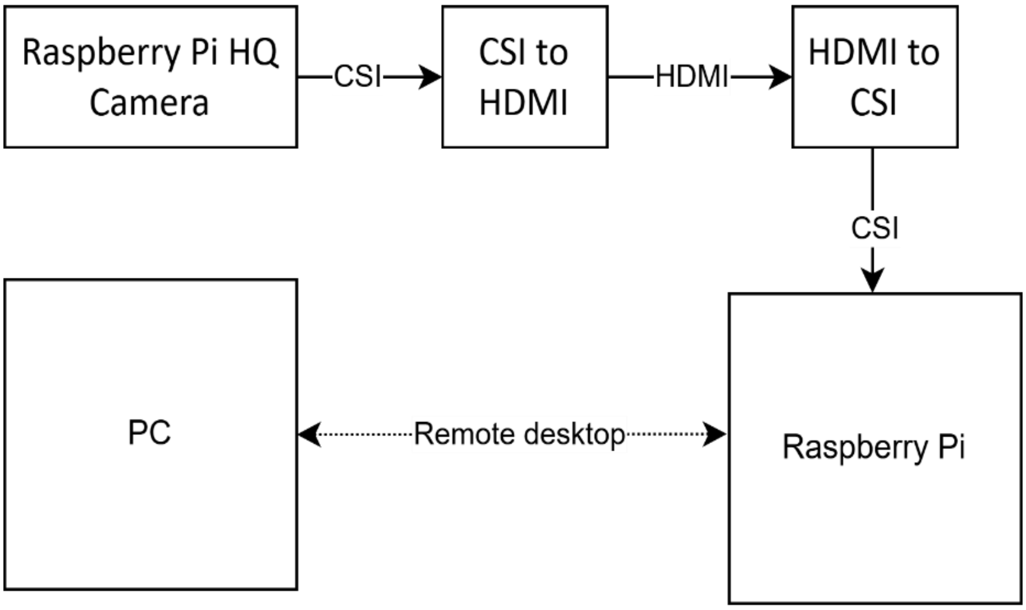


Fig. 6.5 Block diagram of the vision subsystem

FlowChart diagram

In the picture below, see Fig. 6.6, a flowchart diagram is depicted that describes the basic principle of operation of a target detection application using the vision subsystem. This flowchart is used for easier understanding of the algorithm.

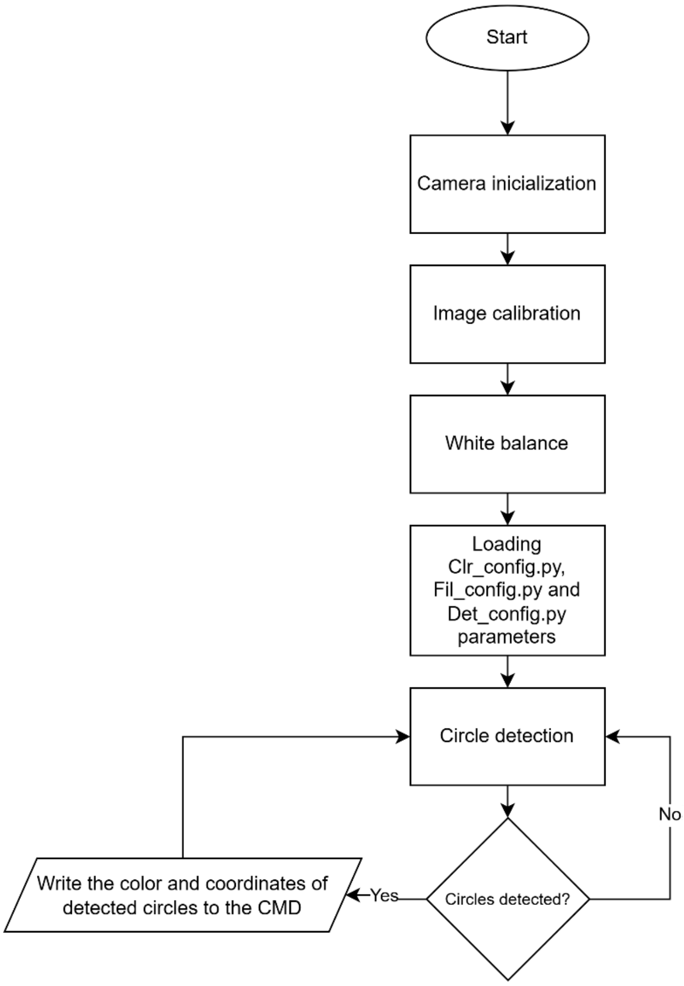


Fig. 6.6 FlowChart diagram of the vision subsystem

The program for the vision subsystem contains individual subroutines that are used for camera calibration, white balancing, edge detection, etc. The FlowChart diagram of the subroutines are shown in the figure on the next page, see Fig. 6.7. These subroutines are followed by FlowChart diagrams that are already related to the application that is used to take the images, see Fig. 6.8, displaying the image of the site, etc. Scanning the pad results in the position of the targets relative to the camera and sending this data to the main control system.

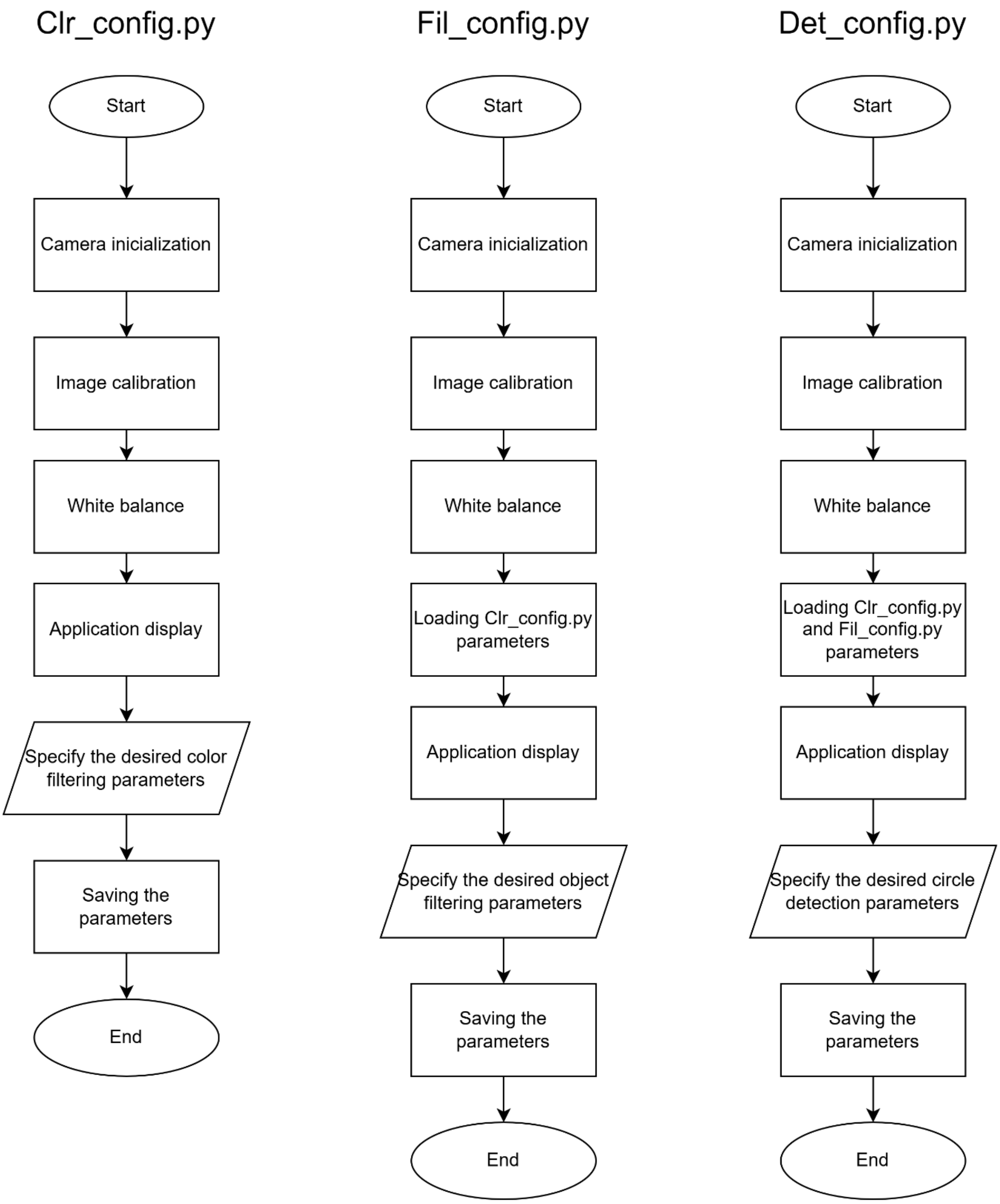


Fig. 6.7 FlowChart diagrams of vision subsystem 1 subroutines

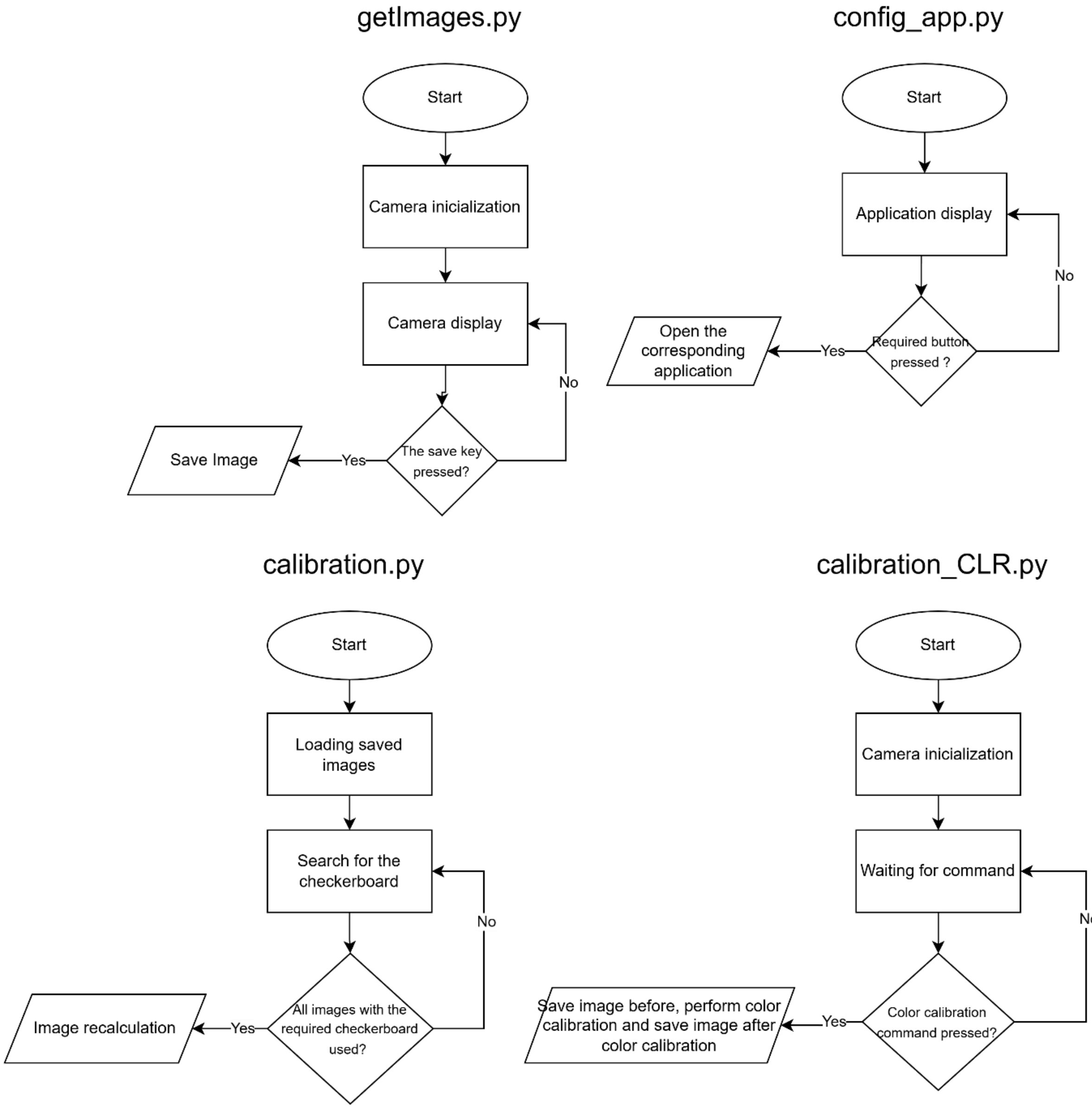
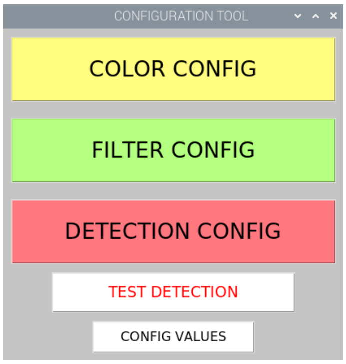


Fig. 6.8 FlowChart diagrams of the vision subsystem 2

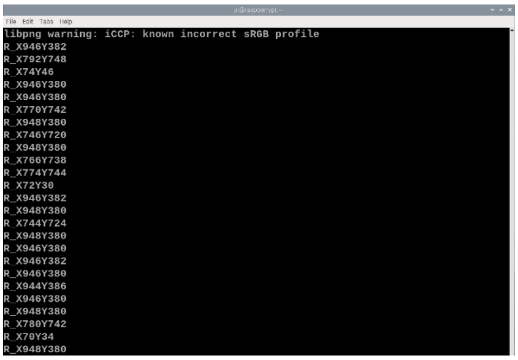
6.1.4 Application of the vision subsystem

To make it easier to control and send data from the vision subsystem, an application was created. The application includes an environment for camera calibration, edge and target detection, sending and outputting coordinates. The application environment is shown in the images below in Tab. 6.5.

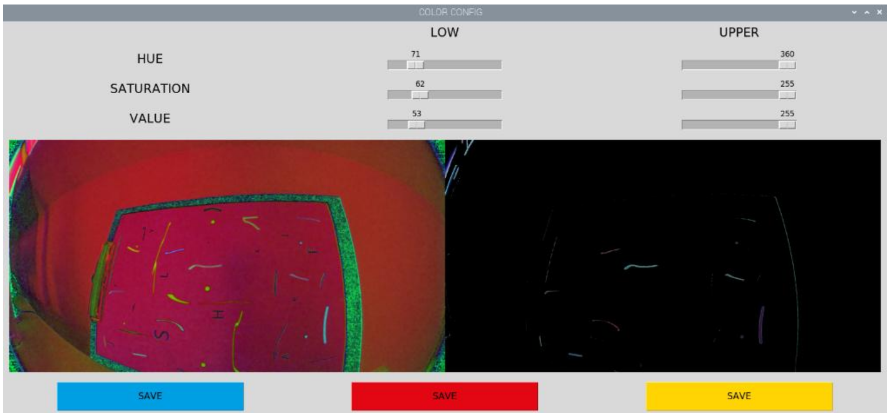
Tab. 6.5 Application of the vision subsystem



Config app



Listing coordinates



Calibration config

Detection config

Detection

6.1.5 Maintenance

Prior to maintenance, the vision subsystem must not be mechanically attached to the drone, the vision subsystem must not be connected to power or communication cables, and the subsystem must be secured against movement. If the subsystem is dirty, it is necessary to remove the dirt so as not to damage any of the mechanical or electrical components. When using water-based cleaners, avoid areas with electronics, as irreversible destruction of the subsystem may occur. Clean these areas using compressed air spray. In the event that a part of the subsystem must be removed for maintenance, always follow the instructions in this document.

WARNING

Before carrying out maintenance, it is necessary that the batteries are disconnected from the wiring, ensuring that the batteries are connected in parallel.

WARNING

Take extra care during maintenance to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, take care for your safety and use protective equipment

6.1.6 Service

In the event of non-standard behaviour of the vision subsystem, design repair or electrical circuit burnout, the module must not be connected to the drone with a power or communication cable. Subsequently, perform the necessary servicing. Servicing shall only be performed by the person responsible for the subsystem. In the event that servicing is performed by a person who is not responsible for that subsystem, it is necessary that the responsible person supervise the person performing the servicing. After the servicing is completed, the previous sub-sections, such as the assembly and commissioning instructions, must be followed.

WARNING

When handling individual parts, use caution and do not use sharp tools that may damage or destroy mechanical or electrical parts of the system. When using tools, be aware of your safety and wear protective equipment.

WARNING

Before servicing, it is necessary to disconnect the energy security subsystem from the system to prevent short-circuiting and subsequent damage to any of the electrical components.

7 ENERGY SECURITY SUBSYSTEM

This chapter describes the energy security subsystem, which consists of a total of 2 LiPol batteries. The subsystem also includes a relay and a switch, this arrangement is used to safely disconnect the batteries from the system. Also included are voltage converters to power the mini computers.

7.1.1 Basic description of the subsystem

The mechanical part consists mainly of LiPol batteries. One battery has a nominal voltage of 22.2 V and a capacity of 4.6 Ah. To keep the batteries firmly attached to the drone, Velcro straps are used to secure the battery to the frame. Since tens of amperes of current are required during operation, it was necessary to use relays through which such high amperes can flow. The relay used is designed for 24 V and up to 120 A. The last part of this subsystem is a voltage converter to power the controllers and computers that are on the drone. The CAD model is shown on Fig. 7.1.

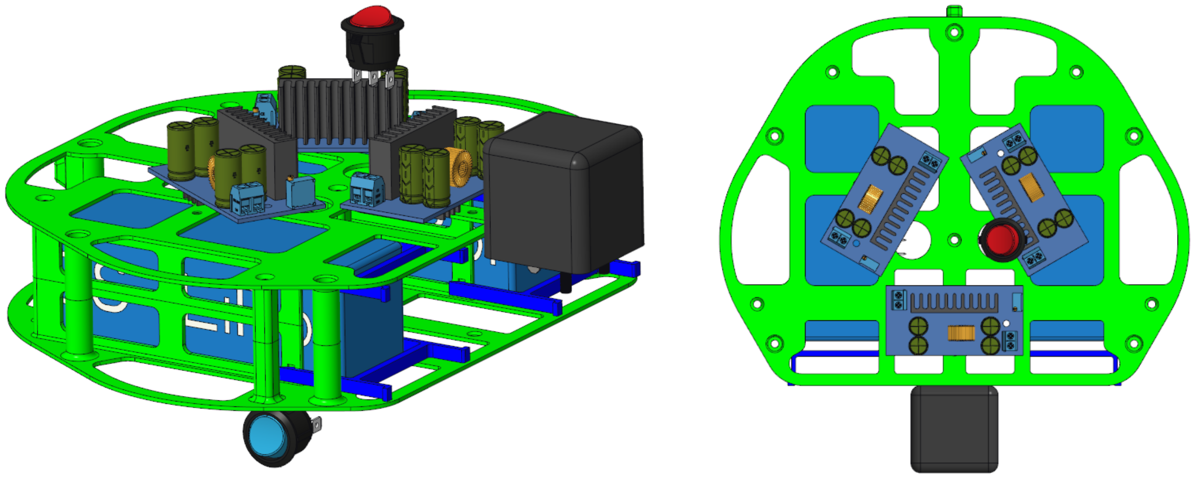


Fig. 7.1 CAD model of the energy security subsystem

Parameters of the energy security subsystem

At Fig. 7.2 shows the basic dimensions of the energy security subsystem, the Tab. 7.1 other essential parameters related to this subsystem are listed.

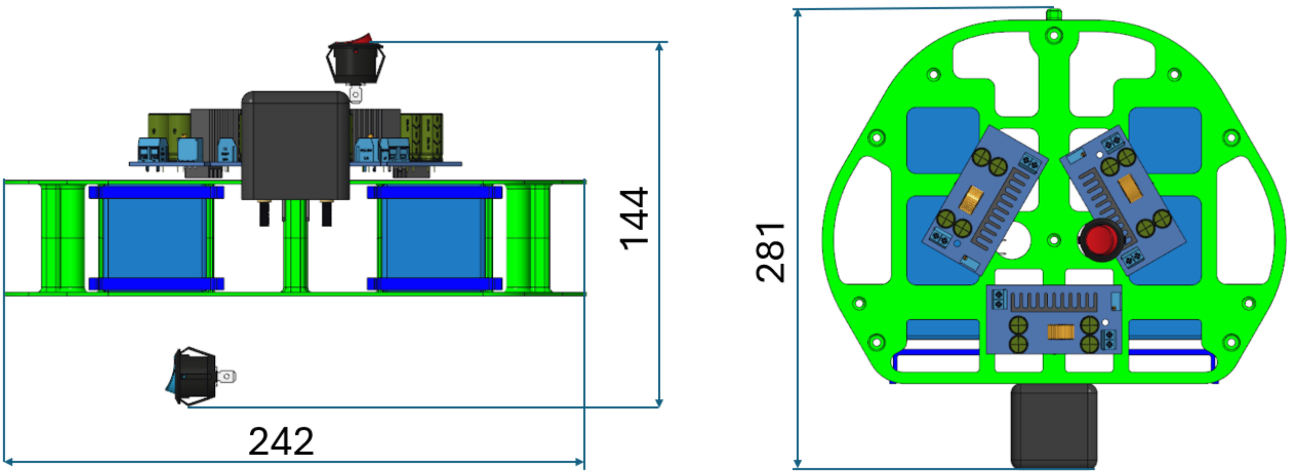


Fig. 7.2 Basic dimensions of the energy security subsystem

Tab. 7.1 Parameters of the energy security subsystem

Parameter	Value
Dimensions	281 × 242 × 144 mm
Number of accumulators	2
Battery type	Li-Pol 6S
Nominal voltage	22,2 V
Cell capacity	4.6 Ah
Total capacity	9.2 Ah
Power connectors	XT-90
Balancer connectors	JST-XH 6S
Switching relay	24 VDC, 120 A
Switch	3 pin rocker switch

Inventory of components

In the table below, see Tab. 7.2, all components that are present in the CAD model of the energy security subsystem are listed. Based on the numbers in the table, the Fig. 7.3 indicates the component in question. The bolded part in the name of a given component is the trade name of that component. Each component name is also accompanied by the corresponding CAD model name.

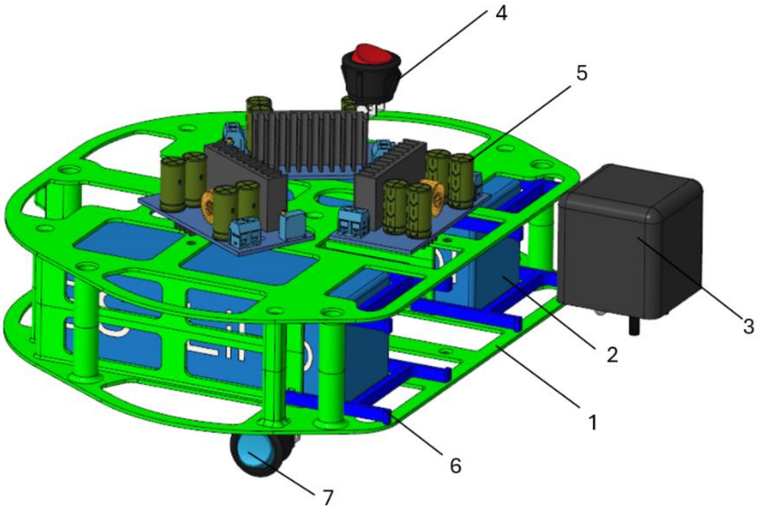


Fig. 7.3 Layout of the components of the energy security subsystem

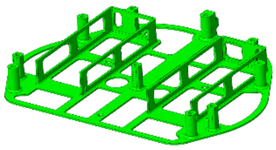
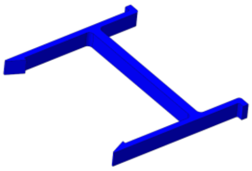
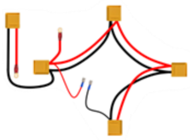
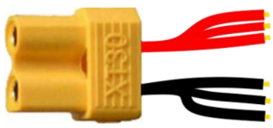
Tab. 7.2 Inventory of components of the energy security subsystem

Number	Ks.	Component	CAD model
1	1	Battery holder	BATTERY_HOLDER.PRT
2	4	Battery lock against movement	BATTERY_STUD.PRT
3	2	Battery **Li-pol battery 4600 mAh 6S 35C Power X6**	BATTERY.PRT
4	1	**Switching** relay **Relay car RL/180-24 24V/120A**	RELE_24V_120A.PRT
5	1	Cradle switch **OFF-ON 12/20A Hadex**	SPINAC_DC.PRT
6	3	Step-Down converter **module with XL4016E1**	STEP_DOWN.PRT
7	1	Cradle switch action sub. **OFF-ON 12V/20A Hadex**	SPINAC_DC_AS.PRT

7.1.2 Assembly instructions

Before the energy security subsystem can be put into operation, it must first be assembled. All components need to be in place before assembly can start, see Tab. 7.3. At the same time, the locomotion subsystem of the drone needs to be available.

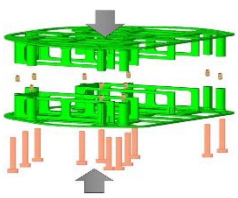
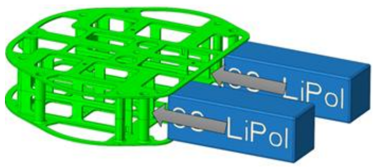
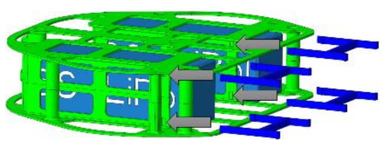
Tab. 7.3 Components needed to build the energy security subsystem

			
Holder ***1*** 2x	Fuse ***2*** 4x	Accumulator ***3*** 2x	Relay 24 V 120 A ***4*** 1x
			
ON/OFF switch ***5*** 1x	Step-Down Converter ***6*** 1x	ON/OFF switch ***7*** 1x	Cabling Accu. ***8*** 1x
			
Cabling switch ***9*** 2x	Inverter cabling ***10*** 8x	Threaded insert M3 ***8*** 6	ISO4762 M4×9 8.8 ***9*** 6x

Assembly of the locomotion subsystem

In the table below, see Tab. 7.4, a pictorial and verbal description for the assembly of the energy security subsystem is shown. During the assembly of the subsystem, it is necessary to have the appropriate equipment and tools available at all times, at the same time it is necessary that the assembly is carried out by the person responsible for the subsystem, in case the assembly is carried out by a person who is not responsible for the subsystem, it is necessary that the responsible person supervises the person carrying out the assembly.

Tab. 7.4 Instructions for setting up the energy security subsystem

		
Step 1 - Use screws ***9***, threaded inserts ***8*** to connect the two battery holders ***1***	Step 2 - Insert both batteries ***3***, into the folded battery holder.	Step 3 - Insert the four fuses ***2*** into the pre-prepared holes in the battery holder.

For the correct connection of the electrical components - the wiring of the battery ***8***, the wiring of the switch ***9***, the wiring of the inverters ***10***, the wiring of the Step-Down converter ***6***, the ON/OFF switch ***5*** and ***7*** and the relay ***4***, it is necessary to follow the wiring diagram of the electronics in the following subsection see 7.1.3.

7.1.3 Preparation for operation

For the commissioning of the energy security subsystem it is necessary to follow the assembly instructions of the previous subchapter and to have assembled all the subsystems that were described in the documentation before this subsystem. It is also necessary to wire the electrical components as prescribed in the wiring diagrams shown in this subchapter.

Electronics wiring diagram

In the picture below, see Fig. 7.4, shows the wiring diagram of the individual electrical components of the energy security subsystem.

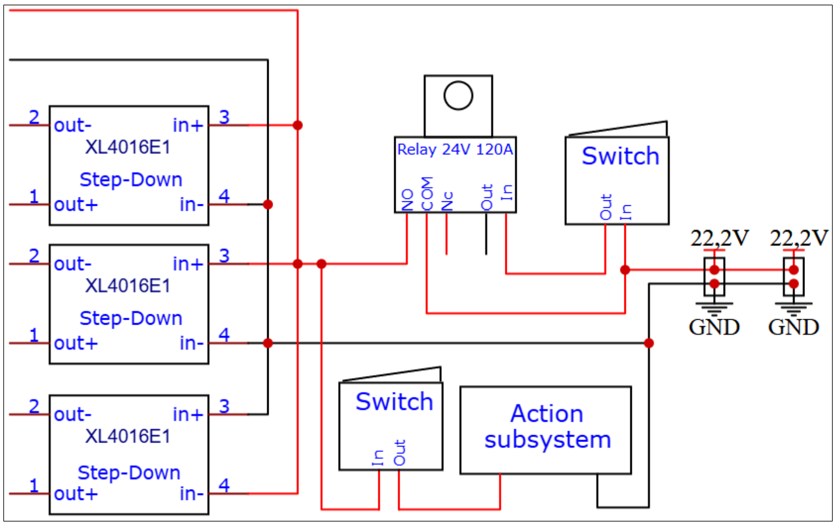


Fig. 7.4 Schematic diagram of the electronics of the energy security subsystem

WARNING

Before commissioning, all switches must be in the off position, i.e. "0". Failure to do so may result in a short circuit and subsequent damage to any of the electrical components of the subsystem.

WARNING

Take extra care before commissioning to avoid damaging or destroying any of the mechanical or electrical parts of the subsystem. When using the tool, take care for your safety and use protective equipment

Block diagram

In the picture below, see Fig. 7.5, shows a block diagram of the energy security subsystem. This diagram shows the interconnection of the individual components and is essentially a simplified wiring diagram.

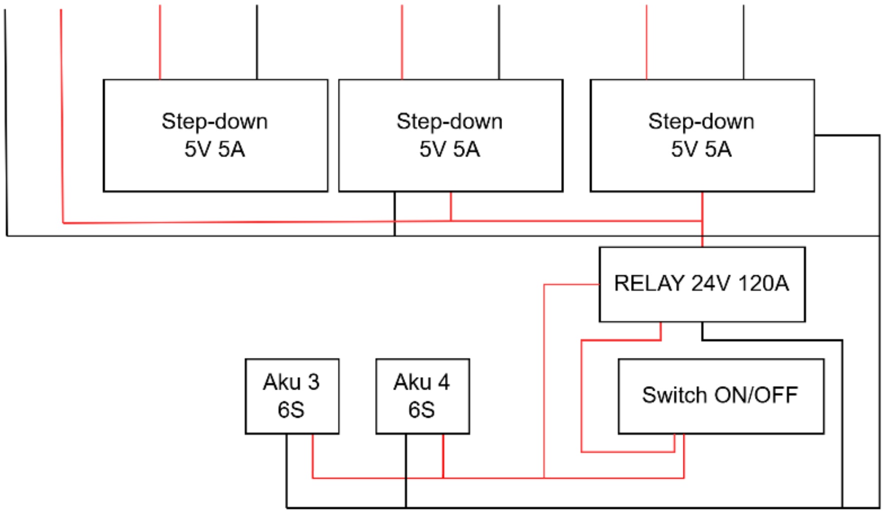


Fig. 7.5 Block diagram of the energy security subsystem

7.1.4 Maintenance

Before maintenance, it is necessary that the power security subsystem is not mechanically attached to the drone, the power security subsystem must not power any electrical component or subsystem, and it is also necessary to secure the subsystem against movement. In the event that the subsystem is soiled, such soiling must be removed so as not to damage any of the mechanical or electrical components. Do not use liquid cleaning agents, as this may irreversibly destroy the subsystem. Clean contaminated areas using compressed air spray. In the event that a part of the subsystem must be removed for maintenance, always follow the instructions in this document.

⚠	**WARNING**
Before carrying out maintenance, it is necessary that the batteries are disconnected from the wiring, ensuring that the batteries are connected in parallel.	

7.1.5 Service

In the event of non-standard behaviour of the energy security subsystem, design repair or electrical circuit burnout, the module must not be connected to the drone, nor must the energy security subsystem power any electrical component or subsystem. Subsequently, perform the necessary servicing. Servicing shall only be performed by the person responsible for the subsystem. In the event that servicing is performed by a person who is not responsible for the subsystem, the responsible person must supervise the person performing the servicing. After the servicing is completed, the previous sub-sections, such as the assembly and commissioning instructions, must be followed.

WARNING

When handling individual parts, use caution and do not use sharp tools that may damage or destroy mechanical or electrical parts of the system. When using tools, be aware of your safety and wear protective equipment.

WARNING

Before servicing, it is necessary to disconnect the energy security subsystem from the system to prevent short-circuiting and subsequent damage to any of the electrical components.

7.1.6 Charging

Before charging the batteries, you must first remove the batteries from the system, i.e. disconnect the batteries from the XT-90 connectors and remove the Velcro strips. The batteries must never be charged when they are placed in the system. Furthermore, they must not be charged if the batteries are visibly damaged and do not match the pictures shown in this document. Always charge the battery with the charger recommended by the battery manufacturer or dealer. The correct connection of the battery to the charger is illustrated on Fig. 7.6, the power and balance connector must always be connected to the charger. Before putting the batteries back into the system, it is always necessary to verify that all batteries are charged to the same and maximum level.

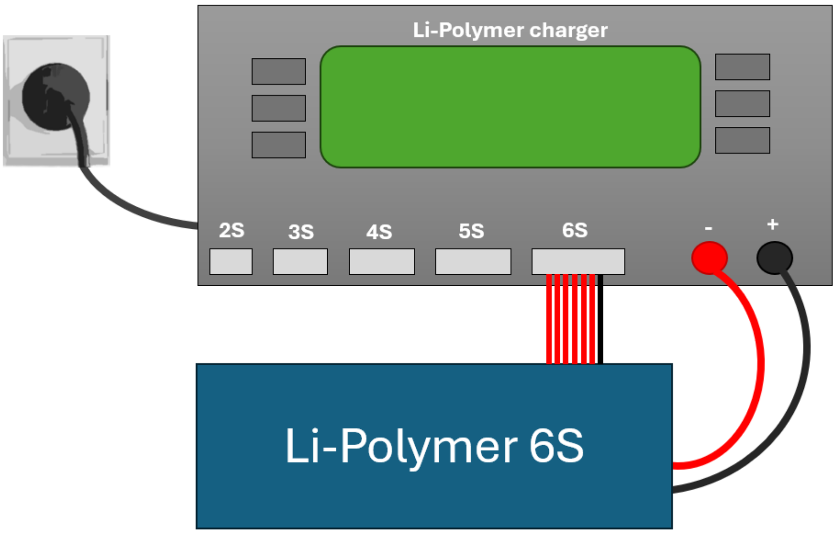


Fig. 7.6 Diagram of the connection of the lithium polymer battery to the

⚠	**WARNING**
Do not use a third-party charger. Do not leave the battery unattended while charging and if there are problems, stop the charging cycle immediately. The battery may heat up to a higher temperature during charging. The battery should be kept in a protective case during charging.	

⚠	**WARNING**
Use caution when handling the battery in any way. Do not use sharp tools, water or other cleaning agents. If the battery is short-circuited or otherwise damaged (mechanical, chemical), there is a risk of explosion, ignition, etc.	

⚠	**WARNING**
Before charging, the batteries must be disconnected from the wiring to ensure the batteries are connected in parallel. At the same time, the battery must not be connected to the system.	

8 MANUAL CONTROL

This chapter describes the manual control of the drone. The drone is manually controlled by the operator using an RC controller. Furthermore, the chapter describes the different possible movements of the drone, or operational states that can be performed remotely using the controller. The chapter also includes a flowchart diagram to understand the program that takes care of the manual control.

8.1 Driver description

For the manual remote control of the drone is chosen RC controller RadioMaster Boxer. This controller has a sufficient number of channels and buttons, so it is possible to configure the necessary operating states on individual buttons during the execution of the bed. The layout of the buttons on the controller is shown on Fig. 8.1, a description of these buttons is then given in Tab. 8.1.

In the event that the drone needs to be controlled manually, it is necessary for the operator to have a RadioMaster Boxer RC controller. The picture below shows all the functional parts of the controller, in Tab. 8.1 then describes the individual parts of the controller and a description of the function.

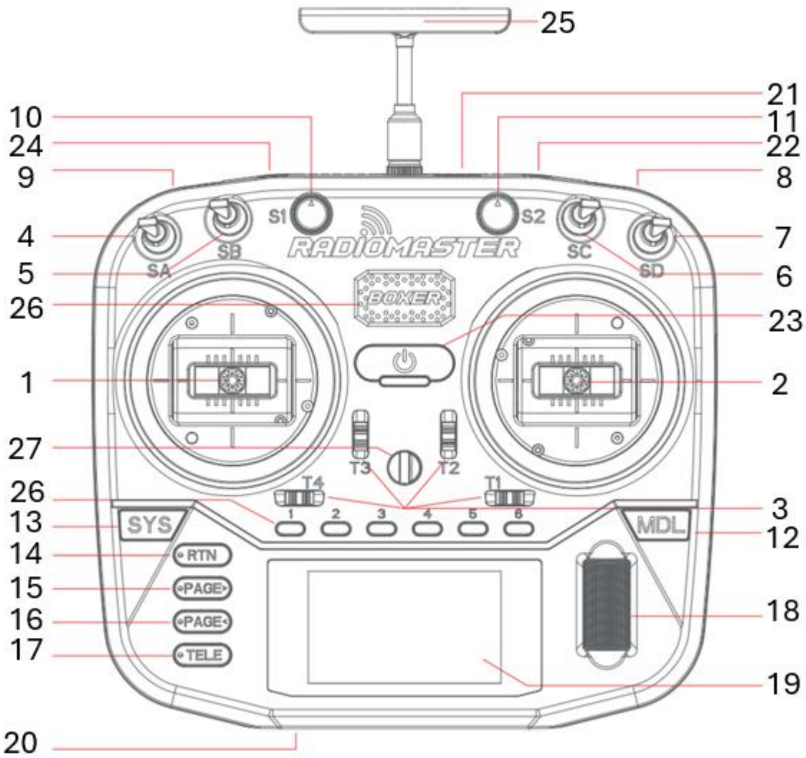


Fig. 8.1 Functional parts of the RadioMaster Boxer RC controller

Tab. 8.1 Description of individual functions of the RadioMaster Boxer RC controller

Number	Name	Description
1	Left Joystick	Controls the yaw and throttle. Vertical motion controls the drone's ascent and descent, while horizontal motion controls the drone's rotation about its axis.
2	Right Joystick	Controls Roll and Pitch. Vertical forward and backward motion controls forward or backward movement of the drone, while horizontal motion controls left or right movement

Number	Name	Description
3	Trim Buttons	Used to fine tune the position of the joysticks. They can be used to balance the drone in flight if it tends to shift or tilt in an unwanted direction.
4	SA	This switch can be adapted for different functions depending on how it is programmed in the control software (e.g. switching flight modes, activating special functions, etc.)
5	SB	
6	SC	This switch can be adapted for different functions depending on how it is programmed in the control software (e.g. switching flight modes, activating special functions, etc.). In our case, the **SD** switch is used as an "ARM/DISARM" switch to turn the drone's motors on or off.
7	SD	
8	SF	This is a programmable torque button that returns to its default position when released. It is often used for functions that require temporary activation, such as resetting a timer or switching to alert mode. In our case, to drop a tennis ball.
9	SE	This is a programmable button with a lock that does not return to the default position when released. It is often used for functions that require an ON/OFF switch, such as activating certain functions.
10	S1	These are programmable wheels that allow for infinitely adjustable values, for example they can be used to control a gimbal.
11	S2	
12	MDL	Access settings for specific drone models.
13	SYS	Access the system settings of the driver.
14	RTN	Back button
15	PAGE>	Switching between settings pages
16	PAGE<	
17	TELE	Button for quick access to telemetry.
18	Scroll wheel	The scroll wheel allows quick navigation through the menu and pressing the wheel confirms the selection.
19	LCD screen	View the menu and information about the drone.
20	USB-C	USB-C charging port for charging the driver battery.
21	USB-C	USB-C data port for data transfer between the controller and the computer.
22	Jack	3.5 mm Jack for headphone connection.
23	ON/OFF button	It is used to switch the driver on and off. The button must be pressed and held for several seconds until the melody is played, then the controller is switched off or on, depending on the previous state.
24	Trainer port	This port allow connection to another controller, which is useful for training new pilots. It is also possible to connect to the trainer via cable.
25	Antenna	It is used to send a signal and communicate with the drone.
26	Buttons 1-6	The six programmable buttons above the RadioMaster Boxer's display are used for quick access to various functions such as mode switching or telemetry. The buttons are backlit in red to indicate their activation and make them easier to navigate. They can be programmed according to the pilot's needs via OpenTX or EdgeTX.
27	lanyard loop	Used for attaching the loop. The operator can then hang the remote over his neck to make operation more comfortable.

Charging the controller

The driver has two states within the battery charge, these states are presented on the driver by a coloured diode in the ON/OFF area, see Fig. 8.2. The first state (green) shows sufficient energy in the battery to power the controller, the second state (red) shows the need to charge the controller. The state where the controller battery needs to be charged is also accompanied by a melody that plays at regular intervals.

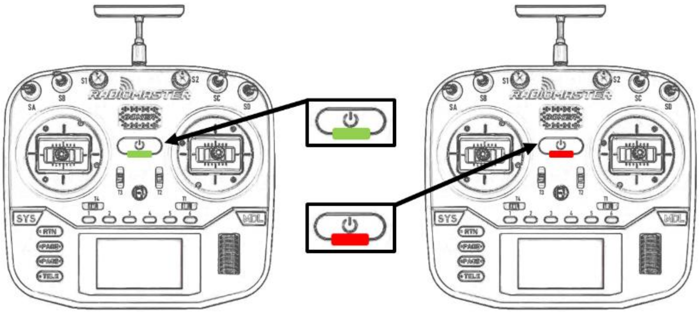


Fig. 8.2 Sufficient and insufficient energy status of the driver battery

As mentioned on the previous page, the controller is equipped with a USB-C charging connector for charging the battery, see Fig. 8.3. Always charge with a certified DC charger. This charger must have a voltage of 5 volts and deliver a maximum current of 2 amps, i.e. (maximum output 10 W), at the same time there must be a USB-C connector at the end of the charger cable, see Fig. 8.3.

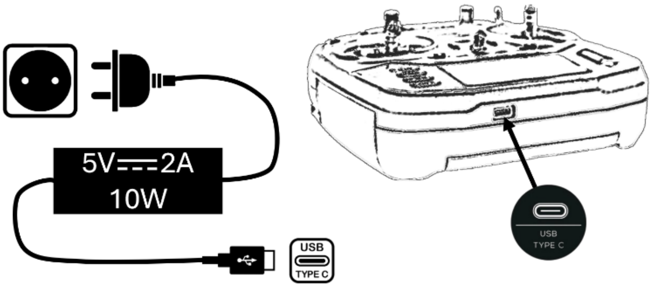


Fig. 8.3 Schematic of the charger and charging connector of the driver

Before connecting the charger connector to the driver's charging connector, check for foreign objects in these areas; if the connectors need to be cleaned, follow the instructions in this document. The charging process is illustrated in the pictures below, see Fig. 8.4.

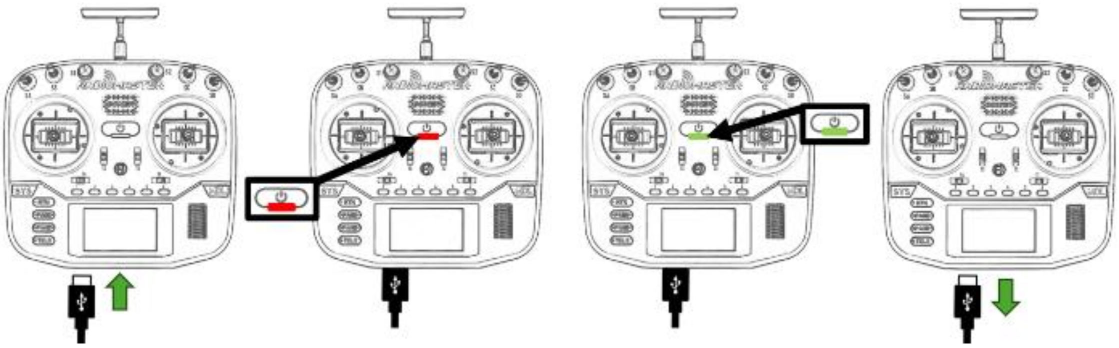


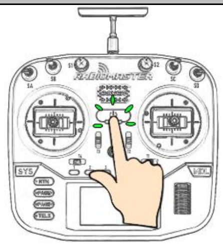
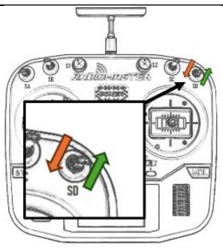
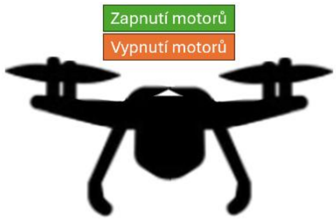
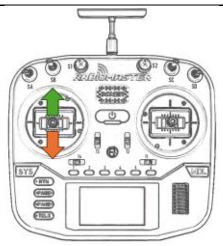
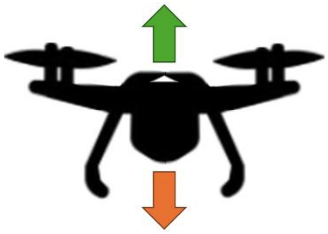
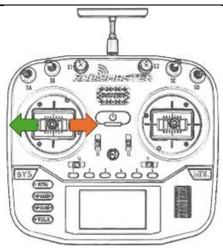
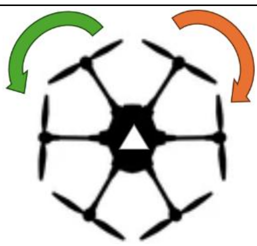
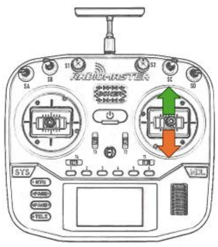
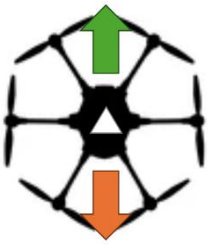
Fig. 8.4 Driver charging flow

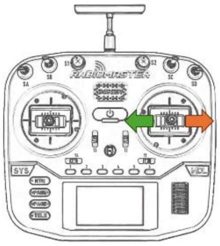
⚠	**WARNING**
Always follow the instructions in the manufacturer's manual for the RadioMaster Boxer, and also follow the instructions in this document.	

8.2 Activation and movements for manual operation

The drone's movements can be controlled using joysticks and buttons on the remote control. The individual function buttons on the remote control are graphically shown in Tab. 8.2. Before starting manual control, make sure that the remote control is sufficiently charged, see previous subsection, and make sure that the drone batteries are charged according to the instructions in this document, see chapter *"Energy security subsystem".*

Tab. 8.2 Controlling the drone with the remote control

Movement on the rotary pushbutton	Drone movement	Description
		Long press and hold the **ON/OFF button** to play the melody and turn the remote off or on. The controller must be close to the drone when switched on.
		Move the **SD** lever as shown to switch the motors on or off. Always stay at least 2 meters away from the drone when switching on the motors.
		Move up and down on the **left joystick** to change the flight altitude. The further the stick is from its rest position, the faster the altitude changes.
		Moving right and left on the **left joystick** rotates the drone around its axis. The further the stick is from its rest position, the faster the drone rotates.
		Move up and down on the **right joystick** to change the direction of flight back and forth. The further the stick is from its rest position, the faster the speed in that direction.

Movement on the rotary pushbutton	Drone movement	Description
		Moving right and left on the **right joystick** changes the direction of flight left and right. The further the stick is from its rest position, the higher the speed in that direction.
		Click on the **SF** button on the top of the controller to release the ball. This button can only be used if the drone is flying with the action subsystem.

Drone take-off and landing procedure

1) Place the drone with its feet on a flat surface.

2) Turn on the remote control and the drone using the switch described in "7".

3) Connect the flight controller via USB cable to your computer.

4) Calibrate the system.

5) Once the calibration is complete, disconnect the USB cable from the flight controller.

6) Move away from the drone to a distance of at least 3 metres.

7) Use the remote control to start the motors.

8) Slowly move the left joystick upwards to take off.

9) Move through the air based on the pictures in the table above.

10) To land, check the landing area to make sure there is nothing on it.

11) Slowly move the left joystick down to land.

12) After landing, shut down the motors and wait until they stop.

13) Turn off the drone, then the remote control.

⚠	**WARNING**
Prior to flight, you must ensure that the owner of the drone is registered with their national authority (if not already registered), and you must verify that the owner's registration number is on the drone and uploaded to the remote identification system. At the same time, you must read this document.	

8.3 Manual control algorithm

Flow chart diagram of the drone manual control algorithm shows the flight control procedure. At the beginning of the flowchart is the initialization of the system and the drone status check. Next, the operator enters commands for the direction and speed of movement, which are evaluated and converted into corresponding drone actions such as takeoff, landing, forward, backward or sideways movement. The battery status and possible collisions are continuously checked, with the system switching to emergency actions in critical conditions. The cycle repeats until a successful landing and system shutdown.

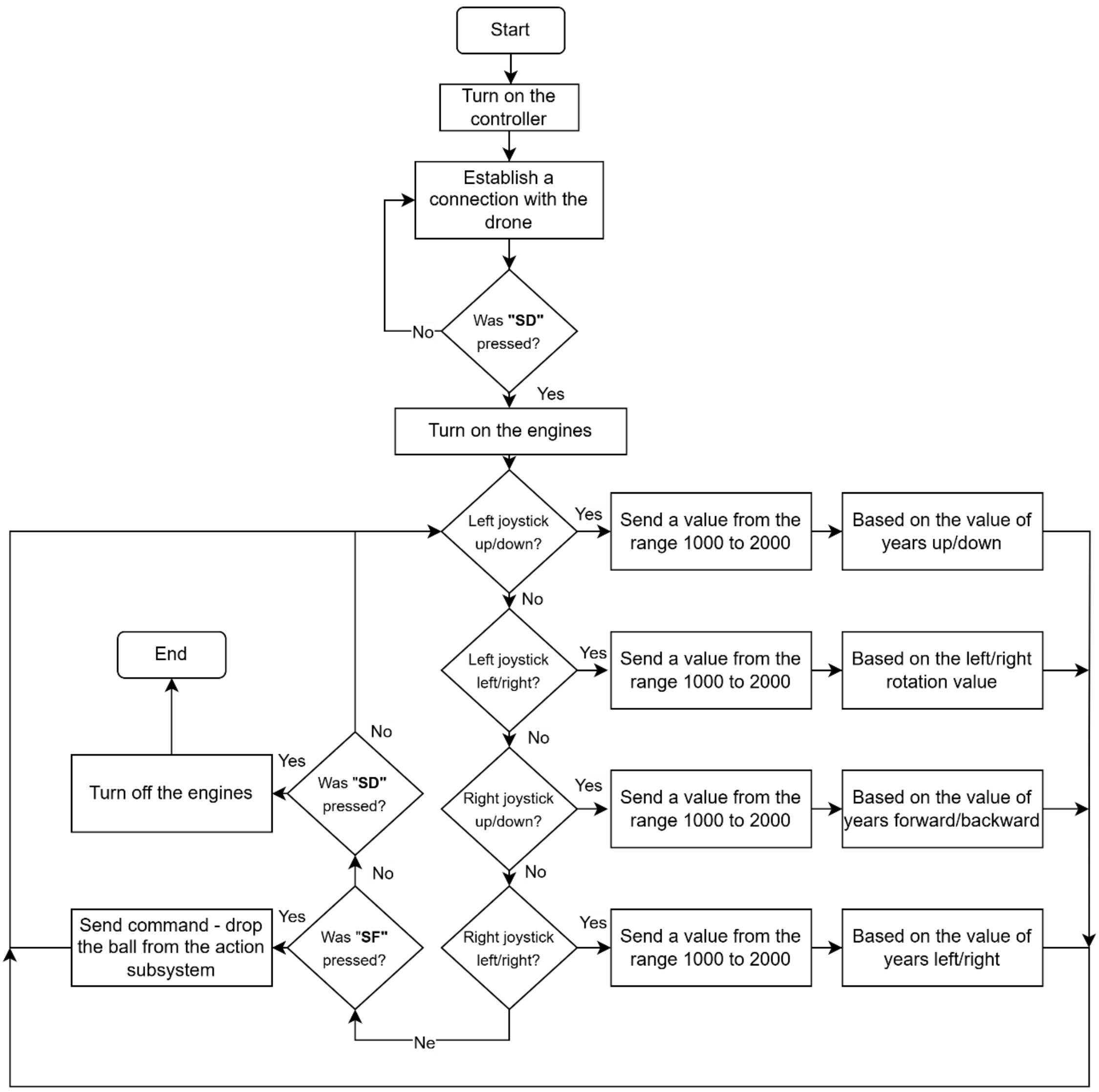


Fig. 8.5 Flow chart diagram of manual drone control

9 AUTONOMOUS CONTROL

This chapter describes the autonomous control of the competition drone. The introduction of the chapter deals with the algorithm of autonomous control, the use of programming languages, etc. Furthermore, a simulation is presented where the autonomous control was designed and tested before being implemented in the system itself. Then the autonomous control program itself is described, including the path generation algorithm and the different states that the program accounts for.

9.1 Autonomous control algorithm

The autonomous control algorithm consists of simulation and real deployment. In the simulation, all new code modifications are tested before they are applied to the real drone. This approach minimizes the risk of non-standard and unexpected program behavior. The drone navigation works on the basis of a blind map, since at the time of writing these sentences it is not possible to automatically generate the map and navigate (SLAM algorithms are not used). The entire program is written in Python, while the route generation is done in C++, which ensures faster computations. Python manages the execution and operation of the C++ code, and once generation is complete, retrieves the results from C++, which it then uses to control the drone.

9.1.1 Autonomous control simulation

Map

The simulation is run on a map created in CoppeliSim Edu that matches the specifications. This map shows a flight area with a height of 5 meters. The starting positions and the individual targets to be shot down with tennis balls are also plotted.

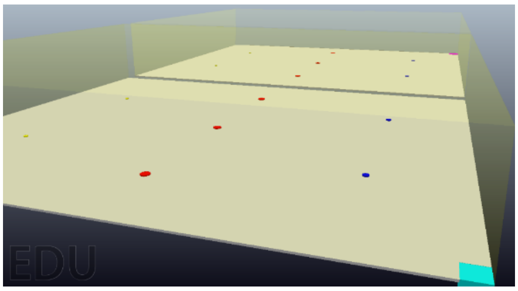


Fig. 9.1 Simulation scene with environment map

A default drone from the simulation environment was inserted into the simulation, which was then modified to match the values of the real drone. In addition, a camera was added to track the targets. See Fig. 9.2.

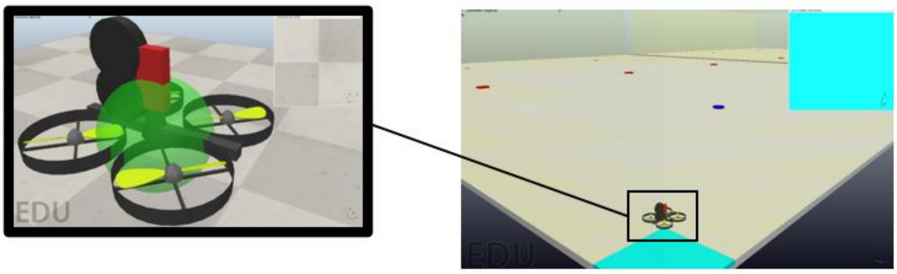


Fig. 9.2 Modified default drone from the simulation environment

Scheme of the whole programme

The diagram shows the scheme of the navigation program. A more detailed description of the individual components is given in the following subheadings.

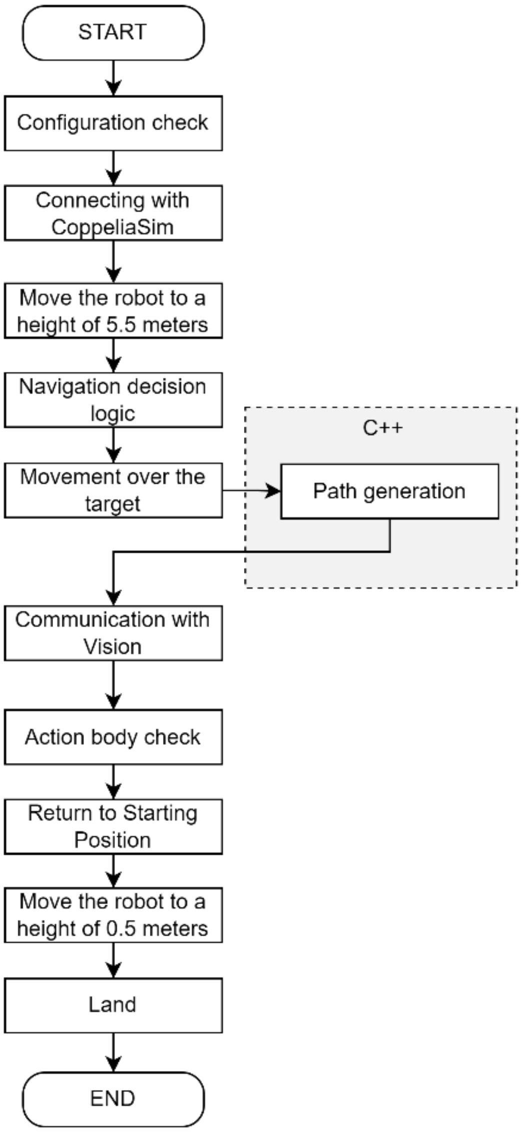


Fig. 9.3 FlowChart diagram of the entire autonomy program

Config check

Each time the drone is launched, it first checks if there is a configuration file in yaml format that contains all the necessary data for autonomous navigation of the drone in the environment. If the yaml file is corrupted or does not exist, the program automatically creates a default configuration file with default values. Otherwise, the current configuration file is loaded, according to which the simulation is then started.

Take-off, landing, movement

The "Move robot (x, y, z)" sub-algorithm is used to move the drone. The key factor for the movement is the knowledge of the movement time, which is used to determine the current position based on odometry. For this reason, the time is restarted at the beginning of the movement, and then a loop (While) is run in which the actual movement is implemented.

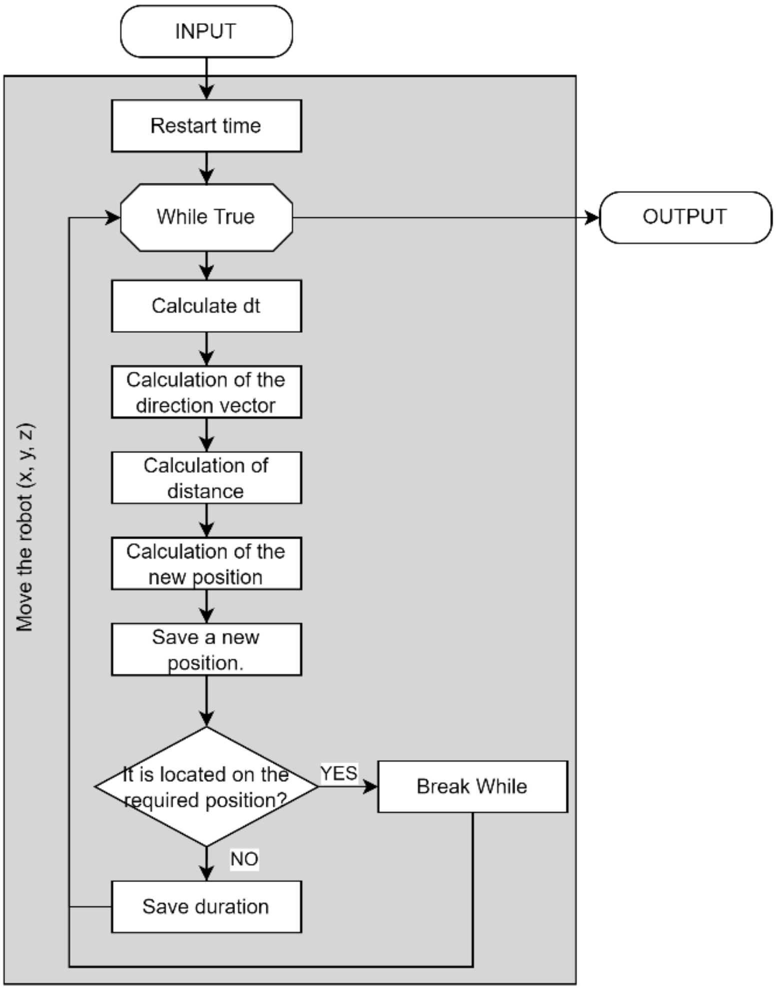


Fig. 9.4 FlowChart diagram for take-off, landing, movement

The logic of navigation decision making

The decision logic is based on an infinite loop that runs until there is a signal from movement over the target, which breaks the loop. In the first phase, all available target coordinates are read from the configuration file. Then all targets are scanned individually. It is checked if the target is no longer in the list of shot down targets, or if a particular colour has not been shot down by the required number. If neither of these conditions is met, the target is entered into the filtered list. After all targets have been checked, the targets in the filtered list are set as not visited. If the filtered list is empty, the loop breaks and the program continues. Otherwise, the algorithm starts moving over the target.

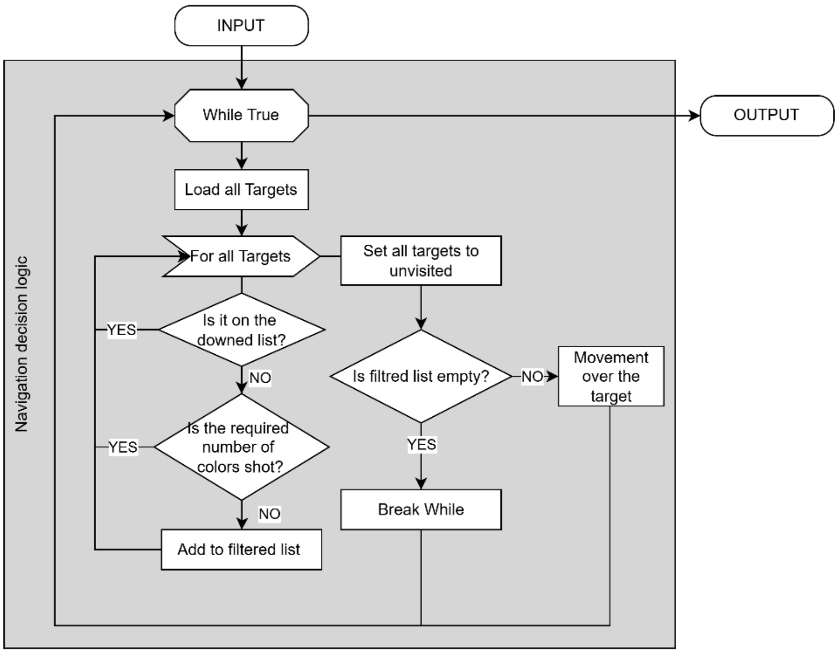


Fig. 9.5 FlowChart diagram for navigation decision logic

Movement over the target

Sub The algorithm for moving over a target is based on a filtered list loop that terminates only when the filtered list is empty. This loop first computes the nearest target and then generates a path according to the selected navigation (e.g. A*, RRT*). Since the path generation is done in C++, it is necessary to load the individual waypoints in Python. For each waypoint, the robot then moves to the next generated waypoint according to the navigation. Once the robot reaches the desired target, it initiates communication with Vision, which is the last part of the filtered list loop.

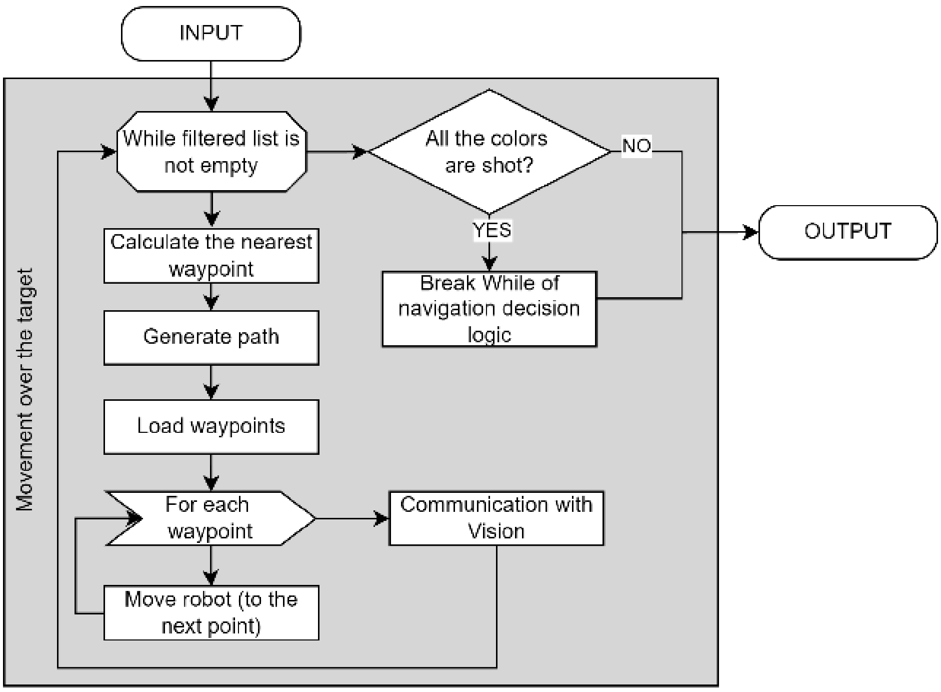


Fig. 9.6 FlowChart diagram for movement over the target

Path generation using A*

Path generation is done in C++ because it is a compiled language, which is much faster than the computation done in the interpreted Python language. The basic structure of the algorithm involves retrieving the data needed for path generation from Python. This is followed by initializing the priority queue using a heuristic computation where the map is divided into a grid, with each point having a cost. The points are ordered in the queue according to this cost, from lowest to highest. A starting point is then initialized, which is rounded to the grid and added to the queue of nodes.

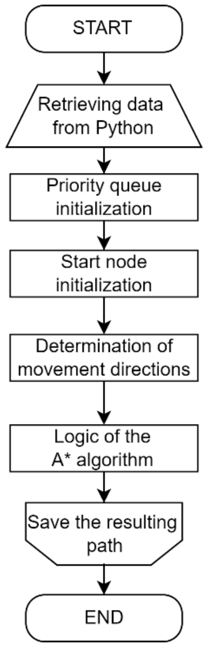


*Fig. 9.7 FlowChart diagram for path generation using A**

It was necessary to determine in which directions the grid could be moved. Vertical, horizontal and diagonal directions were chosen (see figure below). Then the algorithm A* itself is executed to calculate the optimal route. The resulting path is then saved for further processing in Python..

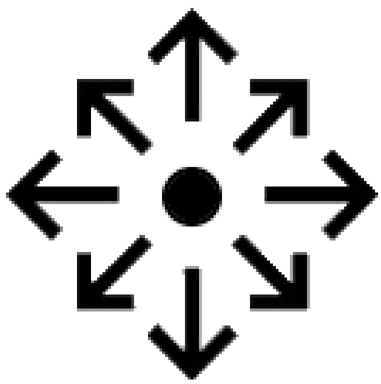


Fig. 9.8 Directions of movement in the

The logic of the A* algorithm is based on a search to find the shortest path between two points in the graph. This algorithm is an optimized method that combines a breadth-first search with information about the distance to the target point, which is a heuristic. In finding the shortest path, the algorithm efficiently traverses the graph and prioritizes the nodes that are likely to lead to the fastest solution. The results are then stored in a file, which is then read by Python.

Path generation using RRT*

Path generation, as already mentioned, is also done in C++, although the RRT* algorithm is used, which allows many times faster calculations than in Python. The main structure of reading data from Python and storing the final path is identical to the A* algorithm, which makes it easier to change the algorithm if necessary.

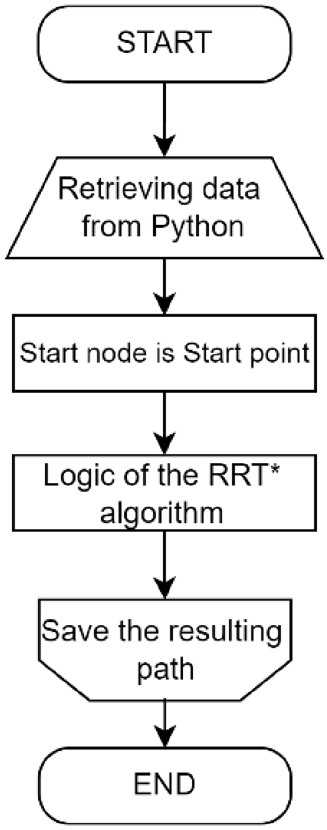


*Fig. 9.9 Path generation using RRT**

Communication with Vision subsystem

When communicating with the Vision module, the color you are looking for is sent to the system. It then waits to receive information about the target, verifying that the target is visible and obtaining information about its position. If the target is not found, a message is displayed indicating that the target is not available and the target is entered into the visited list and removed from the filtered list.

If the target is visible, the robot starts to correct its position relative to the target in the x and y coordinates. A signal is then sent to release the ball from the action subsystem. The target is marked as visited and shot down and removed from the filtered target list. A check is then made to ensure that the required number of targets of a given colour have been shot down to prevent all targets of a given colour from being shot down. Finally, the action subsystem is checked to see if there are any balls left in the hopper.

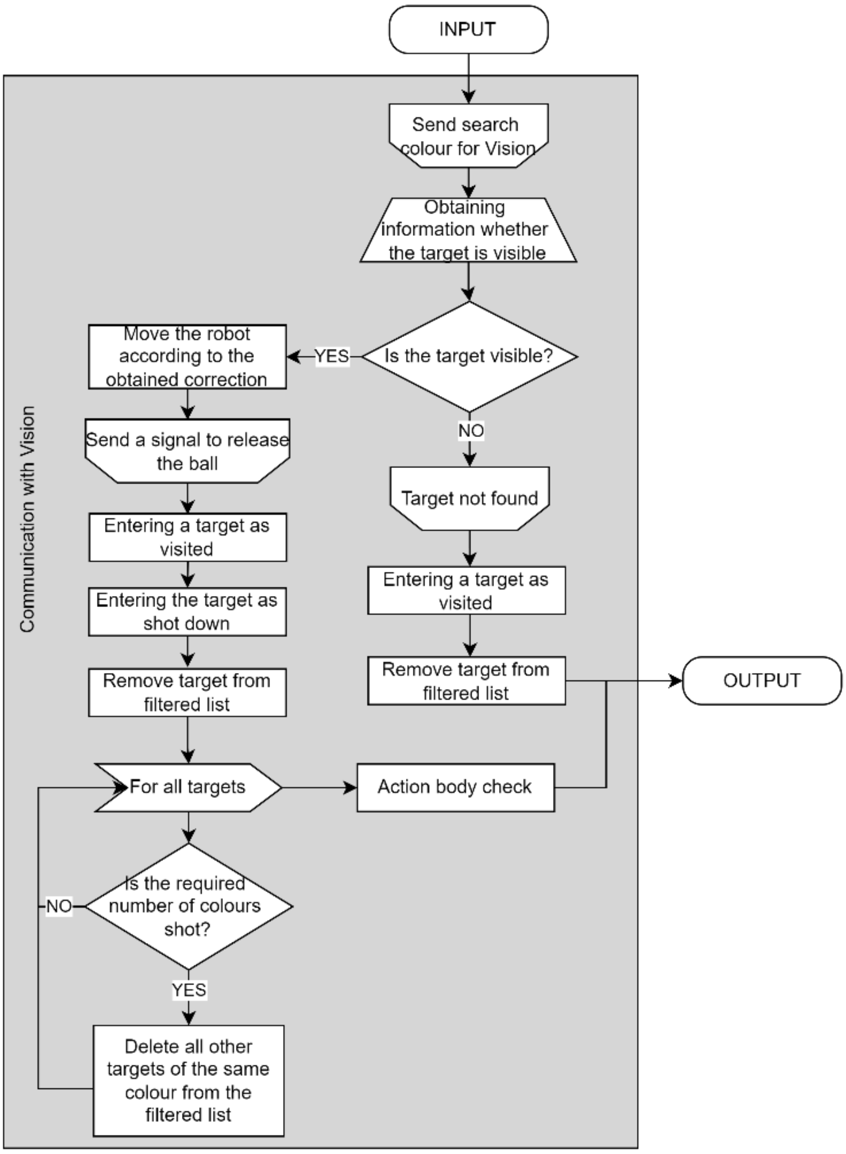


Fig. 9.10 FlowChart for communication with the vision subsystem

Control of subsystem action

Each time a ball is dropped, the program checks if there are still enough balls in the action subsystem. If the hopper is empty, the action subsystem must be refilled. The program then generates a path according to the selected navigation type back to the starting position, retrieves the generated points and moves the robot to this position.

The landing process will then begin. After landing and replenishing the balls, the operator will send the take-off clearance. The program restarts the tray, and the drone automatically takes off to the desired altitude and returns above the last target position where the tray was emptied.

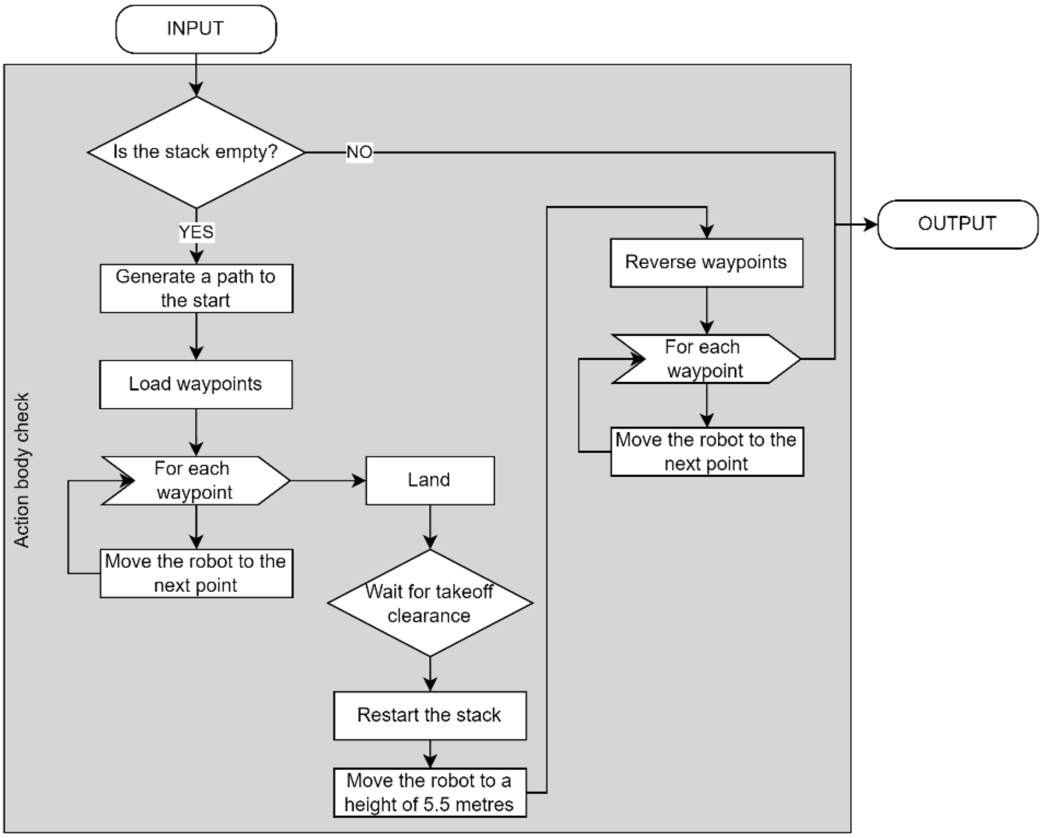


Fig. 9.11 FlowChart diagram for action subsystem control

CONCLUSION

This technical documentation provided a detailed description of the development, architecture and functions of the competition drone, developed by a team from the VŠB-TUO Robotics Department to participate in an international competition held at TDTU in Vietnam. The goal of this project was to create an autonomously controlled drone capable of dropping balls on marked targets with maximum accuracy, which required complex integration of several key subsystems.

The documentation covered in detail the individual subsystems, from the locomotion system ensuring stable and precise movement of the drone, through the action subsystem for ball release, to the vision subsystem and the control subsystem. The power subsystem played a key role in ensuring a sufficient and stable power supply for all components.

Next, the structure of the development team was described, which used modern software tools and simulations to create an efficient drone design plan and optimized its autonomous control. The result is a drone capable of operating in both manual and fully autonomous modes, which was achieved by implementing algorithms such as A* for route planning.

This project represents an important step towards advanced drone autonomy and demonstrates our team's ability to translate theoretical knowledge into practical applications. The results and conclusions from this project provide a solid foundation for the further development of autonomous systems and their use in a wider range of applications.