МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аеронавігації, електроніки та телекомунікацій

Кафедра авіаційних комп'ютерно-інтегрованих комплексів

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач кафедри

В.М. Синєглазов

"______"__21___11_____2022 р.

КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬО-КВАЛІФІКАЦІЙНОГО РІВНЯ

"МАГІСТР"

Тема: "СИСТЕМА УПРАВЛІННЯ ТА МОНІТОРИНГУ ЛІТАЛЬНОГО АПАРАТУ. ПІДСИСТЕМА ФОРМУВАННЯ ПОЛЬОТНОГО ЗАВДАННЯ (КОМПЛ.) "

Виконавець: **Савчук С.Ю.**

Керівник: **д.т.н., професор Синєглазов В.М.**

Консультант з екологічної безпеки: **к.т.н., доцент Явнюк А.А.**

Консультант з охорони праці: **старший викладач Козлітін О.О.**

Нормоконтролер: **к.т.н., професор Філяшкін М.К.**

Київ - 2022

EDUCATION AND SCIENCE MINISTRY OF UKRAINE

NATIONAL AVIATION UNIVERSITY

Faculty of Aeronautics, Electronics and Telecommunications

Aviation computer-integrated complexes department

ADMIT TO DEFENSE
Head of department
Viktor M. Sineglazov
“   ” ____21___11___ 2022

QUALIFICATION WORK

(EXPLANATORY NOTE)

GRADUATE OF EDUCATIONAL AND QUALIFICATION LEVEL

“ MASTER”

THEME: “ CONTROL AND MONITORING SYSTEM OF AN UNMANNED AERIAL VEHICLE. FLIGHT TASK FORMATION SUBSYSTEM (COMPLEX)”

Executor: **Savchuk S.Y.**

Supervisor: **D.t.s., Professor Sineglazov V. M.**

Advisor on environmental protection: **Ph.D., Associate Professor Iavniuk A.A.**

Advisor on labor protection: **Senior Lecturer Kozlitin O.O.**

Norms inspector: **Ph.D., Professor Filyashkin M.K.**

Kyiv - 2022

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аеронавігації, електроніки та телекомунікацій
Кафедра авіаційних комп'ютерно - інтегрованих комплексів

Освітній ступінь: магістр

Спеціальність 151 "Автоматизація та комп'ютерно-інтегровані технології"

Освітньо-професійна програма "Комп'ютерно-інтегровані технологічні процеси і виробництва"

ЗАТВЕРДЖУЮ

Завідувач кафедри

Синєглазов В.М.

" " __21__11__2022 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

Савчука Сергія Юрійовича

1. Тема роботи: «Система управління та моніторингу безпілотного літального апарату. Підсистема формування польотного завдання».

2. Термін виконання роботи: з 19.08.2022р. до 15.11.2022р.

3. Вихідні дані до проекту (роботи): Структурна схема модулів управління польоту БПЛА, інтерфейс побудови польотного завдання, середовище програмування QT/qml

4. Зміст пояснювальної записки (перелік питань, що підлягають розробці):

1. БПЛА та особливості їх застосування 2. Обробка супутникової інформації; 3. Опис системи, структура, принцип дії польотного завдання 4. Опис програмного забезпечення; 5. Електромагнітне забруднення навколишнього середовища при використанні РЛС, ретрансляторів і т. д.; 6. Охорона праці.

5. Перелік обов'язкового графічного матеріалу: Структурна схема БПЛА, графічна реалізація інтерфейсу побудови польотного завдання, структурна схема алгоритму побудови оптимального шляху, схема етапів розробки програмного забезпечення.

6. Календарний план-графік

№ п/п	Завдання	Термін виконання	Відмітка про виконання
1	Аналіз актуальності проблеми	09.08.2022-26.08.2022	
2	Аналіз характеристик безпілотних літальних апаратів та їх застосування	26.08.2022-02.09.2022	
3	Дослідження способів отримання супутникової інформації та аналіз систем дистанційного зондування	02.09.2022-16.09.2022	
4	Дослідження систем керування та моніторингу БПЛА. Розробка структури формування польотного завдання.	16.09.2022-23.09.2022	
5	Розробка та опис програмного забезпечення, використаного для побудови інтерфейсу користувача.	23.09.2022-07.10.2022	
6	Дослідження видів електромагнітного забруднення навколишнього середовища при використанні РЛС, ретрансляторів і т. д.	07.10.2022-21.10.2022	
7	Дослідження охорони праці з питань забезпечення безпеки під час експлуатації електроустаткування	21.10.2022-04.11.2022	
8	Висновки по роботі та підготовка презентації і роздаткового матеріалу	04.11.2022-15.11.2022	

7. Консультанти зі спеціальних розділів

Розділ	Консультант (посада, П. І. Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	Старший викладач, Козлітін О.О,		
Охорона навколишнього середовища	к.б.н., доцент, Явнюк А.А.		

8. Дата видачі завдання _________09_______________08_________2022_____

Керівник: _____ ______ Синєглазов В.М.

(підпис)

Завдання прийняв до виконання: ___ _______ Савчук С. Ю.

(підпис)

NATIONAL AVIATION UNIVERSITY

Faculty of aeronavigation, electronics and telecommunications

Department of Aviation Computer Integrated Complexes

Educational level: master

Specialty 151 “ Automation and computer-integrated technologies”

Educational and professional program “Computer-integrated technological processes and production”

APPROVED BY

Head of department

Victor M. Sineglazov

“ ”__21_11_____ 2022

Graduate Student’s Diploma Thesis Assignment

Savchuk Serhii Yuriyovich

1. The thesis title: ‘Control and Monitoring System of an Unmanned Aerial Vehicle. Flight Task Formation Subsystem’

2.The thesis to be completed between: from 19.08.2022 to 15.11.2022.

3. Output data for the thesis: Structure diagram of UAV flight control modules, interface for building a flight task, QT/qml programming environment

4. The content of the explanatory note (the list of problems to be considered): 1. UAVs and features of their use 2. Processing of satellite information; 3. Description of the system, structure, principle of operation of the flight task 4. Description of the software; 5. Electromagnetic pollution of the environment when using radar, repeaters, etc.; 6. Labor protection.

5. List of compulsory graphic material: Structural scheme of the UAV, graphical implementation of the flight task building interface, the structural scheme of the optimal path algorithm, the scheme of software development phases.

6. Planned schedule:

№	Task	Execution term	Execution mark
1	Analysis of the relevance of the problem	09.08.2022-26.08.2022	
2	Analysis of characteristics of unmanned aerial vehicles and their application	26.08.2022-02.09.2022	
3	Research of methods of obtaining satellite information and analysis of remote sensing systems	02.09.2022-16.09.2022	
4	Study of UAV control and monitoring systems. Development of the structure of formation of a flight task	16.09.2022-23.09.2022	
5	Development and description of the software used to build the user interface	23.09.2022-07.10.2022	
6	Research of types of electromagnetic pollution of the environment when using radars, repeaters, etc.	07.10.2022-21.10.2022	
7	Research on labor protection on issues of ensuring safety during the operation of electrical equipment	21.10.2022-04.11.2022	
8	Conclusions on the work and preparation of the presentation and handout	04.11.2022-15.11.2022	

7. Special chapters' advisors

Chapter	Advisor (position, name)	Date, signature	
		Assignment issue date	Assignment accepted
Labor protection	Senior lecturer, Kozlitin O. O.		
Environmental protection	Ph.D, Associate Professor, Iavniuk V.F.		

8. Date of task receiving: ________________09_______08_________2022_____

Diploma thesis supervisor: _______ _______ Victor M. Sineglazov
(signature)

Issued task accepted: ________ __________ Serhii Y. Savchuk
(signature)

РЕФЕРАТ

Пояснювальна записка до дипломної роботи "Система побудови польотного завдання на основі супутникової інформації. Підсистема організації взаємодії між оператором та БПЛА": 110 с., 47 рис., 3 табл., 18 літературних джерел.

Стимулом до розвитку безпілотної авіації у всьому світі послужила потреба в легких, відносно дешевих літальних апаратах, що володіють високими характеристиками маневреності і здатні виконувати широке коло завдань. Безпілотні літальні апарати (БПЛА) успішно застосовуються в ході військових операцій по всьому світу, і при цьому вони успішно виконують завдання цивільного призначення.

Об'єктом дослідження є системи та підсистеми БПЛА.

Предметом дослідження є вивчення технології побудови польотного завдання на основі супутникової інформації, а також методи удосконалення взаємодії оператора з БПЛА.

Методи дослідження. При вирішенні поставлених задач використовувався метод Калмана, Алгоритм Дейкстри та Алгоритм А* Для математичних розрахунків та моделювання застосовувався фреймворк QT.

Темою дослідження є система побудови польотного завдання з урахуванням супутникової інформації, а також підсистема організації взаємодії між оператором і БПЛА.

Мета дослідження полягає в аналізі системи управління БПЛА, що передбачає вирішення таких **завдань**:

1) розробити інтерфейс взаємодії БПЛА та оператора;

2) визначити найоптимальніші джерела для завантаження супутникових знімків;

3) структурувати отримані супутникові знімки для подальшої побудови польотного завдання;

4) розробити навігаційну панель для відображення ключових метрик БПЛА під час польоту;

5) удосконалити технологію взаємодії оператора із системами БПЛА.

Дослідження має **практичне значення**. Воно може бути використане для виконання завдань безпосередньо пов'язаних з авіаційною сферою, а також для вдосконалення вже існуючих технологій взаємодій оператора з БПЛА.

Актуальність дослідження полягає в тому, що на сьогодні більшість існуючих безпілотних літальних апаратів пілотуються вручну, за допомогою пультів дистанційного керування, що працюють на радіоканалах. При ручному управлінні БПЛА виникають труднощі, пов'язані з підготовкою пілотів, недостатньою робочою дальністю, обмеженнями погодних умов тощо.

БЕЗПІЛОТНИЙ ЛІТАЛЬНИЙ АПАРАТ, СИСТЕМА ПОБУДОВИ ПОЛЬОТНОГО ЗАВДАННЯ, СУПУТНИКОВА ІНФОРМАЦІЯ.

ABSTRACT

Explanatory note to the thesis ‘Satellite-based Flight Management System. A subsystem of the organization of interaction between the operator and the unmanned aerial vehicles (UAV)’: 141 p., 47 fig., 3 tables, 18 references.

The impetus for the development of unmanned aviation over the globe is the need for light, relatively cheap aircraft with high maneuverability characteristics and capability of performing a wide range of tasks. Unmanned aerial vehicles (UAV) are successfully used in military operations around the world, and at the same time they successfully perform civilian tasks.

The object of research: UAV systems and subsystems.

Subject of research: study of the technology of building a flight task based on satellite information, as well as methods of improving the interaction between the operator and UAV.

Methods of research: The Kalman method, the Dijkstra Algorithm, and the A* Algorithm were used to solve the problems of the research. The QT framework was used for mathematical calculations and modeling.

The topic of the research is a system for building a flight task taking into account satellite information, as well as a subsystem for organizing interaction between the operator and UAV.

The purpose of the work consists in the analysis of the UAV control system, which involves solving the following **tasks**:

1) to develop the interaction interface between the UAV and the operator;

2) to determine the most optimal sources for downloading satellite images;

3) to structure the received satellite images for further construction of the flight task;

4) to develop a navigation panel to display key UAV metrics during flight;

5) to improve the technology of operator interaction with UAV systems.

The research has **practical value**. It can be used to perform tasks directly related to the aviation field, as well as to improve already existing technologies of operator interaction with UAVs.

The relevance of the research lies in the fact that today most of the existing unmanned aerial vehicles are piloted manually, with the help of remote controls operating on radio channels. Difficulties arise when piloting a UAV manually, related to pilot training, insufficient operating range, limitations of weather conditions, etc.

UNMANNED AIRCRAFT VEHICLE, FLIGHT MANAGEMENT SYSTEM, SATELLITE INFORMATION.

CONTENT

GLOSSARY

1. UAV is unmanned aerial vehicle.
2. SORP is standards of recommended practice .
3. ANRS is air navigation rules service.
4. RL is radio location.
5. SAR is synthetic aperture radar.
6. DRM is digital relief models.
7. DTM is digital terrain models.
8. OSM is open street map.
9. AUVSI is association for Unmanned Vehicle Systems International.
10. VTOL is vertical takeoff of landing.
11. DSS is distance sensing scanning.
12. GUI is graphical user interface.
13. PC is personal computer.

INTRODUCTION

The impetus for the development of unmanned aviation around the world was the need for light, relatively cheap aircraft with high maneuverability characteristics and capable of performing a wide range of tasks. Unmanned aerial vehicles (UAVs) are successfully used in military operations around the world, and at the same time they successfully perform civilian tasks.

The rapid development of unmanned aerial vehicle technologies in the world, as well as the growing demand for their technologies in the civil and commercial spheres of the world and Ukraine require additional research on the possibilities of their dual use development of the civilian market. To identify potential market opportunities technologies of unmanned aerial surveillance devices on the civilian market research is being conducted to expand the range of work that can be performed to be sought after by a certain group of market consumers and ego segments, evaluation consequences and risk during implementation.

Trends in the development and improvement of unmanned aircraft technology are closely related are connected with the continuation of the processes of structural restructuring of the industry, national priorities for the development of science and technology, the world market situation. The prerequisites for these changes are globalization of the economy, merger processes, interrelationships in the industry, development of information technologies.

Currently, there is an actual problem of safe integration unmanned aerial vehicles into airspace. Stakeholders conduct comprehensive examinations to create protective detection systems and warnings against unintended or illegal interference by drones c frequency sectors, to ensure echeloning relative to other aircraft, to develop a reliable regulatory framework based on the application of Standards of recommended practice (SORP), which are supplemented by air navigation rules service (ANRS), and also conducts medical examinations of crew members UAVs and issue certificates to them.

In this work, we study in detail the characteristics of UAVs, the purpose of their systems, and also develop a user interface for building a flight task using methods for building a route with satellite images included.

CHAPTER I. UAVS AND FEATURES OF THEIR APPLICATION

Unmanned aerial vehicles (UAVs), aerial vehicles without a crew on board, have different degrees of autonomy — from remotely controlled to fully automatic, and also differ in design, purpose, and many other parameters.

1.1 The main characteristics of the UAV

Unmanned aerial vehicles are an unmanned aerial system (UAS), a distinctive feature of which is the absence of a pilot on board. The flight of such a complex can operate with varying degrees of autonomy: using a remote control device; using the automatic piloting system, functioning both on the device itself and on the flight monitoring and control device. Compared to manned aircraft, UAVs are designed to carry out missions that pose a significant danger to people, as well as missions that have an unjustifiably large expenditure of resources to perform primitive actions. Appropriate software can be installed in the UAV to perform various tasks offline, that is, without human intervention.

Currently, the Association for Unmanned Vehicle Systems International (AUVSI) has developed a UAV classification method that, in addition to design features, takes into account many flight characteristics, such as takeoff weight, range, flight altitude and duration, vehicle dimensions, etc. (Table 1.1).

Classification of unmanned aerial vehicles can be made according to various criteria, such as:

- scope of use;
- type of control system;
- flight rules (visual, instrumental and visual-instrumental);
- airspace class (segregated and non-segregated);

- type of wing (airplane, helicopter and tiltrotor);
- takeoff/landing direction;
- type of takeoff/landing;
- engine's type;
- fuel system;
- type of fuel tank;
- number of uses;
- category (taking into account the mass and maximum range);
- radius of action;
- height of use;
- functional purpose.

Table 1.1 UAV classification according to the AUVSI system

UAV Categories	Acronym	Range (km)	Climb rate (m)	Endurance (hours)	Mass (kg)
Micro	μ (Micro)	< 10	250	1	< 5
Mini	Mini	< 10	150-300	< 2	150
Close Range	CR	10-30	3000	2-4	150
Short Range	SR	30-70	3000	3-6	200
Medium Range	MR	70-200	5000	6-10	1250
Medium Range Endurance	MRE	> 500	8000	10-18	1250
Low Altitude Deep Penetration	LADP	> 250	50-9000	0,5-1	350
Low Altitude Long Endurance	LALE	> 500	3000	> 24	< 30
Medium Altitude Long Endurance	MALE	> 500	14000	24-48	1500

1.2 UAVs, their various development trends

Unmanned aerial vehicles are distinguished not only by the way they are used in certain areas of our life or by the difference in design, but also by more stable parameters and characteristics, for example, takeoff weight, range, altitude and duration of flight, the size of the devices themselves, etc.

1.2.1 Classification of UAVs by flight characteristics

Classification UVS International

The International Association for Unmanned Aerial Systems UVSI has proposed a universal classification of UAVs, which combines many of the above criteria.

Table 1.2 universal classification of UAVs

Group	Category	Takeoff weight, kg	Flight range, km	Flight altitude, m	Flight duration, h
Small UAVs	Nano UAV	< 0.025	< 1	100	< 0.5
	Micro UAV	< 5	< 10	250	one
	Mini UAV	20 - 150	< 30	150 - 300	< 2
	Lightweight UAVs to control the front line of defense	25-150	10 - 30	3000	2 - 4
	Light UAVs with a short range	50 - 250	30 -70	3000	3 - 6
	Medium UAVs	150 - 500	70 - 200	5000	6 - 10
Tactical	Medium UAVs with long flight duration	500-1500	>500	8000	10 - 18
	Low-altitude UAVs for penetrating into the depths of enemy defenses	250 2500	>250	50 - 9000	0.5 - 1
	Low-altitude UAVs with long flight duration	15 - 25	>500	3000	>24
	Medium-altitude UAVs with long flight duration	1000-500	> 500	5000-8000	24 - 48
	High-altitude UAVs	2500-5000	> 2000	20000	24 - 48

	with long flight duration				
Strategic	Combat (shock) UAVs	>1000	1500	12000	2
	UAVs equipped with warhead (flying action)		300	4000	3 - 4
	UAV - decoys	150 - 500	0 - 500	50 - 5000	< 4
special purpose	Stratospheric UAVs	> 2500	> 2000	> 20000	> 48
	Exostratospheric UAVs			> 30500	

The above classification today applies to both existing and future developed UAV models. Basically, this classification developed by 2000, when unmanned aerial vehicles were just gaining popularity, but since then it has been revised many times. Even now it cannot be considered established. In addition, many special types of devices with non-standard combinations of parameters are difficult to attribute to any particular class.

There are the following types of UAVs, differing in design and principle of operation, takeoff / landing and purpose:

- aircraft-type UAV;
- Multirotor UAVs;
- Aerostatic UAV;
- Unmanned tiltrotor and hybrid models.

Let's look at each of these types below.

aircraft-type UAV

This type of aircraft is also known as a rigid wing UAV. The lift force they have is created aerodynamically due to the pressure of air flowing onto the fixed wing. As a rule, devices of this type are distinguished by a long flight duration, a large maximum flight altitude and high speed.

There is a wide variety of subtypes of aircraft-type UAVs, differing in the shape of the wing and fuselage. Almost all aircraft layouts and fuselage types that are found in manned aviation are also applicable to unmanned aircraft.

Fig. 1.1 - Proteus aircraft

On fig. 1.1 shows an experimental multi-purpose aircraft Proteus developed by the American company Scaled Composites. Both manned and unmanned versions of this aircraft have been developed. A design feature is the tandem arrangement of the wings. Its length is 17.1 m, the rear wingspan is 28 m, the ceiling height is 16 km (with a load of 3.2 tons), the takeoff weight is 5.6 tons, the maximum speed is 520 km/h (at an altitude of 10 km), the flight duration is up to 18 hours Power plant - two turbojet engines with a thrust of 10.2 kN.

Fig. 1.2 - UAV RQ-4 Global Hawk

On fig. 1.2 shows the RQ-4 Global Hawk reconnaissance UAV, developed by the American company Teledyne Ryan Aeronautical, a subsidiary of Northrop Grumman. It is distinguished by an unusual shape of the fuselage, in the bow of which radar, optical and communications equipment is located. The device is made of composite materials based on carbon fiber and aluminum alloys, has a length of 13.5 m, a wingspan of 35 m, a takeoff weight of about 15 tons, and is capable of carrying a payload of up to 900 kg. The RQ-4 Global Hawk can stay in the air for up to 30 hours at an altitude of up to 18 km. The maximum speed is 640 km/h. The power plant is a turbojet engine with a thrust of 34.5 kN.

Fig. 1.3 - UAV Kh-47V

On fig. 1.3 shows a promising combat deck UAV X-47B, developed by Northrop Grumman (USA). It is shaped like a broadly curved "V" without a tail. The wings can be folded, which is important for the limited deck area of an aircraft carrier. For flight control, the UAV is equipped with 6 working planes. Turbojet engine of the Canadian company Pratt amp. Whitney provides high speed flight of the unmanned vehicle and is located at the rear of the vehicle. The drone consists of four parts, assembled from composite materials and connected approximately in the middle of the body. The aircraft has a length of 11.6 m, a wingspan of 18.9 m (9.4 m when folded), a curb weight of 6.3 tons, and a maximum takeoff weight of 20.2 tons. The cruising speed is 900 km/h. Range 3900 km. Ceiling 12.2 km. Presumably the device will be adapted for refueling in the air. At the same time, the UAV will be ready, if necessary, continuously longer than the duration of the flight of combat aircraft with pilots.

As propellers for aircraft-type devices, pulling or pushing propellers are usually used, as well as impellers (blade machines enclosed in a cylindrical casing - English: impeller, ducted fan, shrouded propeller) or jet engines.

Aircraft-type vehicles usually require a runway (runway) or launch catapults (Fig. 1.4). There are also light-class aircraft UAVs launched "by hand". When landing, a runway, a parachute or special traps (cables, nets or stretch marks) can be used.

Fig. 1.4 - Starting catapult

Takeoffs and landings of traditional aircraft-type UAVs are a rather laborious and costly process that requires special aids (runways, launch and landing devices), so the developers of new technology are increasingly turning to non-traditional schemes of aircraft UAVs, which make it possible to create non-aerodrome unmanned systems. We are talking primarily about vertical takeoff and landing (VTOL) aircraft. To date, there are many varieties of GDP devices. Many of these are airplane/helicopter hybrids and are discussed in the next section. The same VTOL aircraft, which are more inherent in the properties of an aircraft than a helicopter, usually have a jet engine, an impeller or small propellers as a propulsor.

Tailsitters in the starting position usually rest with their tail on the ground. If pulling screws are used as a propeller, then they are located in the bow (Fig. 1.5). Landing, as well as takeoff, for such devices is usually carried out vertically. The most difficult thing for VTOL aircraft is the transition from the vertical phase of flight to the horizontal and vice versa. The SkyTote UAV shown in Figure 1.6, for example, even uses a special neural network controller to control the flight in these phases.

Fig. 1.5 - SkyTote UAV

There is a special type of UAV - a device with a rigid umbrella-shaped wing, based on the Coanda effect. Although these devices bear little resemblance to airplanes, in terms of the principle of flight, they nevertheless most closely correspond to this classification group.

Multi-rotor (helicopter) systems

One of the most popular UAVs is the multicopter. This group includes UAVs with more than two rotors. The reaction moments are balanced by rotating the rotors in pairs in different directions or by tilting the thrust vector of each screw in the desired direction. Unmanned multicopters, as a rule, belong to the classes of mini- and micro-UAVs.

The main purpose of multicopters is photo and video shooting of various objects, so they are usually equipped with controllable camera gimbals. Multicopters are also used as devices for real-time monitoring of the situation, for agricultural work (for example, spraying), for the delivery of light loads.

Tricopter is the simplest scheme for building multicopters (Fig. 1.7). Typically, a tricopter moves with two propellers forward, and the third is tail. The first two screws have opposite directions of rotation and mutually compensate for reactive twisting moments, while the tail rotor does not have a pair, therefore, to compensate for its reactive moment, the axis of rotation of this screw is slightly tilted in the direction opposite to the direction of twisting. This is done with the help of a special servo and thrust, which are used to stabilize or control the position of the device along the course.

Fig. 1.7 - Tricopter

A quadcopter is the most common multicopter construction scheme. The presence of four rigidly fixed rotors makes it possible to organize a fairly simple scheme for organizing movement. There are two such movement patterns: the "+" pattern and the "x" pattern. In the first case, one of the rotors is the front, the opposite is the rear, and two of the rotors are side. In the "x" scheme, two rotors are simultaneously front, the other two are rear, and displacements in the lateral direction are also implemented simultaneously by a pair of corresponding rotors. The propeller speed control algorithm for the “+” scheme is somewhat simpler and clearer than for the “x” scheme, however, the latter is still used more often due to its design advantages: with such a scheme, it is easier to place the fuselage, which can have an elongated shape, the onboard video camera has freer view.

Hexacopters and octocopters, having 6 and 8 motors respectively, have a much higher carrying capacity compared to quadrocopters. They are also capable of maintaining stable flight when one engine fails. Such devices are also distinguished by a much lower level of vibrations, which is especially important for video shooting.

Unmanned convertiplanes and hybrid schemes

Hybrid rotorcraft - gyroplanes and convertiplanes. In addition to the considered classes of aircraft and multi-rotor vehicles, there are their hybrid varieties, such as gyroplanes and tiltrotor aircraft, which have some features of both helicopters and aircraft.

Autogyro (other names: gyrocopter, gyroplane, rotaplane, English: autogiro, gyrocopter, gyroplane, rotoplane) - a scheme similar to an airplane, which has a freely rotating propeller as a wing (or in addition to it) (Fig. 1.8).

Fig. 1.8 - Autogyro

Like a helicopter, a gyroplane needs a main rotor to generate lift, but the main rotor of a gyroplane uses a different principle to generate lift. It creates a virtual disk surface, when an oncoming air flow runs into it, a lifting force is created. It is essential here that in flight this propeller is tilted back, against the flow - like a fixed wing with a positive angle of attack (a helicopter, on the contrary, tilts the propeller in the direction of motion, since it creates both lifting and horizontal propulsion forces by the driven main rotor at the same time). In addition to the main rotor, the gyroplane also has a pulling or pushing main propeller (propeller), like a conventional aircraft. This main propeller informs the gyroplane of horizontal speed.

Most gyroplanes cannot take off vertically, but they require a much shorter takeoff run (10-50m, with pre-rotation) than airplanes. Almost all gyroplanes are capable of landing without a run or with a run of only a few meters. In terms of maneuverability, they are between airplanes and helicopters, somewhat inferior to helicopters and absolutely superior to airplanes. Autogyros are superior to airplanes and helicopters in flight safety. It is dangerous for the aircraft to lose speed, as it falls into a tailspin. The gyroplane begins to descend when it loses speed. In the event of an engine failure, the gyroplane does not fall, instead it descends (plans) using the autorotation effect (in the event of an engine failure, the main rotor of the helicopter is also switched to autorotation mode, but several seconds are lost and the rotor speed drops, which are important during a forced landing).

The speed of an autogyro is comparable to the speed of a light helicopter and somewhat inferior to a light aircraft. In terms of fuel consumption, they are inferior to airplanes, the technical cost of a flight hour of a gyroplane is several times less than that of a helicopter, due to the absence of a complex transmission. Typical gyroplanes fly at speeds up to 180 km/h), and fuel consumption is 15 liters per 100 km at a speed of 120 km/h. Other advantages of gyroplanes are much less vibration than in helicopters, as well as the ability to fly in significant (up to 20 m/s) wind.

A tiltrotor (English: convertiplane, heliplane) is an aircraft with rotary propellers, which work as lifting during takeoff and landing, and as pulling in horizontal flight (while in flight the lifting force is provided by an aircraft-type wing). Thus, this device behaves like a helicopter during takeoff and landing, but like an airplane in level flight. The large tiltrotor propellers help it in vertical takeoff, but in level flight they become less efficient compared to the smaller diameter propellers of traditional aircraft.

Among convertiplanes, three fundamentally different subclasses can be distinguished: devices with rotary screws (Tiltrotor), with a rotary wing (Tiltwing) and with a free wing (Freewing).

In convertiplanes with rotary rotors, it is usually not the propellers themselves that are rotary, but the nacelles with propellers and engines. The wings (usually of a small area) remain motionless. On fig. 1.9 shows an example of an unmanned tiltrotor of the Tiltrotor type.

Fig. 1.9 - Tiltrotor

In convertiplanes with a rotary wing, the entire wing rotates along with the engines and propellers installed on it. The advantage of such a scheme is that during vertical takeoff, the wings do not block the air flow from the propellers (thus increasing the efficiency of the propellers).

1.2.2 Classification by control method

Unmanned aerial vehicles can also be qualified by the method of control. There are three types of them:

1. Remotely piloted aircraft (RPV). This category includes UAVs entirely controlled by the operator from the ground. The most common type of UAV control is signal transmission over a radio frequency channel, but due to the possible presence of a large number of both induced and natural interference in this range, this method of control is the least reliable, so now the 5G channel is increasingly used to guide the actions of small UAVs. RPVs with a long range are usually controlled via satellite channels, while drones operating in a direct line of sight can be controlled via various optical communication channels.

2. Automatic UAVs with a fully autonomous control system. Since such devices perform a programmed flight task, they need to have a built-in microprocessor, preferably equipped with neural network algorithms. Another condition, without which it is impossible to independently navigate the UAV in flight, is the availability of onboard navigation equipment. Most often, its role is played by one or two GNSS antenna receivers, which provide a satellite signal with coordinates refined by RTK

(Real Time Kinematic). However, in case of loss of communication with the satellite, it is also recommended to include an inertial measurement unit (IMU) in the navigation complex, which allows you to maintain the accuracy of the course offline. An example of such an integrated navigation system is the BW-GI100/200 (Fig. 1).

Fig. 1.10 - Integrated navigation system based on MEMS components BW-GI100/200

A hybrid UAV control system, when the operator from the ground can at any time connect to the control of an autonomous UAV or when, on the contrary, the UAV, which for some reason has lost contact with the operator, is able to continue flying in automatic mode. Typically, medium and heavy UAVs with a long range have such a backup control system.

1.2.3 Classification of UAVs according to their design features

If we resort to the classification of UAVs according to their design features, then we can distinguish the following types:

- Fixed-wing aircraft UAVs;
- Unmanned helicopters (single-rotor coaxial UAVs);
- Multicopters (UAVs with several opposed engines);
- UAV with a hybrid design, i.e. devices that combine different design principles.

Next, we will talk about each type of drones in more detail.

Multicopters (multirotor UAVs)

Multicopters have become widespread due to the emergence of compact and sufficiently powerful rotary-type electric motors. The minimum number of such propellers for a stable UAV flight is three engines (tricopter), while the maximum number of engines is practically unlimited (there are models with more than 30). However, drones with four engines (quadcopters) are the most popular, due to the simplicity and convenience of their control.

In addition to ease of control, the absolute advantages of multirotor UAVs include their relatively low cost, the possibility of vertical takeoff from any unprepared site and the ability to hover over a ground object if necessary, as well as high positioning accuracy. The main disadvantages are low speed, high energy consumption, limited range, insufficient carrying capacity and short flight time (usually within an hour).

Unmanned aircraft

Fixed-wing UAVs are considered the oldest and fastest type of drones. They are also distinguished by their long range and high flight duration, so most medium and heavy UAVs are precisely aircraft-type drones with a classic aerodynamic plumage scheme.

However, even compact samples of unmanned aircraft require a specially equipped place for takeoff and landing (either a runway or a starting catapult and a parachute system), and their remote control requires the operator to have serious piloting skills.

Unmanned helicopters

Another classic type of UAV are single-rotor drones, which, like manned helicopters, come with coaxial propellers, or in addition to one main propeller, they can be equipped with an additional stabilizing propeller on the tail. These UAVs traditionally have high speed and good heading stabilization. Unmanned helicopters are also distinguished by the fact that almost any type of engine can be installed on them (DVR, gas turbine or electric motor, as well as hybrid installations). The downside in the operation of helicopter UAVs can be their complex aerodynamic design, high energy consumption and large dimensions of the lead screw, which go beyond the dimensions of the aircraft itself.

UAV hybrid design

The most famous type of hybrid drone is the so-called. "Vtol", which combines the design principles of an aircraft and a quadcopter:

Such a UAV has the advantages of vertical takeoff due to the presence of four additional engines located under the wing plane (two on each side) and at the same time it can develop serious speed in flight due to the aerodynamic design of a fixed wing aircraft.

In addition, there are many other hybrid UAV systems. Here are just a few of them:

A hybrid of an unmanned helicopter and an aircraft (tailsitter);

Coleopter (ring plane) - UAV with an annular closed wing, which allows you to increase the angles of attack and maneuverability of the drone, as well as improve the ratio of takeoff weight and payload;

UAV based on the Coanda effect (umbrella), in addition to unprecedented maneuverability, such a drone has no moving parts, which allows it to effectively bypass closely spaced obstacles;

A UAV with a flexible wing (paraglider), as you know, the gliding effect during free flight can provide significant savings in engine energy;

Aerostatic UAV (unmanned airship), which is quiet and has a high payload;

UAV with a flapping wing (ornithopter) imitating the flight of a bird, due to which high energy efficiency is achieved.

And although so far most of the development of hybrid UAVs exist only in the form of prototypes, in the future they may well find a worthy application in various fields of human activity.

CHAPTER II. PROCESSING OF SATELLITE INFORMATION

2.1 Methods of obtaining satellite images for building a flight task

There are two directions for obtaining spatial information about the Earth's surface from space: imaging in the visible and infrared wavelength ranges of electromagnetic waves (optical-electronic systems) and imaging in the centimeter radio range (radar systems).

2.1.1 Optical-electronic sensing

Optical-electronic satellite systems for remote sensing of the Earth (DSS) make it possible to obtain spatial information about the Earth's surface in the visible and infrared ranges of electromagnetic wavelengths (Fig. 2.1). They are able to recognize the passive reflected radiation of the earth's surface in the visible and infrared ranges. In such systems, the radiation falls on the appropriate sensors that generate electrical signals depending on the intensity of the radiation.

As a rule, sensors with continuous row scanning are used in optical-electronic systems of DZZ. Linear, transverse and longitudinal scanning can be distinguished.

The full angle of scanning across the route is called the viewing angle, and the corresponding value on the Earth's surface is the width of the survey strip. Part of the data stream received from the satellite is called a scene. Schemes of slicing the flow into scenes, as well as their size for different satellites, have differences.

Optical-electronic systems of DZZ carry out imaging in the optical range of electromagnetic waves.

Fig. 2.1 - Optical picture

Panchromatic images occupy almost the entire visible range of the electromagnetic spectrum (0.45-0.90 μm), so they are black and white.

Multispectral (multizone) imaging systems form several separate images for wide spectral zones in the range from visible to infrared electromagnetic radiation. Multispectral data from new-generation spacecraft, including RapidEye (5 spectral zones) and WorldView-2 (8 spectral zones), are of greatest practical interest.

Satellites of the new generation of high and ultra-high resolution, as a rule, shoot in panchromatic and multispectral modes.

Hyperspectral systems form images simultaneously for narrow spectral zones in all parts of the spectral range. For hyperspectral imaging, the important thing is not the number of spectral zones (channels), but the width of the zone (the smaller, the better) and the sequence of measurements. So, a shooting system with 20 channels will be hyperspectral if it covers the range of 0.50-070 μm, while the width of each spectral zone is no more than 0.01 μm, and a shooting system with 20 separate channels that cover the visible region spectrum of the near, short-wave, medium- and long-wave infrared regions will be considered multispectral.

Spatial resolution is a value characterizing the size of the smallest objects visible in the image. Factors affecting the spatial resolution are the parameters of the optical-electronic or radar system, as well as the height of the orbit, that is, the distance from the satellite to the object being photographed. The best spatial ability is achieved when shooting at the nadir, when deviating from the nadir, the resolution deteriorates. Space images can have low (more than 10 m), medium (from 10 to 2.5 m), high (from 2.5 to 1 m), and ultra-high (less than 1 m) resolution.

Radiometric resolution is determined by the sensitivity of the sensor to changes in the intensity of electromagnetic radiation. It is determined by the number of color gradation values corresponding to the transition from the brightness of absolutely "black" to absolutely "white", and is expressed in the number of bits per pixel of the image. This means that in the case of a radiometric resolution of 6 bits/pixel, we have only 64 color gradations, 8 bits/pixel – 256 gradations, 11 bits/pixel – 2048 gradations.

2.1.2 Radar sounding

Radar (RF) surveying (Fig. 2.2) is a type of aerospace surveying carried out by a radar - an active microwave sensor capable of emitting and receiving polarized radio waves scattered by the earth's surface in certain wavelength ranges (frequencies) specified by the Radio Regulations (Table 2.2) . The return signal carries information about the physical and geometric properties of the probed surface.

Radar space imaging is performed in the ultra-short-wave (ultra-high-frequency) region of radio waves. The radar directs a beam of electromagnetic pulses to the object. Part of the pulses is reflected from the object, and the sensor measures the characteristics of the reflected signal and the distance to the object. All modern space-based radar systems (SAR) are synthetic aperture radars.

Radar emits its own signal of a certain frequency and registers it (unlike optical sensors that register reflected solar radiation), and therefore does not depend on illumination. Radio waves in the centimeter range penetrate through clouds, so radar images do not depend on cloudiness either.

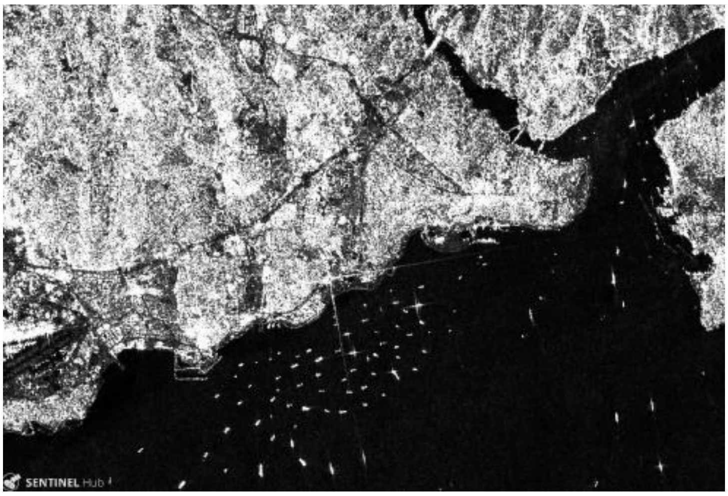

Fig. 2.2 - Radar image

Table 2.2. Ranges of wavelengths and frequencies for radar sounding of the Earth

Marking	Wavelength range, cm	Frequency range, GHz
Ka	0.75-1.18	0.75-1.18
K	1.19-1.67	1.19-1.67
Ku	1.67-2.4	18.0-12.5
X	2.4-3.8	12.5-8.0
C	3.9-7.5	8.0-4.0
S	7.5-15.0	4.0-2.0
L	15.0-30.0	2.0-1.0
P	30.0-100	1.0-0.3

Most spaceborne radar systems operate at wavelengths between 0.5 and 75 cm in the ranges below.

X-band: 2.4 to 3.75 cm (12.5 to 8 GHz). Data in this range are widely used to solve military intelligence tasks and a wide range of civilian tasks, including the study and classification of glaciers.

C-band: 3.75 to 7.5 cm (8 to 4 GHz). Data of this range are most widely used to solve a large number of tasks in the civil sector, including the construction of digital terrain models (DTM) and digital relief models (DRM), monitoring of landslides on the earth's surface.

S-band: 7.5 to 15 cm (4 to 2 GHz). The range is interesting for a number of military and civilian tasks.

L-band: 15 to 30 cm (2 to 1 GHz). Vegetation shines through, including a not very dense forest. Radiation of this range can partially (up to a depth of several meters) penetrate dry snow, ice, and dry soil.

P-band: 30 to 100 cm (1 to 0.3 GHz). Translucent vegetation, including dense, dry soil, dry snow, ice to a depth of several meters. Used to estimate biomass. Implemented only on aircraft carriers. The penetrating power of radar beams increases with increasing wavelength. Radars with wavelengths longer than 2 cm can see through clouds, but rain and snow are serious obstacles for radar systems with wavelengths up to 4 cm.

Interferometric processing of pairs and series of images in order to determine subsidence of the Earth's surface is one of the unique and promising directions in the use of radar images. Radar interferometry is a measurement method that uses the effect of interference of electromagnetic waves. The technique of interferometric processing of radar data involves obtaining several coherent measurements of the same area of the earth's surface with a spatial shift of the receiving antenna of the radar.

Remote sensing of the Earth in the radio wave range has a number of fundamental differences from other types of surveying:

- radar imaging uses much longer wavelengths than optical imaging; these waves are almost not absorbed or scattered by clouds, which allows you to obtain images of the earth's surface and objects located on it, almost regardless of meteorological conditions;

- the principle of active shooting allows you to receive radar images regardless of sunlight, that is, the radar is a means of round-the-clock surveillance; especially this feature of radar surveying is important for obtaining information about subpolar latitudes, where the polar night phenomenon is observed for a significant part of the year;

- the obtained shooting materials carry information about such components of the signal as amplitude and phase; differences in signal amplitude make it possible to recognize objects or their properties from radar images; the phase component with special types of shooting and further processing (radar interferometry) allows obtaining information about the height of the surface or its shifts, as well as about the speed of movement of objects;

- radar surveying uses such a property of waves as polarization, which is determined by the direction of the electric field intensity vector in a plane perpendicular to the direction of wave propagation; usually in RL sounding, linear polarization of the radiated signal is used (horizontal - Γ or vertical - B), and reception of the return signal can be carried out on agreed polarizations (in this case, the abbreviations ΓΓ and BB are accepted) or on crossed ones (ΓB, BΓ); radar surveying can be carried out with a different set of polarization channels - with one, two or four; recently there are options for shooting in compact and hybrid polarization modes, when radiation uses linear polarization with an orientation angle of 45º or circular (right or left) polarization, respectively, and a horizontally and vertically polarized signal is received; differently polarized waves interact with terrain objects in different ways, mainly depending on their orientation relative to the incident wave and internal structure; it is noted that the return signal in matched polarizations is usually higher than in crossed ones, and in the absence of distorting factors, the combinations of HV and HV are the same; an example of images obtained simultaneously in different polarizations is shown in Figure 1.3.

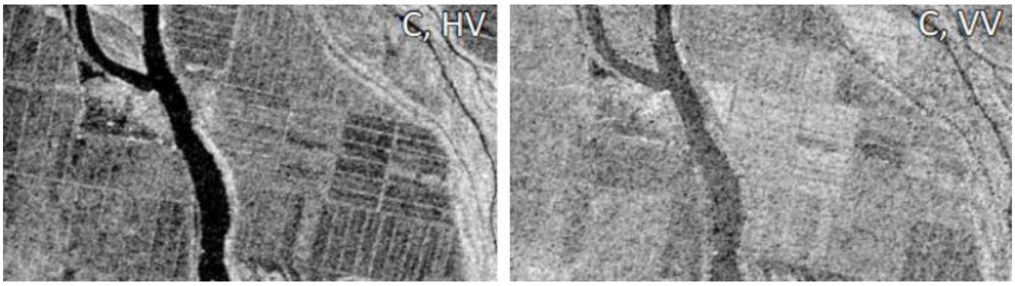

Fig. 2.3 - Radarsat-2 radar images in different polarizations

- the nature of radar images is influenced by the properties of probed objects that are not detected in images obtained in other ranges of the electromagnetic spectrum: the smoothness of the surface and its dielectric properties; as a rule, the value of the return signal (and, accordingly, the brightness on the RL image) increases with an increase in the size of surface irregularities and relative dielectric constant;

- in some cases, subsurface objects are detected on radar images; as a rule, the penetrating ability of the signal increases with increasing wavelength;

- the display of objects on radar images is influenced by their orientation in relation to the direction of radiation, the internal structure of these objects, which collectively lead to the formation of various wave scattering mechanisms; with one-time scattering, the waves are mirrored away from the radar, with three-dimensional scattering, radio waves are repeatedly reflected from parts of objects, as a result of which some part of the radiation is returned to the radar; double scattering occurs when the wave is reflected twice: from vertically and horizontally oriented objects, as a result of which a significant part of the radiation is returned to the radar; as a rule, objects characterized by single scattering have the lowest brightness on radar images,

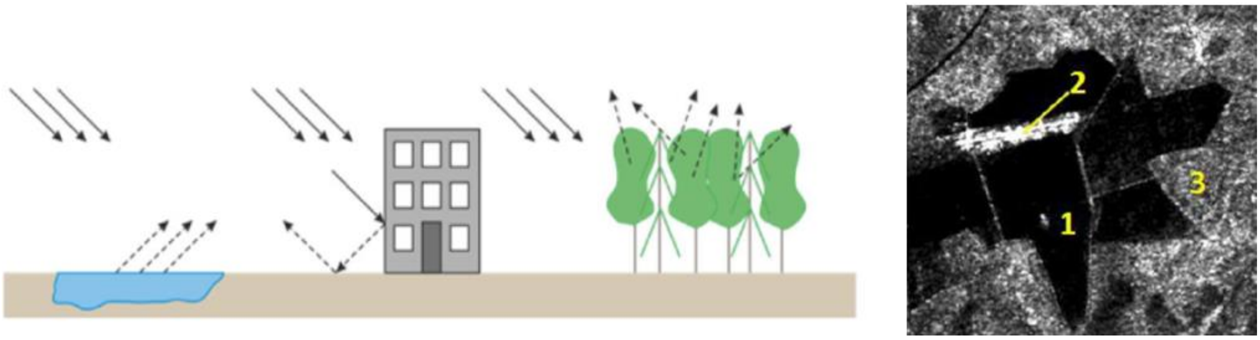

Fig. 2.4 - The main mechanisms of radio wave scattering: schematic representation and display on a radar image

- radar images have specific radiometric and geometric features; radiation generated by synthetic aperture radars (SAR; currently, space radar imaging is carried out by this type of equipment) is coherent, and after reflection from the earth's surface, the coherent waves interfere, which leads to a weakening or strengthening of the amplitude of the signal that appears on the image as a grain called speckle noise.

On the one hand, the variety of signal parameters recorded by the radar, a large number of terrain properties affecting the return signal, the specificity of the images themselves cause some difficulties in the use and perception of radar data. On the other hand, data of this kind can provide new information about the terrain, unavailable when using images in the light range, which opens up new opportunities for geographical research and mapping.

An important trend in the development of satellite radar systems, in addition to increasing the spatial resolution and increasing the number of shooting modes, is the expansion of polarization capabilities, especially simultaneous shooting in four polarizations. A unique feature of fully polarimetric data is the ability to classify objects in the image based on the physical type of display.

2.2. Problems of processing satellite images

The process of gluing images is complicated by the following situations:

- the presence of different types of objects in the images;
- the presence of shifts in satellite images for different dates and with different sensors;
- different weather conditions during shooting; bad weather conditions;
- partial overlap of the image;
- partial hitting of objects in frames;
- image of the object at different angles from different distances.

Remote sensing data contain a number of random, systematic and systematic distortions associated with the influence of the atmosphere, the curvature of the Earth and the movement of the camera relative to its surface at the time of shooting, the physical characteristics of the used sensors and communication channels. To eliminate the mentioned, quite numerous distortions, taking into account their specificity, correction of several types is used: atmospheric, radiometric, geometric and calibration. There are different combinations of distortion causes for different types of space imagery.

Let's consider the causes of distortion below.

The curvature of the Earth's surface. Geometrical distortions of the images caused by the curvature of the Earth's surface result from the fact that the points of the terrain being scanned do not lie in the same plane and the observation is not at nadir, but at an angle to the Earth's surface. Therefore, when moving away from the central line of scanning (where the shooting is conducted at the nadir), the distortion of the shape and size of objects increases.

Distortion of the shape of objects. A straight line on the terrain will be a curve on the picture, a square will be a rectangle, etc. This type of distortion can be neglected if the viewing angle of the scanner is small (MSS - Landsat, viewing angle approximately 5.8).

Scale distortion. For pictures taken with an optical-mechanical scanner

(MODIS, AVHRR, ETM and MSS - Landsat, Aster (TIR)) – the scale becomes smaller as you move away from the center line of the image. That is, if you take two pixels of the image: one from the central area of the image, and the other from the side, then the pixel from the side area will contain a large area of the Earth, although their size is the same. For images (SPOT satellites, IRS, Ikonos, Aster sensor (VNIR, SVIR), the scale does not change when removed from the center line of the image.

Uneven terrain. Terrain irregularities cause the same distortions as the curvature of the earth's surface, but the task of eliminating them is more difficult, due to the fact that landforms are more complex than the shape of the Earth, which is close to a sphere.

Since space photographs are taken from a great height, the influence of landforms is insignificant, so this type of distortion is taken into account only for mountainous areas.

Rotation of the Earth. Scanning the Earth from space does not happen instantly, like photography, so the rotation of the Earth (in 1 minute the Earth rotates by 0.25o) causes a change in the shooting conditions during the scanning of one scene.

The movement of the spacecraft in the process of image formation. The shape and height of the satellite's orbit affect the quality and properties of the images. For example, a circular orbit ensures the same height of the Earth's surface, and therefore, for the same equipment, the same coverage and expansion of images. Geometric distortions are divided into distortions associated with internal flaws in the geometry of the sensor, and distortions caused by external factors (sensor operating conditions, shape of objects, etc.).

The fact that the radar survey is carried out exclusively with a side view (not at the nadir) determines the presence of geometric distortions, which are combined simultaneously with brightness (these distortions are observed in areas with fragmented terrain, in the presence of tall vertical objects, for example, multi-story buildings): stretching and compression of the image of the slopes, which is accompanied by an increase in the brightness of the slopes facing the radar, and its decrease in the opposite direction (the accepted name in the English-language literature is foreshortening), overlay (layover) and radar shadow (radar shadow). Schemes of the occurrence of distortions, examples of radar images illustrating these types of distortions, and photos in the optical range corresponding to the selected areas are shown in Figure 2.5.

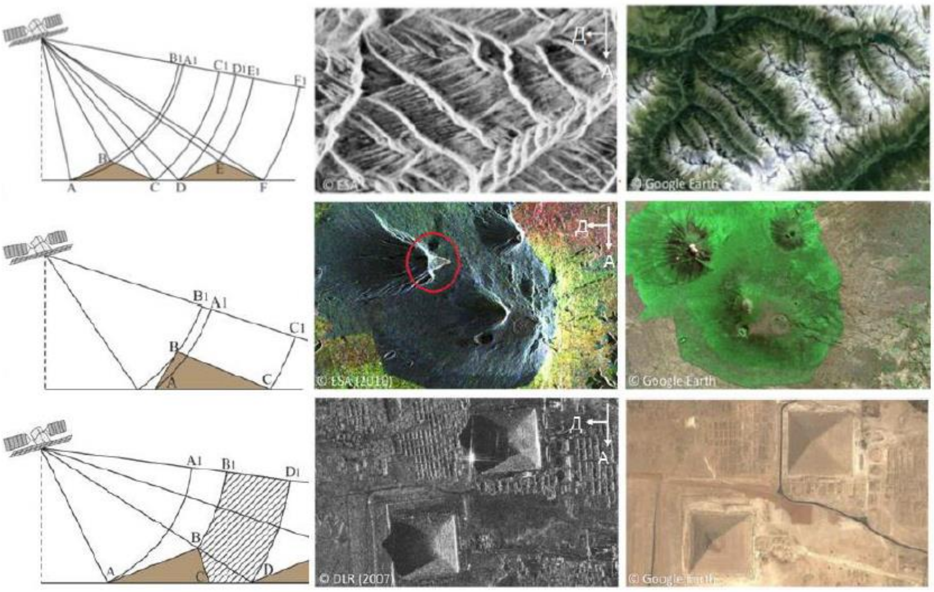

Figure 2.5 - The main types of geometric distortions of radar images: stretching of slopes, overlap, radar shadow. On the left are diagrams of the formation of distortions, in the center - fragments of radar images, on the right - fragments of images in the visible range

2.3. Use of satellite images in the development environment

To obtain satellite images, the SAS.Planet program is used, the interface of which is shown in fig. 2.6. SAS Planeta is a mapping and navigation program. First of all, this program is intended for viewing satellite images and maps that are available to us online. Many online maps are available in the program menu, including topographical and satellite images from Google, Yandex, Bing and a number of other providers.

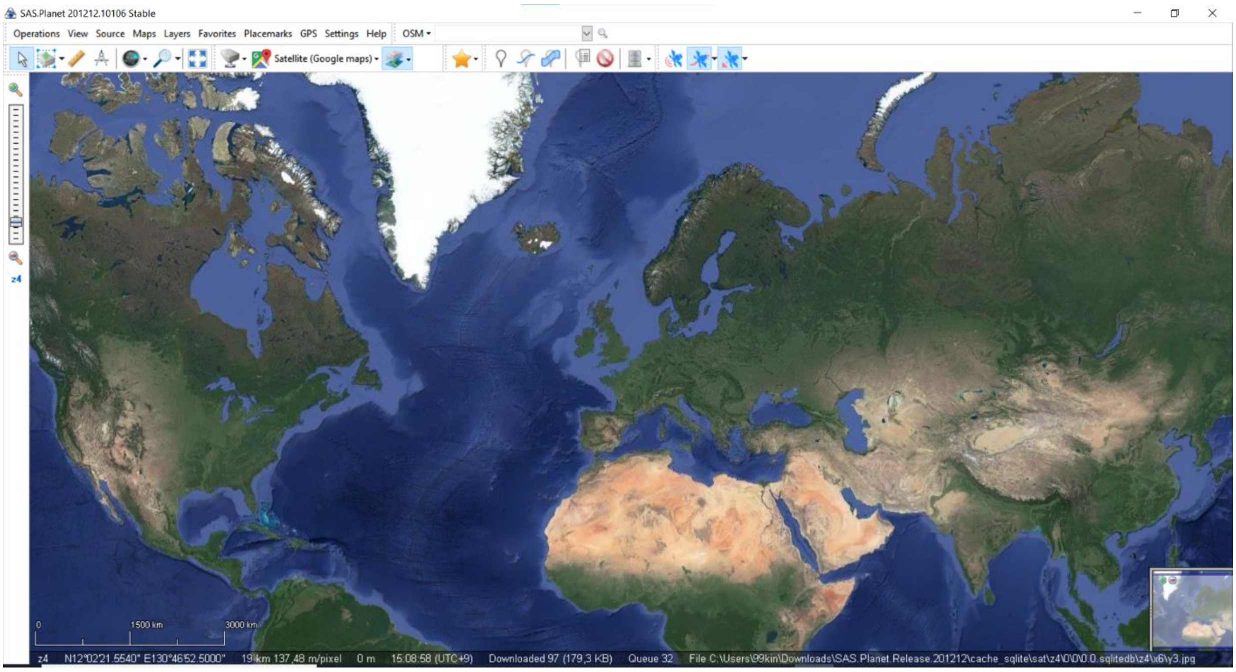

Fig. 2.6 - SAS.Planet program interface

One of the main advantages is that you can quickly view the place you need on several maps and satellite images, switching between them in the menu. The program also allows you to measure distances on the map, mark points and draw routes. You can easily download the map fragments you need to your computer, and then view them in the absence of the Internet. You can also convert these maps into different formats, for example, JPG graphic format (received a map in the form of a regular picture of any size) or some other format (if, for example, you need a map for a navigator).

SAS Planeta does not require installation and can work even from a flash drive. You need to unpack the downloaded archive and place it on the most capacious disk of your computer. This is necessary due to the fact that SAS Planeta caches (that is, saves to the computer) viewed sections during its operation. This, of course, is a plus, since upon repeated viewing the program will work faster, showing sections of the map no longer from the Internet, but saved on the computer.

So, open the program and select the card you need. This can be done either in the "Maps" menu, or just below on the toolbar. What is available to us? Google maps, Yandex maps, satellite images from different providers (Google, Yandex, Bing, etc.), historical maps (for example, 19th century), maps OpenStreetMap_and many other things.

You can turn on the display of one of the layers (Fig. 2.7), which will be superimposed on the map you are currently viewing. Among the useful layers, you can distinguish Google Hybrid, Panoramio, Wikimapia, Mapsurfer (elevation contours).

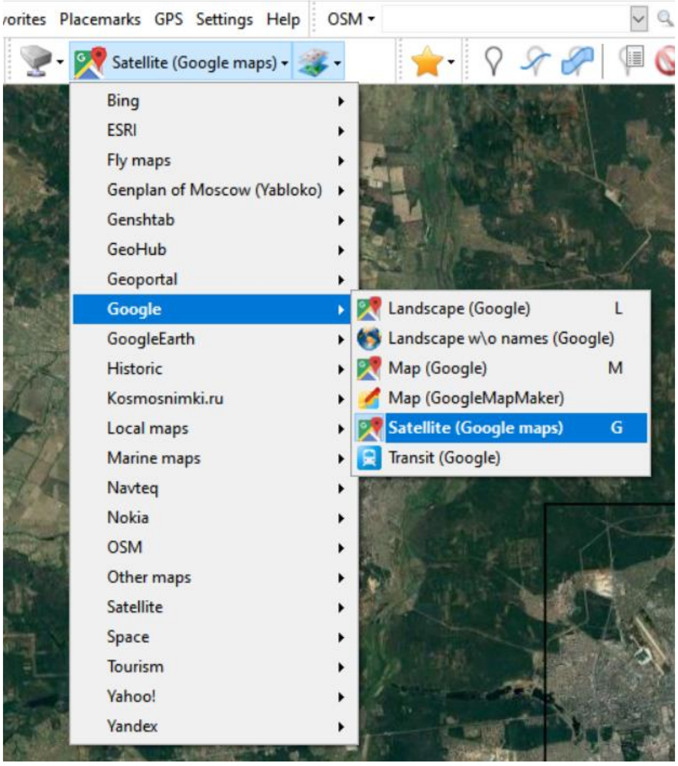

Fig. 2.7 - SAS.Planet style selection menu

During viewing, map sections are saved on your computer, forming a so-called cache. It is a set of small image files. This is convenient because the next viewing of the same section will show images not from the Internet, but those already available on the computer. Firstly, it is much faster. Secondly, it allows you to do without the Internet.

Viewing modes are switched in the "Source" menu. The most convenient item is "Internet and cache", that is, those images that are already in the cache will be displayed, and the missing ones will be downloaded from the Internet (Fig. 2.8).

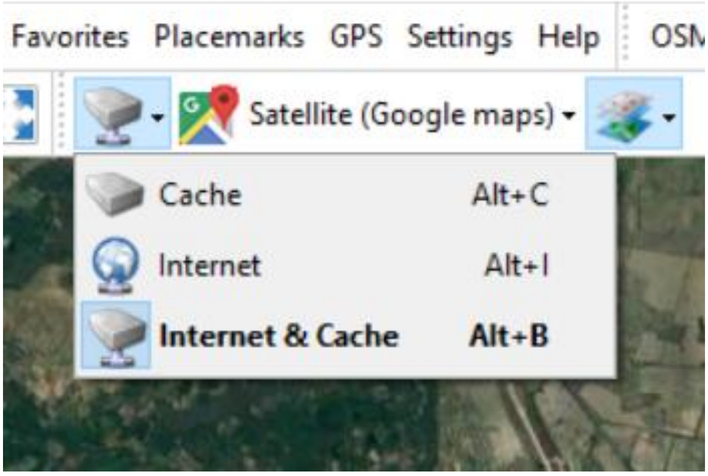

Fig. 2.8 - Selection of card caching method

The item "Cache" will be useful if you pay for the volume of Internet traffic and want to use only the images already downloaded to the computer, and nothing new is downloaded from the Internet. Since some providers regularly update maps, the "Internet" item will come in handy. If you select it, images will be displayed exclusively from the Internet, while they will be saved to your computer, replacing older fragments, which allows you to update the cache you have.

You can download the maps you are viewing to your computer in advance. To load, first select, as shown in fig. 2.9, the required area (top left button "Operations with selected area").

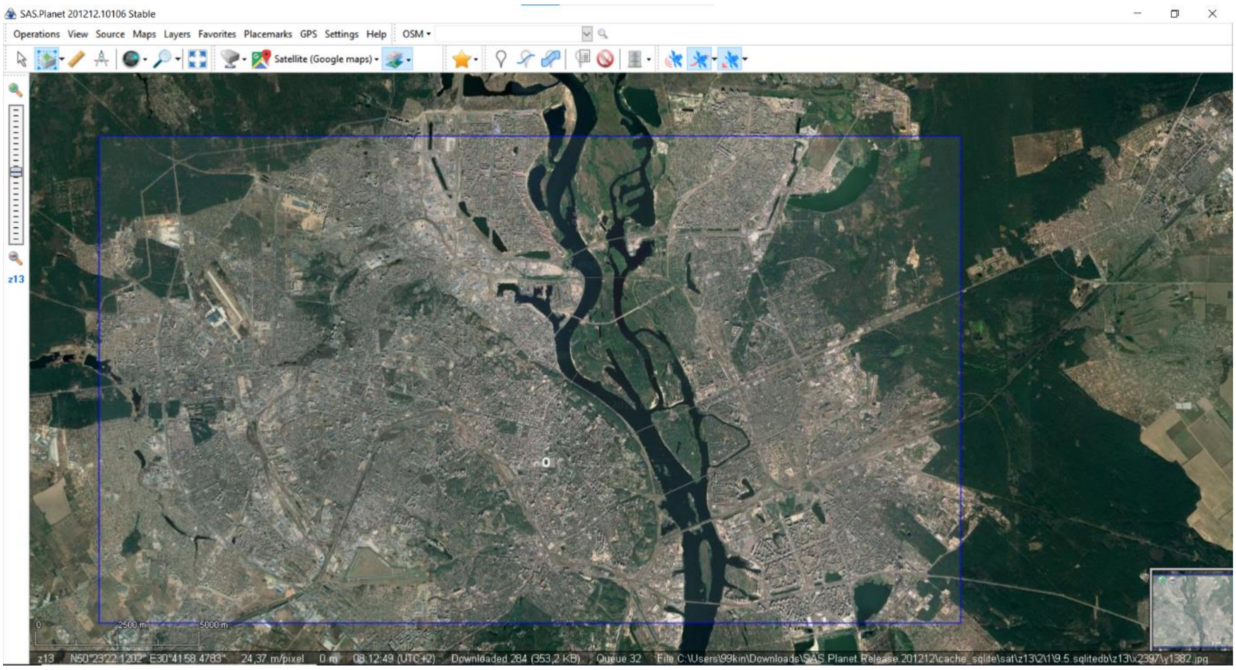

Fig. 2.9 - Selection of the map area for caching

Next, go to the "Export" tab ("Operations with selected area" - "Previous selection"). Here we choose one of the formats: JNX (map for Garmin navigator), RMP (map for Magellan navigator), RMaps SQLite (map for Android and iOS programs: RMaps,OsmAnd,Locus Map, Guru Maps, AlpineQuest), or any other format you need. Then you need to perform a minimum of settings and click the "Start" button, the view of the window is shown in fig. 2.10.

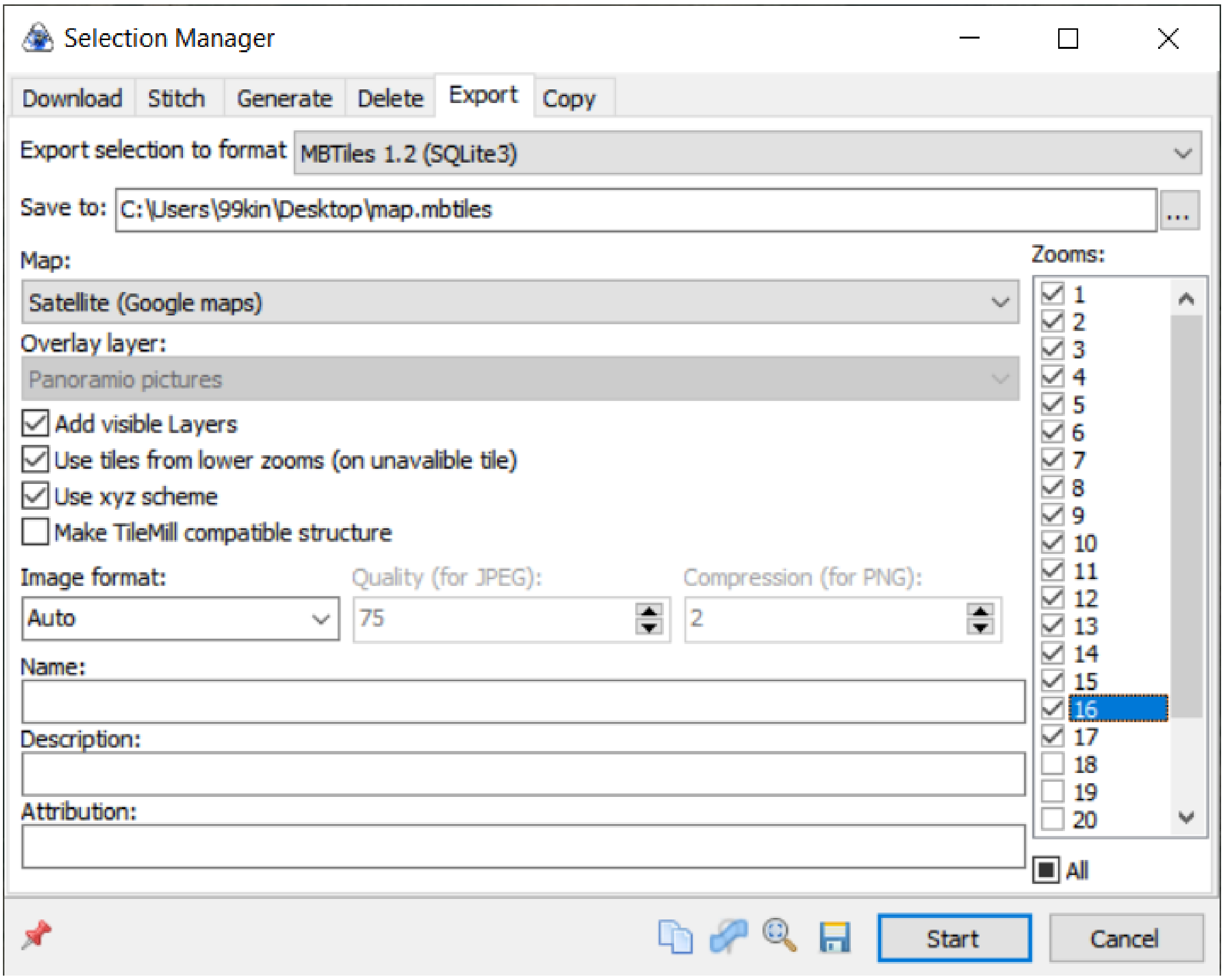

Fig. 2.10 - Export of satellite images in MBTiles format

After conversion, the pictures take place in the structure of the SQLite database (Fig. 2.11), this database is convenient for its simplicity and compatibility with the QT framework.

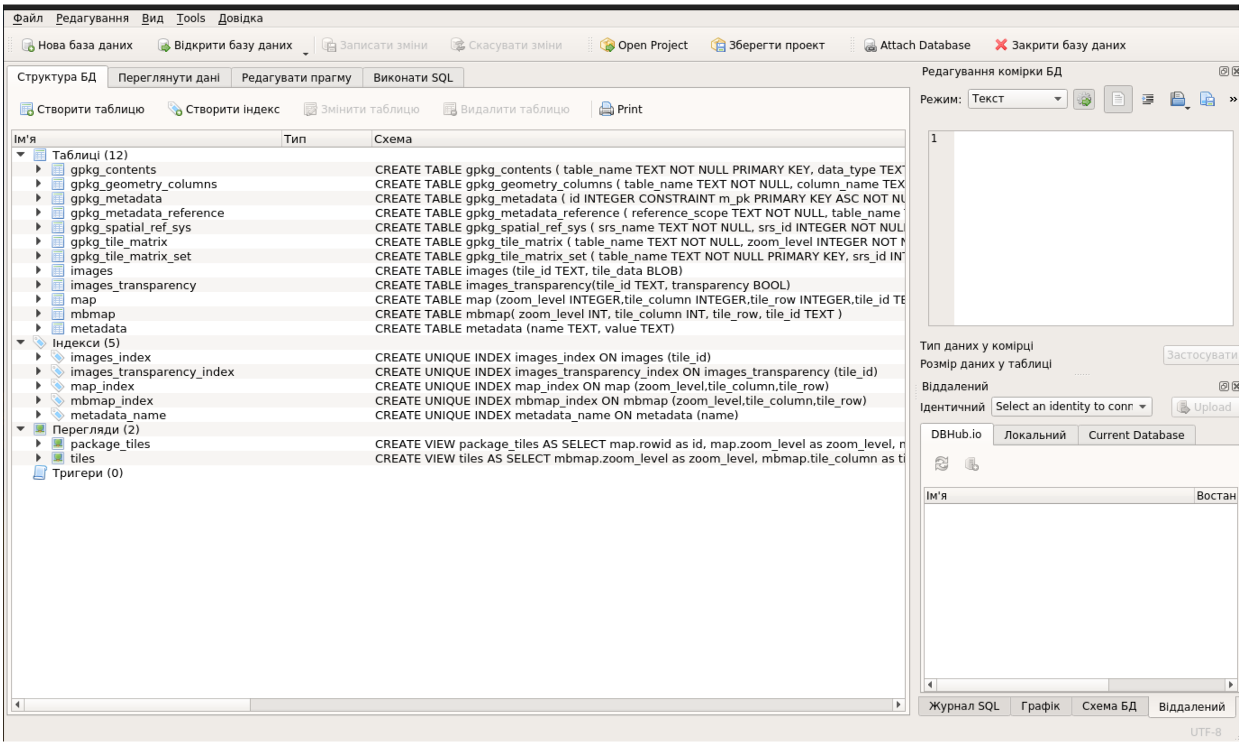

Fig. 2.11 - SQLite database structure

With the help of the utility for viewing filesDB Browser allows you to easily navigate the structure of the databasewhere each tile can be checked by finding it in accordance with its coordinates (Fig. 2.12).

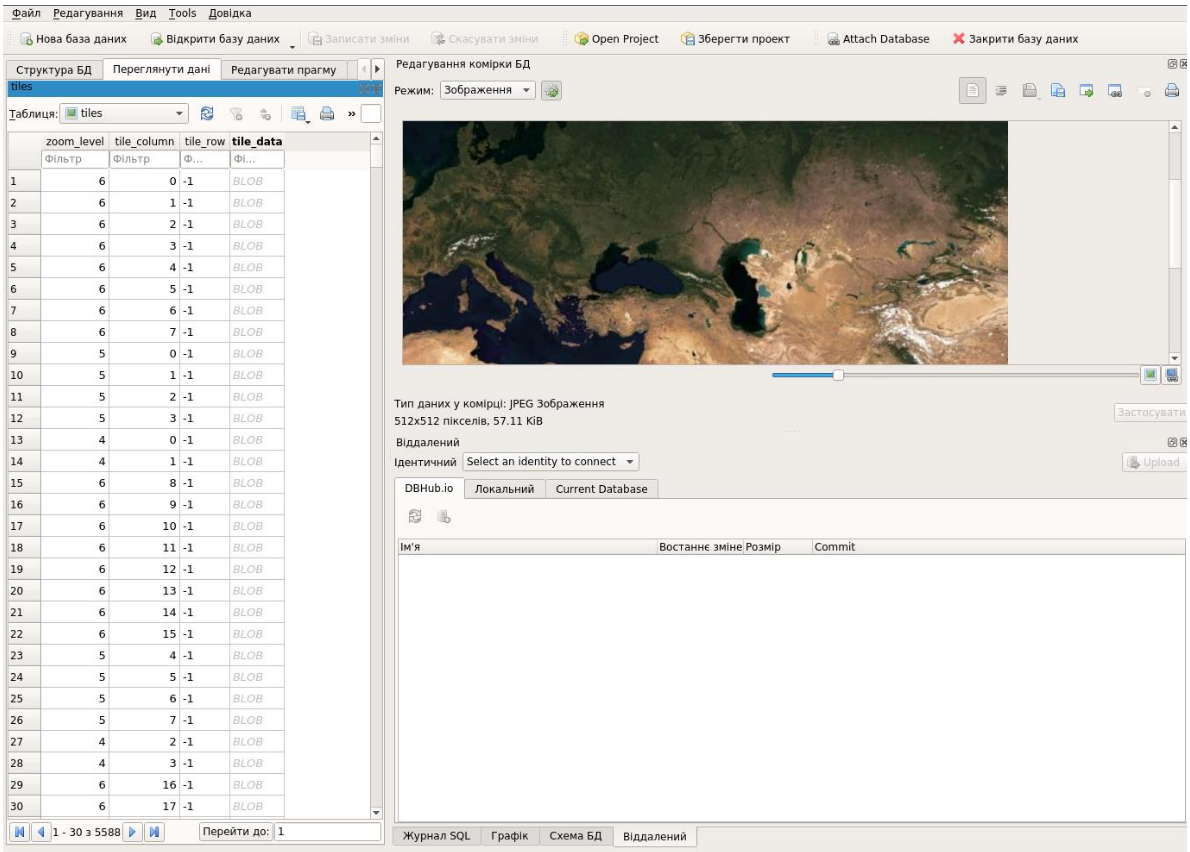

Fig. 2.12 - Displaying MBTiles tiles

A QT-based server (Fig. 2.12) is used to render satellite images and work with the database, which processes them and displays them on the program interface (Fig. 2.13) for further work with them and building a flight task based on them.

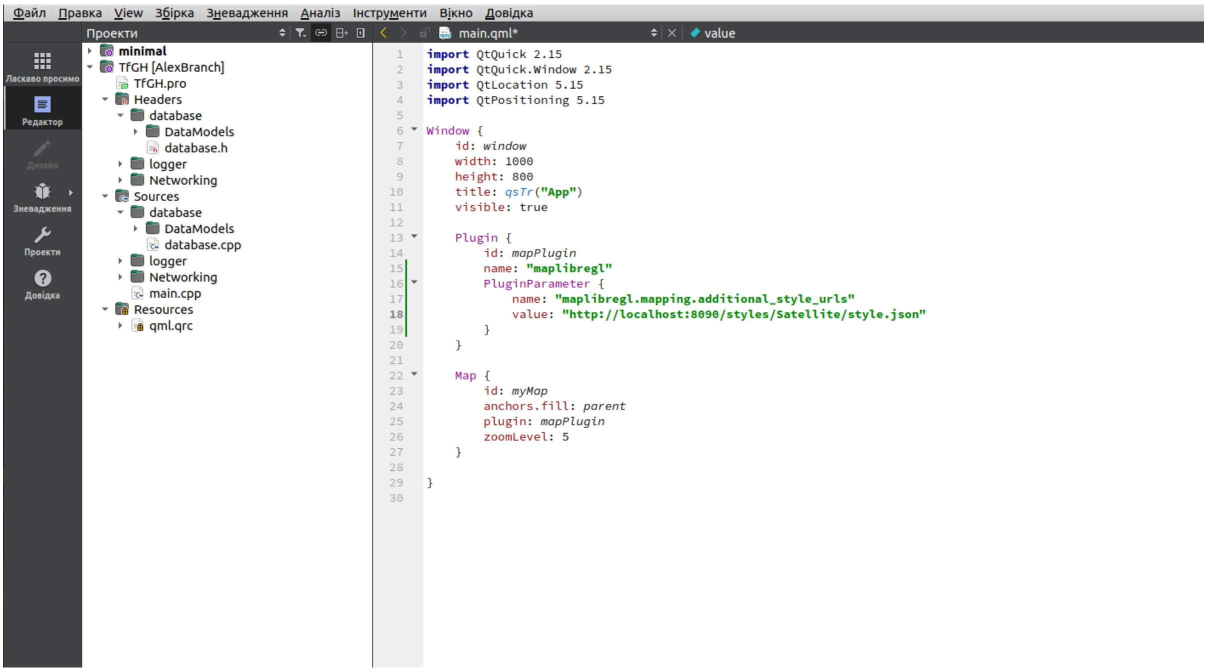

Fig. 2.13 - Structure of a QT-based server

The final result of loaded tiles MBTiles is an application that uses a layer of loaded tiles to display them in accordance with real coordinates on the map (Fig. 2.14).

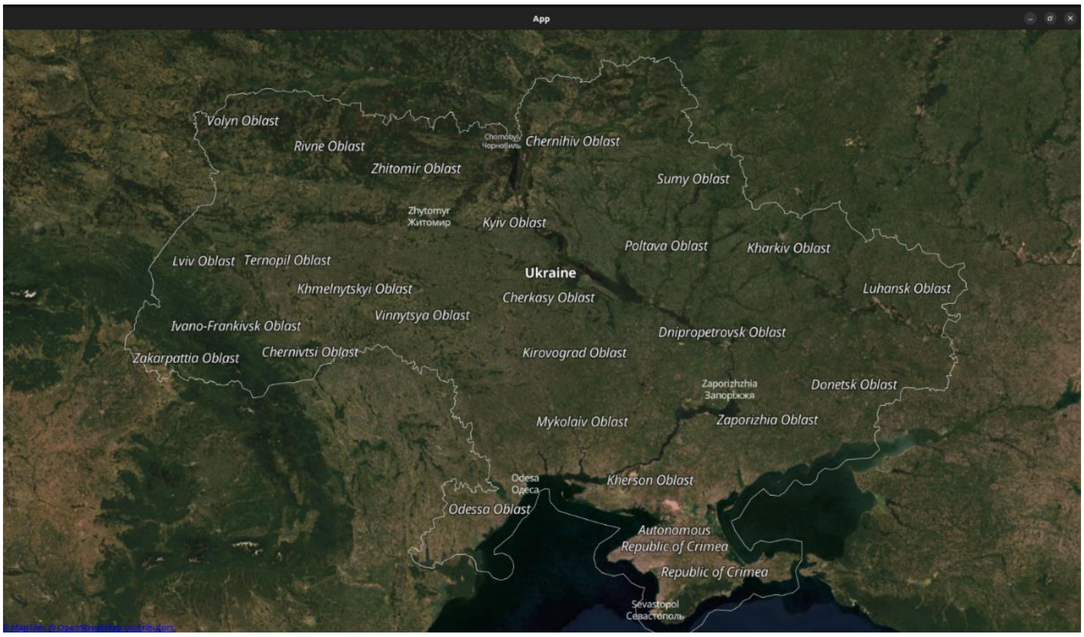

Fig. 2.14 - Visualization of satellite images from the MBTiles file

CHAPTER 3 DESCRIPTION OF THE SYSTEM, STRUCTURE, PRINCIPLE OF THE FIELD PLANT

3.1 UAV control and monitoring system

Consider such a criterion as a control system in view of the fact that the interaction of this system via wireless communication channels with the operator or the air traffic control system is key. According to this criterion, UAVs can be classified as:

- remotely piloted - controlled directly by the operator in the visibility zone through a ground station;
- remotely controlled - operate autonomously, but can potentially be controlled by a pilot or operator using only feedback through other control subsystems;
- automatic - perform pre-programmed actions without pilot control and do not have the ability to change the action plan during the flight or adapt to external changes, but reusable ones can be reprogrammed before each flight, taking into account changes in the environment and the material collected on previous flights;
- remotely controlled by the aviation system - perform low-level control of embedded systems or a ground station, and high-level control of the flight path and / or status is controlled by the operator;
- unmanned automatic - flight is controlled by fully integrated unmanned automatic systems without operator intervention or the use of a ground station, which can be reprogrammed to take into account changes in the environment or new targets.

3.2 The need for planning a flight task and the principle of its construction

The UAV autonomous flight scheme includes three main stages: flight task planning, route planning and autonomous flight using the control system. Flight route planning is understood as the search for the optimal route from its known initial position S0 (starting point) to a given final position SF (destination), taking into account the dynamic characteristics of the UAV and solving the obstacle avoidance problem.

The flight route in real time is calculated taking into account the minimization of a certain indicator (flight time, fuel consumed, etc.). In order to solve this problem, an approach is proposed, the essence of which is as follows: it is necessary to develop a linearized dynamic model of the UAV; use as the main component, minimizing the objective function, the flight time between adjacent reference points, in which the flight route changes; apply partial-integer linear programming to introduce linear constraints with mixed forms, consisting of logical and continuous variables, to describe obstacles when avoiding obstacles.

If the complete flight route from the start point to the target point is calculated once, then the amount of computation will be quite large. At the same time, the calculation process is limited by the capabilities of the on-board computer: the allowable computation time and the amount of memory. On the other hand, if the information about the environment where the flight is performed is incomplete, then it is necessary to carry out its further research and clarification. Therefore, for an unknown environment, it is almost impossible to calculate the complete flight route once. When expanding or identifying new flight targets, the flight route can be formed and calculated for individual sections.

The need for planning a flight task is that this stage helps:

- to carry out intelligent multi-criteria planning of tasks under conditions of high uncertainty;

- calculate UAV routes taking into account the terrain and objects of the tactical situation;

- to automatically prepare flight tasks for autonomous UAVs;

- determine the order of joint actions and form flight tasks for groups of jointly operating UAVs in accordance with the quality criteria specified by the user (safety, assurance of target servicing, optimal use of available resources and equipment, etc.);

- adjust the assigned flight tasks in the course of their performance, taking into account the current set of technical means and their characteristics in real time;

- receive from external systems or set and change manually by the operator the initial data (on the tactical situation) for operational planning and control;

- simulate the processes of completing tasks to analyze the speed and quality of their implementation and calculate the need for resources (UAVs, equipment).

3.3 The structure of the formation of the flight task

The aim of the study is to create a program for constructing UAV flight tasks. The process of creating a program can be divided into the following functional stages:

1. Using the interface to create a UAV flight task;
2. Handling program events (program reactions to user interaction with the interface);
3. Setting up data transfer via communication channels;
4. Loading the flight task on the UAV;
5. Feedback from the UAV to the station.

To build a flight task, you need to use the right side of the application, the operator sets the initial take-off position of the UAV and, using the graphical interface, begins to set points on the map, guided by satellite images that were previously uploaded to the server. By double clicking on the map, he can set a waypoint and its coordinates appear in the top right of the window, if possible, they can also be changed by dragging one of them. After double clicking, the position of this point relative to the map area available on the screen is compared with the coordinates of the earth's surface and saved into the model for further processing (Fig. 3.1).

```
MouseArea{
    id: mainMouseArea
    anchors.fill:parent
    onDoubleClicked: {
        var inputCoordinate = myMap.toCoordinate(Qt.point(mouse.x,mouse.y))
        modelWaitPoint.append( { "latitude" : inputCoordinate.latitude,
                                 "longitude" : inputCoordinate.longitude,
                                 "activeState" : false } )
        polyLine.addCoordinate(inputCoordinate)
        mIndex++
    }
}
```

Fig. 3.1 - Writing a correction point to the model

Along the way, based on this model, we are building a representation of correction points on the user interface, with which we can interact to change the flight task (Fig. 3.2).

```
MapItemView {
    model: modelWaitPoint
    delegate: WaitPoint{
        id:wPoint
        latitudeWaitPoint: model.latitude
        longitudeWaitPoint: model.longitude
        index: model.index+1

        signal sendIndex2(double wLat, double wLon, int index)
        property int wIndex: 0

        MouseArea{
            anchors.fill: parent
            drag.target: parent
            onPositionChanged: polyLine.replaceCoordinate(index, wPoint.coordinate)
            onClicked: wPoint.deletePoint(statePoint)
            onReleased: {
                var nextCoordinate = wPoint.coordinate
                if (index !== 0) wIndex = index - 1
                else index = 0
                if (model.latitude !== nextCoordinate.latitude || model.longitude !== nextCoordinate.longitude) {
                    sendIndex2(nextCoordinate.latitude, nextCoordinate.longitude, wIndex)
                }
            }
        }
        onDeletePoint: {
            model.activeState = state
            for (var i = 0; i < modelWaitPoint.count; i++) {
                if (modelWaitPoint.get(i).activeState) {
                   modelWaitPoint.remove(i)
                   polyLine.removeCoordinate(i+1)
                }
            }
            var newPath = []
            for(var j = 0; j < (modelWaitPoint.count+1); j++) {
                newPath[j] = { latitude: polyLine.coordinateAt(j).latitude,
                               longitude: polyLine.coordinateAt(j).longitude }
            }
            polyLine.path = newPath
            mIndex--
        }
```

Fig. 3.2 - Model for representing the coordinates of the flight task

All interactions in the program work thanks to signals that either signal some kind of action or transmit data to another area of the program where they are used for calculations or algorithms for performing a flight task, an example of signals is shown in Fig. 3.3.

```
timer = new QTimer(this);
parser = new Parser();
request = new Requests();
connect(timer,SIGNAL(timeout()),this,SLOT(timerSlot()));
connect(parser,SIGNAL(sendData(QJsonDocument)), request, SLOT(requestData(QJsonDocument)));
connect(request,SIGNAL(receivedAnswer(QByteArray)), parser, SLOT(readData(QByteArray)));
connect(parser,SIGNAL(signalReceiveMsg(StrMainPackage,StrParamValueList)),this,SLOT(parametrValue(StrMainPackage,StrParamValueLis
```

Fig. 3.3 - qml signals and slots

A server is used to simulate a real UAV flight and transfer data to it.and a simple mathematical model, which contains the logic of a real lethal machine (Fig. 3.4).

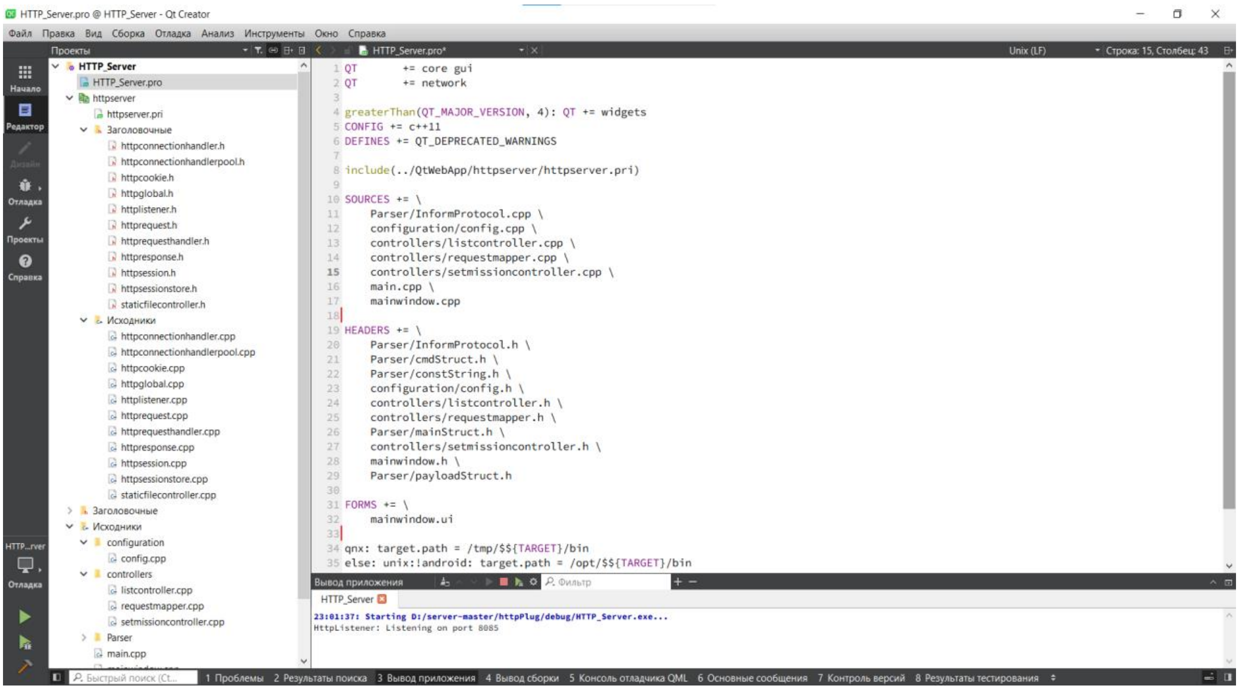

Fig. 3.4 - Structure of the QT server

First, we send the data received using the interface to a separate class where they are structured and transmitted over a secure channel to device, an example of the structure can be seen in Fig. 3.5.

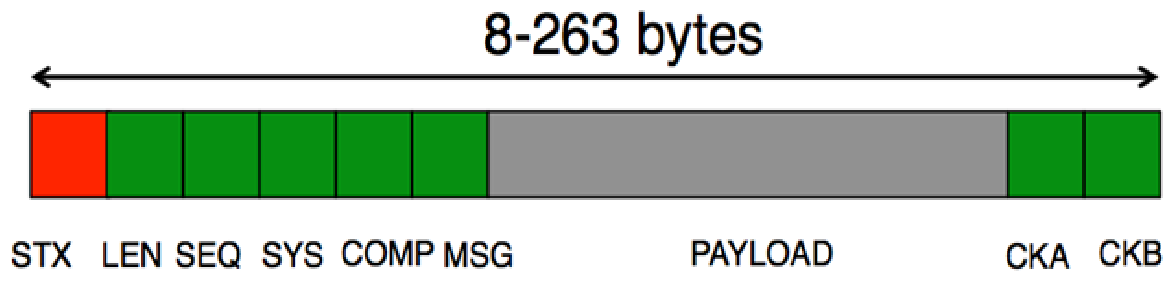

Fig. 3.5 - Mission message structure

The protocol describes the information interaction between the UAV and the ground control station, as well as their constituent parts - components.

The first byte of the packet (STX) is the start character of the message; LEN is the payload (message) length. SEQ - contains a packet counter (0-255), which will help us identify the loss of a message. SYS (System ID) is the ID of the sending system, and COMP (Component ID) is the ID of the sending component. MSG (Message ID) - message type, it depends on what data will be in the payload of the package. PAYLOAD - packet payload, message, size from 0 to 255 bytes. The last two bytes of the packet - CKA and CKB, the lower and upper byte, respectively, contain the checksum of the packet.

Loading mission elements. The process shown in Fig. 3.6 consists of the following sequence:

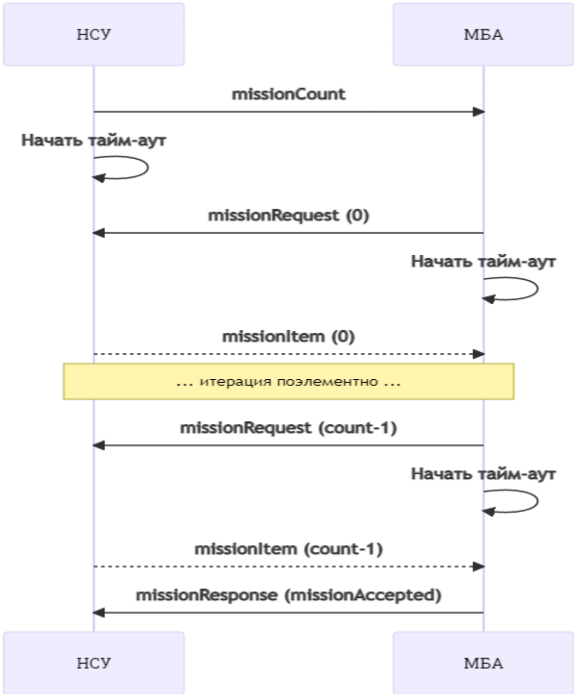

Fig. 3.6 - Loading chart for mission elements

1. The ground station makes a missionCount request to the MCU. The request defines the number of mission elements to be loaded (parameter missionCount). After sending the message, the NSO starts a timeout to wait for a response from the MBA.

2. The MBA receives the message and responds with a missionRequest message requesting the first element of the mission (sequence == 0). Drone timeout to wait for response message from missionItem ground station.

3. The ground station receives the missionRequest message and responds with the requested mission item with a missionItem message.

4. The MBA and the ground one repeat the missionRequest / missionItem cycle, iterating the sequence until all items are loaded (sequence == count - 1).

5. After receiving the last mission element, the MBA replies to the NSO with a missionResponse message with the type field equal to missionAccepted, which corresponds to the successful loading of all mission elements. (The MBA must set the new mission as the current mission by deleting the original data; the MBA considers the download complete).

6. The ground station receives a missionResponse with missionAccepted to indicate that the operation has been completed.

After the transfer of the flight task, we can track the key parameters from the UAV, for this, a special request is submitted from the ground station, which contains the information that we need to receive, in this case, these are the parameters of the object. The required request is sewn into the message structure (Fig. 3.6) and transmitted to the aircraft according to the protocol.

```
void Parser::slotSendMsg(StrMainPackage mainPckg, StrParamRequestList msg)
{
    QJsonObject paramRequestListObj =
            QJsonDocument::fromJson(paramRequestList.toUtf8()).object();

    paramRequestListObj["targetSystem"]    = msg.targetSystem;
    paramRequestListObj["targetComponent"] = msg.targetComponent;

    QJsonObject mainPckgObj{convertMainPackage(mainPckg)};

    mainPckgObj.insert("payload",paramRequestListObj);

    emit sendData(QJsonDocument(mainPckgObj));
}
```

Fig. 3.6 - Method for requesting flight task parameters

This message is transmitted to the UAV with a certain interval, where the structure is parsed by a separate method (Fig. 3.7), and sends back a response with indicators of the key parameters of the lethal vehicle, where we use the same method to receive data from the input structure and display the result on the instrument panel. panel on the left side of the interface.

```
void Parser::readData(QByteArray btArr)
{
    QJsonDocument mainDoc = QJsonDocument::fromJson(QString::fromStdString(btArr.toStdString()).toUtf8());

    if(!mainDoc.isEmpty())
    {
       if(mainDoc.isObject())
       {
          QJsonObject inputObj = mainDoc.object();

          if(inputObj.contains("stx")
             && inputObj.contains("seq")
             && inputObj.contains("sysId")
             && inputObj.contains("complId")
             && inputObj.contains("msgId")
             && inputObj.contains("payload"))
          {
              StrMainPackage mainPackag;

              mainPackag.stx         = inputObj["stx"].toInt();
              mainPackag.seq         = inputObj["seq"].toInt();
              mainPackag.sysId       = inputObj["sysId"].toInt();
              mainPackag.complId     = inputObj["compId"].toInt();
              mainPackag.msgId       = inputObj["msgId"].toInt();
              QJsonObject payloadObj = inputObj["payload"].toObject();

              convertPayload(mainPackag.msgId,
                             payloadObj,
                             mainPackag);
          }
       }
    }
}
```

Fig. 3.7 - Flight task message parsing method

The final result is the display of all parameters and their visualization on the dashboard (Fig. 3.8).

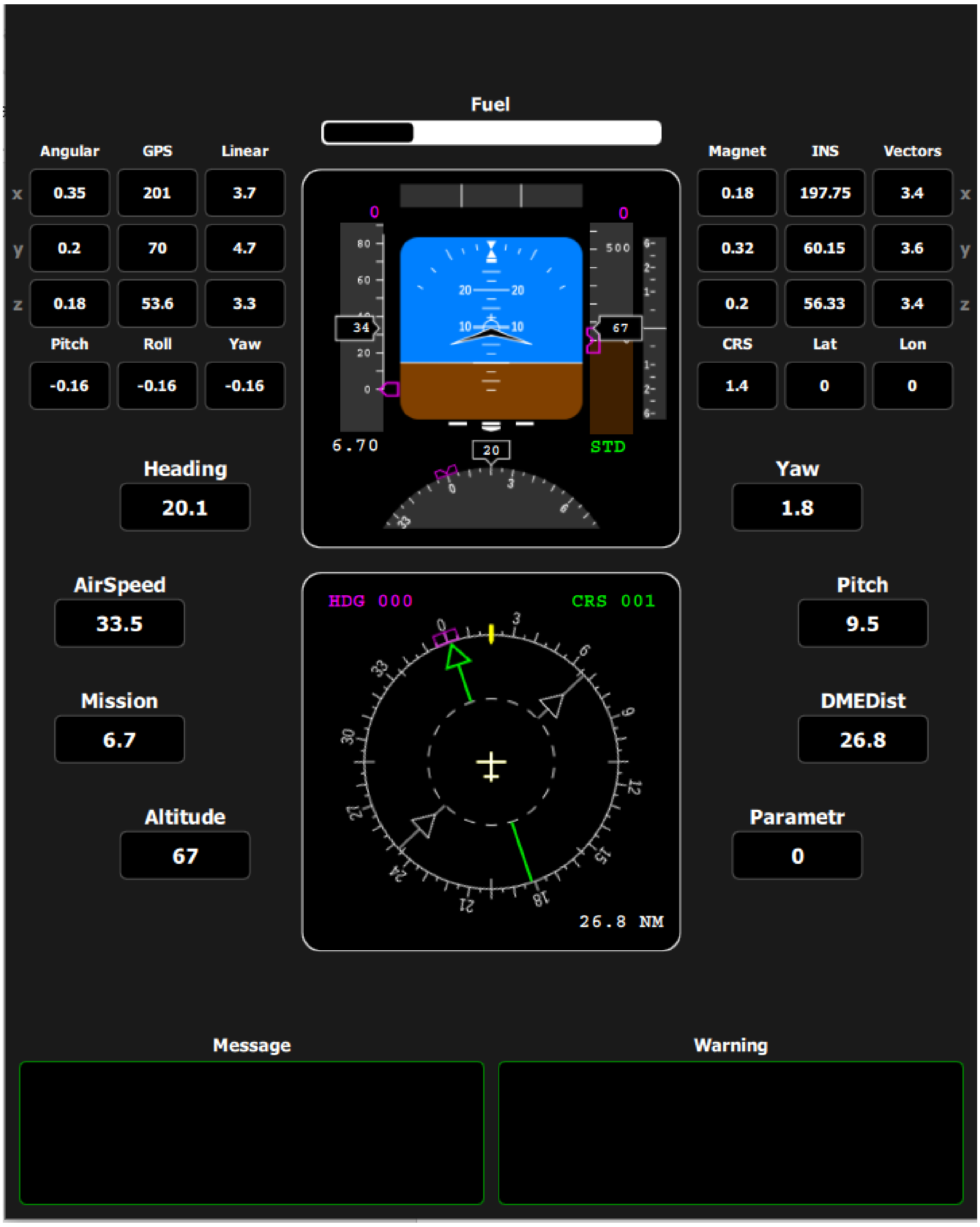

Fig. 3.8 - UAV parameters display interface

3.4. Planning and management. General information

This subsection provides a general overview of the architecture of the planning and control modules, as well as their submodules.

3.4.1. Architecture: planning and management in a broad sense

As shown in fig. 3.9, the map and location module collects raw data such as point clouds and GPS data. It then converts them into UAV location information. The Perception module is responsible for detecting objects in the immediate vicinity of the UAV. Both of these modules are focused on the perception of the objective world, while other modules, such as the module of routing, motion prediction, behavioral decision making, motion planning and feedback control, are focused on the subjective aspect: they are responsible for how the UAV predicts the behavior of the external environment, as well as its further movement in space.

All modules in Fig. 3.9 use a common central clock generator. In a clock cycle (also called a frame), each module independently retrieves the most recently published data from upstream modules, then performs its calculations and then publishes the result for use by subsequent modules.

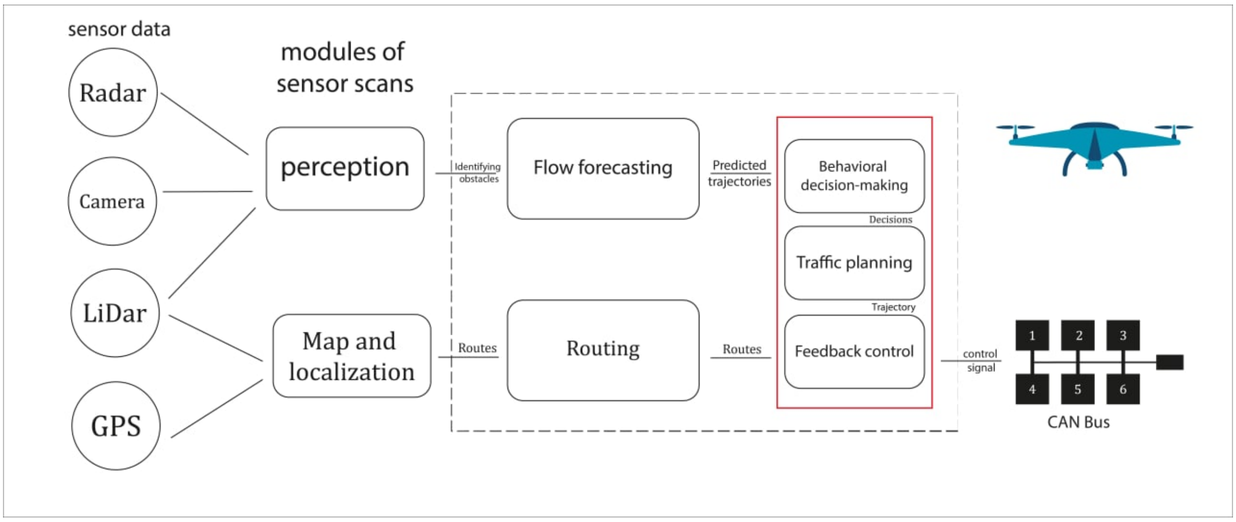

Fig. 3.9 - Planning and control modules

Such a system of modules is complex and includes both hardware and software. Software in unmanned transport systems directly depends on the interaction of various modules, including the module of computing hardware, integration of sensors, perception, motion prediction, as well as planning and control modules that ensure the safety and reliability of the system. The interaction of all these modules, especially the perception module and the planning and control modules, is critical.

Successful interoperability between these modules can be achieved by effectively minimizing the range of tasks to be solved and the scale of the problems that the modules are designed to solve. In the next subsection, we'll look at how feature modules work from a divide-and-conquer perspective, following the natural flow of data and gradually fleshing out the problem. Under this approach, the prediction and routing modules fall under the broader category of planning and control, acting as data dependency modules, which we will discuss in more detail later in this chapter.

Despite the fact that the methods described in this section are widely used in the creation of unmanned transport systems, thanks to the development of artificial intelligence technologies, the use of end-to-end learning systems is becoming an increasingly popular (and necessary) approach. This section presents a consistent and complete working solution that covers many aspects, including the use of various heterogeneous sensor and map inputs (in other words, an objective assessment of the surrounding world by an unmanned vehicle) to calculate the actual actions of driving a vehicle, as well as all intermediate solutions.

3.4.2 The area of responsibility of each module: what tasks the modules solve

Routing can be understood as moving from the current position to the final one by explicitly following the direction. However, although this all resembles the function performed by traditional navigation mapping services such as Google Maps, the UAV routing module usually contains more detail and consists directly of H-maps created specifically for the unmanned system. Thus, such a module in its complexity differs significantly from traditional navigation cartographic systems.

The next module is the motion prediction module (or just the prediction module). The input to this module is information about perceived objects along with their "objective" attributes such as position, speed, and class. The prediction module then calculates the trajectories of each object and passes this information to the behavioral decision module.

The predicted trajectory includes both spatial and temporal information, which will then be used by subsequent modules. In early work, the prediction function was implemented as a peripheral software library, either in the sensing module to refine its output, or in the decision/scheduling modules to preprocess inputs about detected objects. The advantage of implementing prediction as a software library is that software libraries do not need to periodically fetch data from the upstream and publish data to the downstream, and are stateless or memoryless. Software libraries provide

PI (application programming interface) interfaces. They make function calls and then provide the results of the calculations. Therefore, the use of software libraries is a simpler approach in terms of computational logic. On the other hand, a module in an unmanned system must receive the results of the upstream and publish the results of its calculations periodically, by frame. To increase the accuracy of calculations, modules must maintain states, which are memory of previous frames.

With the development of unmanned technologies and the ability of UAVs to function effectively in real airspace, more and more attention has been paid to traffic forecasting. It should be noted that in most modern unmanned systems, the prediction module is implemented as a functional module, and not as a software library. This section discusses the application of a modern machine learning-based approach to formulating and solving motion prediction problems.

The module immediately after the motion prediction module is the behavioral decision module, which serves as a "co-pilot" in unmanned systems. It accepts input from both motion prediction modules and routing modules. Based on the received input data, the behavioral decision-making module generates commands that determine the further control of the vehicle.

The behavioral decision module determines the behavior of the UAV itself and performs a behavioral assessment of any object detected or displayed on the map. Let's take a more concrete example. Suppose that the UAV has detected another aircraft on the current flight path. In this case, the routing module will instruct the UAV to stay on the current trajectory. According to the decision of the UAV itself (synthetic solution), it can remain in this trajectory. Also, a vehicle detected in front may decide to follow another vehicle in front (individual decision). The behavioral decision for each individually perceived obstacle is translated into optimization constraints and costs in motion planning.

The behavioral decision of the UAV is synthesized from individual behavioral decisions and is therefore called synthetic. A synthetic solution is needed to determine the motion conditions in the final state when planning the motion. The details of the set of output commands of the behavioral decision module may differ depending on the implementation. In modern UAVs, algorithms for making behavioral decisions are implemented as a separate module. However, in some UAVs, behavioral decision-making algorithms and their role are integrated into subsequent modules, for example, into a motion planning module.

As already mentioned, the joint operation of the modules is an important condition for the effective functioning of the UAV. Therefore, the logic of the higher-level behavior decision module must be consistent with the logic of the subsequent motion planning module. This means that the motion planning module must accurately take into account the behavioral decisions (information about which it receives from the output of the behavioral decision making module) and accurately integrate them when generating trajectory plans for the UAV. Although the set of behavioral decision commands is intended to cover as many other vehicle behavior scenarios as possible, it is not necessarily complete. Of course, there are also some uncertain scenarios in which even human pilots will not be able to make an unambiguous decision. An explicit set of behavioral decision commands is useful for diagnostics and debugging, but what really matters is how these behavioral decisions are translated into specific motion planning constraints or costs. In the worst or strangest scenario, where it is not possible to make a reasonable individual decision, the default solution should be to pass information about the implicit cost of collision avoidance to the traffic planning module.

The motion planning module provides a planned path or trajectory for moving from point A to point B. The optimization task is to find a local path from point A to point B, where point A is usually the current location. Point B can be any point in the target local area, such as any point that is on a sequence of target flight paths. In traffic planning, the output of the behavioral decision module is considered by the system as constraints, and the output of the routing module is considered as goals.

Compared to the behavioral decision making module, the task solved by the motion planning module is more specific. It consists in calculating the trajectory along with trajectory points that carry information about the location, course of movement, speed, acceleration, curvature of movement, and even higher-order derivatives of these attributes. Since we emphasize the importance of interaction between the described modules, the motion planning module must enforce two important rules.

First, the planned trajectory must be consistent with successive planning cycles, ensuring that the trajectories of two successive cycles do not change drastically under the influence of a slight change in external factors. Secondly, the motion planning module must ensure that that the UAV follows the planned trajectory according to the feedback control module. This module makes sure that attributes such as path curvature or its derivative are continuous and smooth enough to avoid going beyond physical limits.

Although this approach may seem redundant, it appears to be safer because it backs up the motion prediction data. Also, new obstacles may be detected during motion prediction processing. In both cases, when prediction fails or new obstacles are detected, redundant perceptual information, along with a readily available auxiliary terrain survey and localization data library, will ensure that the behavioral decision and motion planning modules have at least basic information about the object, which will allow them to take the necessary steps to prevent a collision.

The feedback control module is located on the server side. It communicates directly with the vehicle control system via a controller area network (CAN - Controller Area Network). The main task of this module is to calculate the actual electrical signals, taking into account the points of the planned trajectory. The main requirement for such calculations is the correspondence between the actual trajectory of the vehicle and the planned trajectory. In this case, the system must take into account the physical models of the vehicle and the characteristics of the airspace where the movement is carried out.

Within the framework of the general concept of planning and control in unmanned systems, the modules described above are the main ones. The philosophy behind this division is to effectively and intelligently break down the complex planning and management task into a number of subtasks. When each module is focused on solving one problem, the complexity of software development is greatly reduced due to modularity and the organization of parallel execution of functions. Consequently, the efficiency of research and development is greatly increased. This approach is the hallmark of our solution. In fact, modules for behavioral decision making, motion planning and feedback control solve the same problem at different levels. Due to their position in the data stream, the results of their calculations depend on each other. An important point in the implementation of such modules is to ensure the consistency and consistency of calculations. As a general rule of thumb, when a conflict occurs, it is better to push the upstream module to resolve the conflict than to force the downstream module to adapt.)

3.5 Motion prediction

Being on the path of the direct updraft after the planning and control modules, the motion prediction module (Prediction) aims to predict the behavior of the detected objects. It calculates the details of the forecast (spatio-temporal points of the trajectory) and passes them on to downstream modules. As a rule, obstacles detected by perception algorithms have attributes such as position, speed, heading, acceleration, etc. Based on a combination of these attributes and simple physical rules, the system makes a timely forecast. However, the purpose of the prediction module is not so much to immediately make a prediction based on physical attributes, but to make behavioral predictions. With this type of prediction, many factors must be taken into account, such as previous recorded data on the behavior of the object,

For example, a motion prediction module needs to determine whether another vehicle will fly straight ahead or turn right. Such behavioral predictions can be formulated as classification problems and solved by applying machine learning techniques. But simple behavioral prediction is not enough, because the actual results of motion prediction must be certain trajectories consisting of points marked with information about time, speed and direction. Thus, we formulate the motion prediction problem in the form of two subtasks:

- tasks of classifying the categorical behavior of a road object;
- regression problems for path prediction with speed and time information.

3.5.1 Vehicle trajectory generation

After predicting the behavior of the vehicle, the module must generate the actual space-time trajectory based on the predicted flight path sequence. One of the possible solutions for generating trajectories is based on physical rules and certain assumptions. To track the coordinates of a vehicle based on an airspace map, we propose to apply the Kalman filter. This approach is based on the assumption that the vehicle will gradually follow the center line (or the so-called reference line). We propose to apply the Kalman filter to track the coordinates (s, l) of the predicted vehicle trajectory points. In simple terms, s is the distance along the center reference line (longitudinal distance), and l is the lateral distance that is perpendicular to s at any point. The motion transformation matrix of the Kalman filter is as follows:

$$\left(\frac{S_{t+1}}{l_{t+1}}\right) = A \times \left(\frac{S_t}{l_t}\right) + B\ \left(\frac{\Delta t}{0}\right), where\ A = \left(\frac{1}{0}\ \frac{0}{\beta t}\right) and\ B = (\frac{v_s}{0}\ \frac{0}{0})$$

The Kalman filter can be applied to each predicted sequence, which will allow tracking the predicted trajectory for each specific trajectory sequence. In the state transition matrix A, the rate of approach of the predicted trajectory to the central reference line is determined by the parameter ßt. In each prediction cycle, ß can be adjusted as the Kalman filter measurements are updated, and therefore the speed at which the UAV approaches the center line will be affected by previously recorded measurements. Once ß is given, we can perform the Kalman filter prediction step for a certain number of steps and generate a point for each future frame of the predicted trajectory.

In addition to the rule-based method mentioned above, machine learning-based solutions are possible when generating the trajectory. The advantage of such solutions is that previously recorded actual trajectories can be used here, due to which the model will tend to generate a trajectory similar to them, rather than relying on rules. In such a scenario, it is appropriate to use regression models in machine learning. In other words, we can enter previously recorded information as input features and then try to build models that reflect the actual paths of the vehicles. We believe that modeling a real trajectory is much more difficult, moreover, it is less important than a behavioral model. Here it can be noted that when generating the actual trajectory of the target vehicle, we use a simple approach based on reference lines. In fact, here, to generate the trajectories of other vehicles (objects), any planning methods designed to calculate the trajectories of movement can be used.

So, we have formulated the motion prediction problem as two problems: predicting the behavior and then calculating the actual trajectory. We presented the problem of predicting behavior as a binary classification question for each possible sequence of trajectories, and also concluded that the solution to the problem of calculating actual space-time trajectories can be borrowed from motion planning methods. When solving the problem of predicting behavior, interactions between vehicles (objects) are not considered explicitly, since this may cause additional difficulties. However, there is one point of view, according to which, if the frequency of prediction is high enough, interactions between vehicles (objects) can be implicitly included.

3.5.2 Routing algorithms

This section introduces two main routing algorithms: Dijkstra's algorithm and A* Algorithm.

Dijkstra's algorithm

Dijkstra's algorithm is one of the most popular algorithms in graph theory, whose task is to find the shortest path. Introduced by Edsger W. Dikstra in 1959, the algorithm computes the shortest path from a source to a destination vertex in a weighted graph. According to this algorithm, routing based on lane points is performed as follows. 1. From the ND-map interface, within the radius range, the graph data of the associated traffic lanes is read. Next, a selection of points is carried out and a graph of connected bands is constructed. The point closest to the current position of the UAV (“leading vehicle”) is taken as the starting vertex of the graph, and the point closest to the destination is taken as the end point. Then the cost of the original vertex for all other vertices is set to infinity (inf), which means, that the cost between the start and end vertices is infinity. In this case, the cost of the path from the original vertex to itself is set as 0.

2. The current vertex of the graph is set as the initial point of the strip, and all other points are marked as "unvisited" and combined into one set (the set of unvisited

points). On the map (prev_map), the current lane point is mapped to the previous one. This map contains data on the shortest path from the visited point to the previous point.

3. Then the approximate distance from the current lane point to all considered neighboring unvisited points is calculated. For example, the distance to the current lane point is X = 3, and the distance between X and Y = 5. Then the approximate distance to Y could be 8 (3 + 5). This value is then compared with the current designated distance to Y. If the current designated distance is less, this value is retained. Otherwise, the current designated distance to Y is replaced with the new estimated distance, and prev_mar is updated to reflect the changes.

4. The process described in step 3 is repeated for all unvisited points associated with the current lane point. After all neighboring points of the current lane point have been processed, the current vertex is marked as visited and removed from the set of unvisited points. Points removed from the set no longer participate in updating the minimum labeled distances.

5. As long as the end point is in the set of unvisited points, flight path points are extracted from there, marked as current vertices, and then steps 3 and 4 are repeated with respect to them. The process is completed when the end point of the lane is extracted from the set of unvisited points or when the minimum approximate distance of a vertex in the unvisited set is not set to infinity, indicating that within a certain radius it is not possible to get from the origin to the vertices remaining in the unvisited point set. The latter case suggests either no available routes or a failure of the routing request. If the request fails, the routing module must notify the downstream module or try to make a new request by expanding the radius of the road graph.

When finding the shortest path, the actual shortest path from prev_mar is rebuilt.

```
1 function Dijkstra_Routing(PointsOfTrajectoryGraph(V,E), src, dsf)
2   create a vertex set Q
3   create maps dist, prev
4   for each point of the trajectory v in V:
5     dist[v] = inf
6     prev[v] = nullptr
7     add v to Q
8   dist[src] = 0
9   while Q not empty:
10    u = vertex in Q pseudo dist[u] minimum
11    remove u from Q
12    for each associated point of the trajectory v of vertex u:
13      candidate = dist[u] + cost[u,v]
14      if candidate < dist[v]:
15        dist[v] = candidate
16        prev[v] = u;
17 ret = empty sequence
18 u = prev[v]
19 while prev[u] != nullptr:
20   insert u into the beginning ret
21   u = prev[u]
22 insert u into the beginning ret
23 combine the point of the trajectory into ret with the appropriate
indicator and sent the unified sequence
```

Fig. 3.10 Dijkstra's Algorithm Routing Pseudocode Based on a Weighted Directed Lane Point Graph

Listing 3.10 is pseudocode that implements Dijkstra's algorithm on a weighted directed motion graph. Lines 2-16 are Dijkstra's typical algorithm, which produces a table of minimum approximate distances between lane points. Then from lines 17-22, based on the minimum approximate distance corresponding to the previous point, the algorithm builds the actual shortest path, gradually moving along the path. The output of the algorithm is a sequential list of lane points, the elements of which are then grouped into actual lane routing segments, such as {(lane, start_position, end_position)} on line 23.

The resulting traffic lane point graph has V nodes and E edges. When using the minimum prioritized queue to optimize the extraction of the minimum distance vertex in line 10, the time complexity of Dijkstra's algorithm can be equal to O(|E| + Vlog|V|).

Algorithm A*

Another popular routing algorithm applicable to UAV routing is the A* algorithm, which is a heuristic-based search algorithm. Like breadth first search (BFS) and depth first search (DFS) algorithms, A* also searches in space according to certain metrics. This algorithm can be considered as a merit-based search algorithm or a best-first search algorithm.

A* operates on a set of vertices called openSet, which includes potential vertices to extend the search. In each cycle, A* extracts the vertex with the lowest expansion cost. The cost of extracting a node f(v) is determined by two components: f(v = g (v + h (v)). Firstly, in the search tree A*, each node will have a cost corresponding to the cost of moving from the original node to the current one - g (v), with each vertex y having a heuristic cost, denoted h(v).The heuristic cost h(v) is an estimate of the minimum cost of going from the current vertex to the final vertex. If h(v) satisfies certain properties, A* is guaranteed to be able find the path from the source to the end point with the minimum cost.

```
function AStar_Routing(PointsOfTrajectoryGraph(V,E), src, dst)
  create vertex set closedSet  //set of visited nodes
  create vertex set openSet  //set of nodes that should be extended
  add src in openSet
  create gScore, fScore with a default value inf
  create prev_map with a default value nullptr
  fScore[src] = h(src, dst)
while openSet is not empty:
  current = nodle v in openSet so that fScore[v] minimum in openSet
  if current = dst
    send reconstruction_route(prev_map, current)
  remove current from openSet
  insert current into closedSet
  for each adjacent node u current:
    if u in closedSet:
      continue;  //ignore adjacent node , which has been assigned the value
    candidate_score = gScore [current] + h{current, u)
    if u not in openSet: // the new node is found
      insert u in openSet
    else if candidate_score >= gScore[u]:  // this is not the best path
      continue;
    prev[u] = current
    gScore[u] = candidate_score
    fScore[u] = gScore[u] + h(w, dst)
```

Fig. 5.11. Pseudocode for implementing Algorithm A* for UAV routing

Algorithm A* is a heuristic-based search algorithm, so it can find the minimum cost path provided that the function h() satisfies the allowed exponent, which means that the estimate of the minimum cost h(v, dst) does not exceed the actual minimum cost. If this condition is not met, there is no guarantee that A* can find the minimum cost path. In an UAV routing scenario using a motion trajectory point graph, one way to determine the heuristic measure between any two motion points A and B is h(u, v) = dist(u, v). Dist() is the distance in the Mercator projection between two points of the motion path in the geographic coordinate system of the Earth. Algorithm A*, as a "first best match" algorithm, can be seen as an extension of Dijkstra's algorithm.

3.5.3. Routing Graph Cost: Weak or Strong Routing

In practice, the choice of algorithm is usually not as important as the cost configuration in UAV routing. Ways to select costs between the points of the trajectories of movement are a critical factor in building a working module of routing.

Considering that the actual road graph information data is large, the routing module can preload the road graph and build a case-specific flight path point graph. If the route to the destination is not available due to the small radius of the loaded path graph, the routing module can reload the path graph data with a large radius, rebuild the path point graph, and recalculate the route. There are usually two types of routing requests: the first type usually occurs at the start of a trip, and the UAV passenger sets the origin and destination by sending a routing request; the second type of routing is usually initiated by downstream modules (such as a behavioral decision module or a motion planning module).

Here we introduce the concepts of strong and weak routing (strong routing and weak routing.). Strong routing implies that downstream modules will strictly follow the results of the routing module. This means that as the UAV moves, the decision and planning modules will do their best to stay on the paths indicated by the route. When they cannot follow the given routes, they send a request to change the route, as described in the second type of routing requests. With weak routing, downstream modules will not strictly follow routing results under certain scenarios. As a result, the actual sequence of movement trajectories will differ from the received route, or, in other words, we will get a completely different behavior of the UAV.

Consider a scenario where the routing output indicates that the UAV needs to stay on the current path and that another vehicle is slowly moving ahead of it on the current path. With strong routing, the UAV will slow down and simply follow it. With weak routing, the UAV can change to an adjacent parallel path, bypass a slow moving vehicle, and then return to the previous path, as most human pilots do. Regardless of the choice of strong or weak routing, whenever an emergency occurs or the need to perform emergency maneuvers occurs, downstream modules will first of all act in accordance with the general principle of "safety first", so in such cases, as a rule, a request to change the route is sent.

CHAPTER 4. SOFTWARE DESCRIPTION

4.1 Qt C++ Framework

Today it is almost impossible to imagine an application without a user interface. The concepts of Software (software product), Apps (applications) and GUI (Graphical User Interface, graphical user interface) are inextricably linked with each other.

Although each of the operating systems has everything you need to create a graphical user interface, using these available "tools" requires a lot of time and practical experience. Even libraries designed to facilitate the process of writing programs do not make the process of creating programs and applications as simple and easy as we would like. Therefore, today developers still spend a lot of time implementing the user interface. But the biggest disadvantage associated with the use of such libraries isis a platform dependency.

Platform independent implementation of applications is the future of the software industry. Every day it will become more and more important. The benefit of implementing platform-independent applications is obvious: development time is significantly reduced, since you do not have to write code repeatedly for each platform, and, no less important, there is no need to know the nuances of each of the platforms for which the program is being written. It is also not necessary to form special subteams of developers for each implementation platform during product development - all this can significantly reduce development time, but also the cost of your product.

And at the same time, the quality of applications will noticeably improve, as they will be tested on several platforms, and errors will be fixed in the same source code of the program.

Qt provides support for a wide variety of operating systems: Microsoft Windows, Mac OS X, Linux, FreeBSD, and other UNIX clones from X 11, as well as mobile operating systems for IOS, Android, Windows Phone, Windows RT, and BlackBerry.

Moreover, thanks to the built-in package Qt Embedded, all the features of Qt are also available in Embedded Systems. Qt uses a low-level API, which allows cross-platform applications to work just as efficiently as applications developed specifically for a particular platform.

While the platform independence it provides is one of the library's most enticing features, many developers use Qt to build applications that only run on a single platform, given that the requirements for a software product are constantly changing over time, it will not be a big deal when the need to provide a product for any other platform.

Using different C++ compilers in development further improves the correctness and reliability of your code, because you will receive warning and error messages from different compilers, which will make your program code more perfect every time.

To speed up and simplify the creation of user interfaces, Qt provides the Qt Designer program, which allows you to do this interactively. You can also greatly increase the speed of creating user interfaces using Qt Quick technology with a descriptive language QML, whose modules and tools are an integral part of Qt.

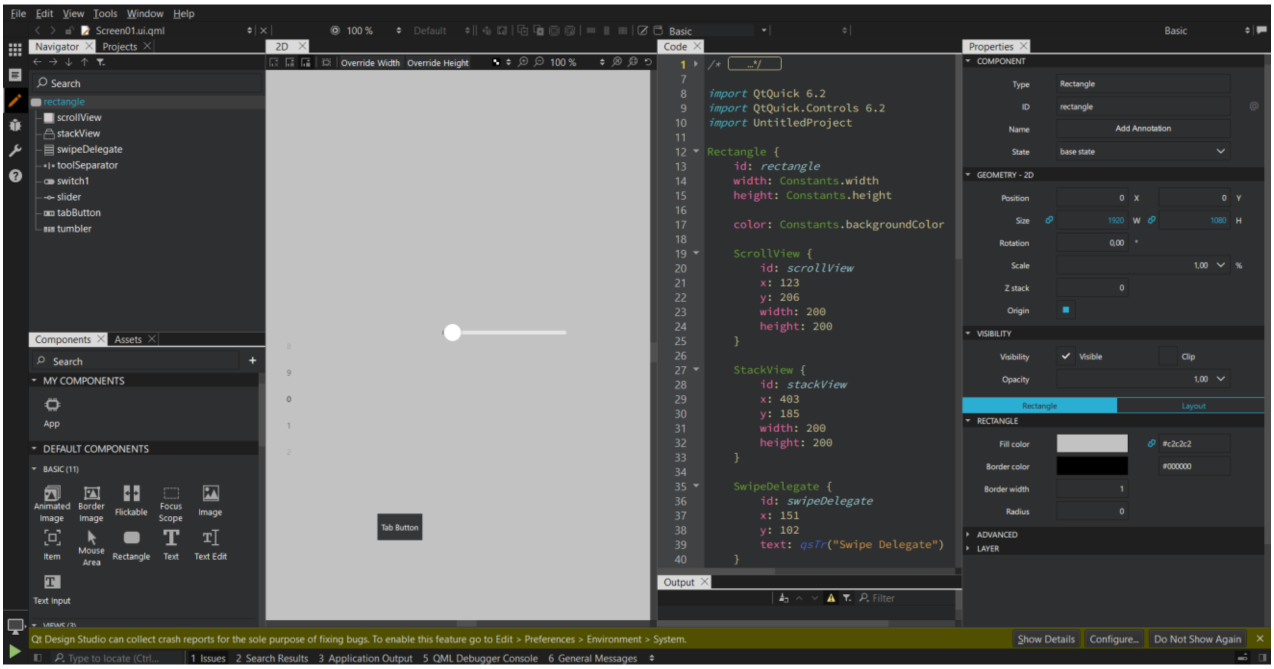

Fig. 4.1 - The interface of the Qt Designer program

Today Qt is a product widely used by developers all over the world. There are more than four thousand companies focused on this library. Active users of Qt include companies such as: Adobe, Amazon, AMD, Bosch, BMW, 8lackbegry, Canon, Cisco Systems, Disney, Intel, 18M, Panasonic, Parallels, Pioneer, Philips, Oracle, HP, Goober, Google, Mercedes, NASA, NEC, Neonway, Nokia, Rakuten, Samsung, Siemens, Sony, SUN, Tesla, Xerox, Xilinx, Yamaha, etc.

Qt is a completely object oriented library. The new concept of conducting inter-object communications, called "signals and slots", completely replaces the previously used not quite reliable model of callbacks. There is also the possibility of handling events - for example, keystrokes on the keyboard, mouse movements, etc.

The provided system of extensions (plug-ins) allows you to create modules that extend the functionality of the applications you create. Users of your program can receive these extensions not only from you, but also from other developers.

Despite the fact that the Qt library was originally created for the C++ programming language, this does not mean at all that it is impossible to use it in other languages. On the contrary, in many programming languages there are modules for working with this library - for example: Qt# in C#, PerlQt in Perl, PyQt in Python, PHP, Ruby, etc.

Programs implemented with Qt can use the JavaScript scripting language. This technology allows users of your application to extend its capabilities without changing the source code and without repackaging the application itself to change the "behavior" of the application.

Qt is well-documented, thanks to which, using the Qt Assisstant program, you can always learn about it any information you are interested in. And if this is not enough, then do not forget that Qt is an open source library (Open Source), and you can always look into it and understand in detail how this or that part of this library works.

And to be extremely brief, the Qt library can be described in three words: Simplicity + Speed + Power.

4.2. Qt QuickQml

Qt Quick is a set of technologies designed to create the next generation of animated, dynamic, user interfaces that are becoming the norm not only on desktops, but also on mobile devices. In addition, this is a completely new approach to their development. The set of technologies itself consists mainly of the following components:

- QML is a new language and immediately an engine for interpreting it. Easy to learn and has a JSON-like syntax;
- Qt is a library;
- JavaScript - programming language;
- Qt Creator - integrated development environment;

The QML language (Qt Meta-Object Language, Qt meta-objective language) was developed as a means for designers to communicate with the program stami. Thanks to QML, the designer speaks the same language to the developer, and they do not have to explain anything to each other, they can simply modify the source code. And this makes it possible to quickly create prototypes (Rapid Prototyping) of software products. Acting as a bridge, QML allows software developers to work together with designers.

The Qt Quick technology is interpreted, which gives one more advantage - there is no intermediate compilation process. Compilation takes time for the developer, as he has to wait until the executable module is fully compiled and linked. Not compiling allows you to quickly change the program, run it immediately, and see your changes in action immediately. That is, each developed element will immediately be available for use.

Qt Quick provides lightweight, easily modified and extensible elements from both the Qt Quick side and the C++ side.

4.3. User interface

The interface is an important component of the application, since it is used by the operator to set the flight task, use terrain images for orientation, correct the flight task and monitor the UAV flight parameters. The block diagram of the construction model using the interface is shown in Fig. 4.1.

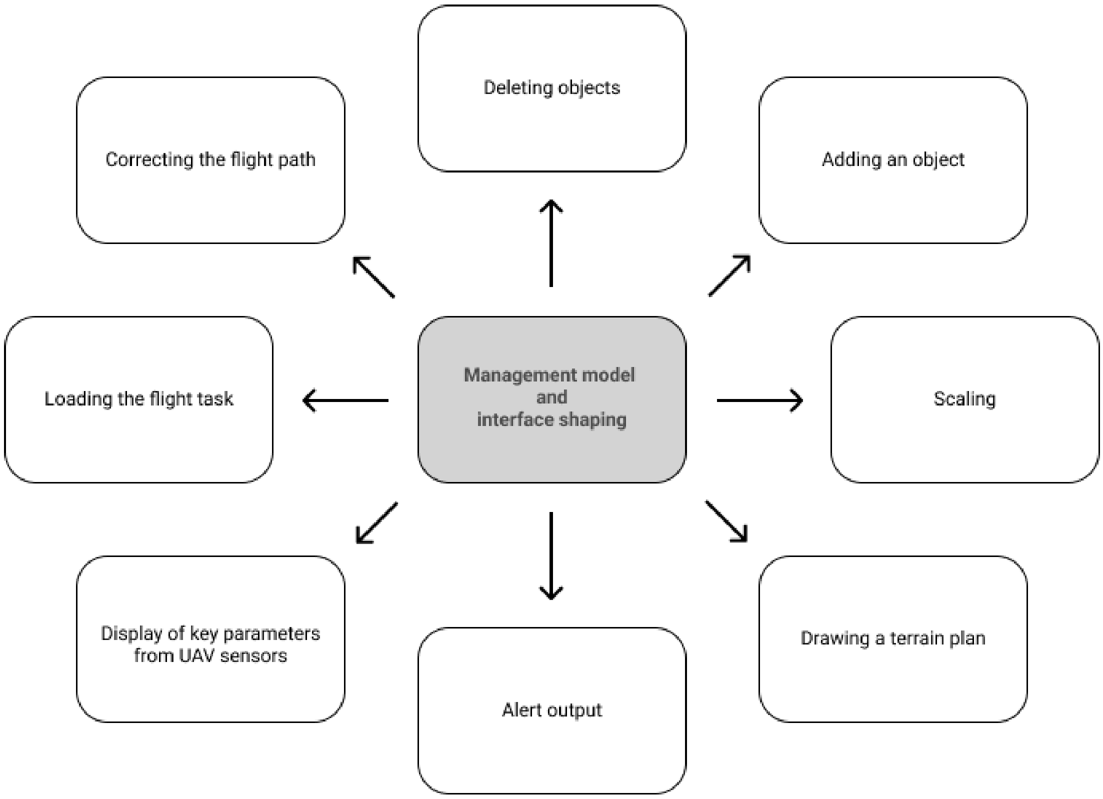

Fig. 4.1 - Structural diagram of the build interface

A general view from the user's side is shown in Fig. 4.1, it is visually divided into two parts, the left one is responsible for monitoring the indicators of sensors from the UAV, in our case, the readings are taken from the flight model of the aircraft.

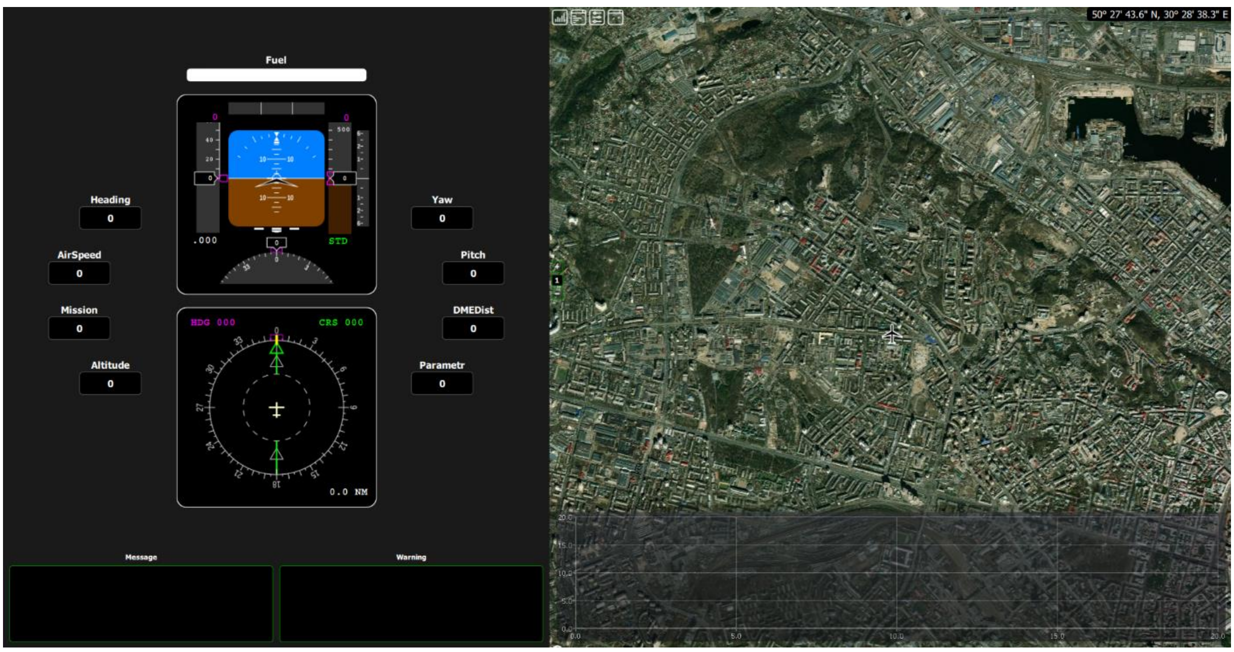

Fig. 4.2 - General view of the application

By clicking on the parameters icon (Fig. 4.2) at the top of the screen, we can open an additional area with parameters.

Fig. 4.3 - Toolbar

If we plan to check all indicators during the execution of a flight task, the window is shown in Fig. 4.3 and includes :

-Angular velocities

- Linear accelerations

- BINS coordinates

- Magnetometer parameters

- Orientation angles

- Delta controls

- GPS velocity vectors

- Direction

- Speed

- Fuel level

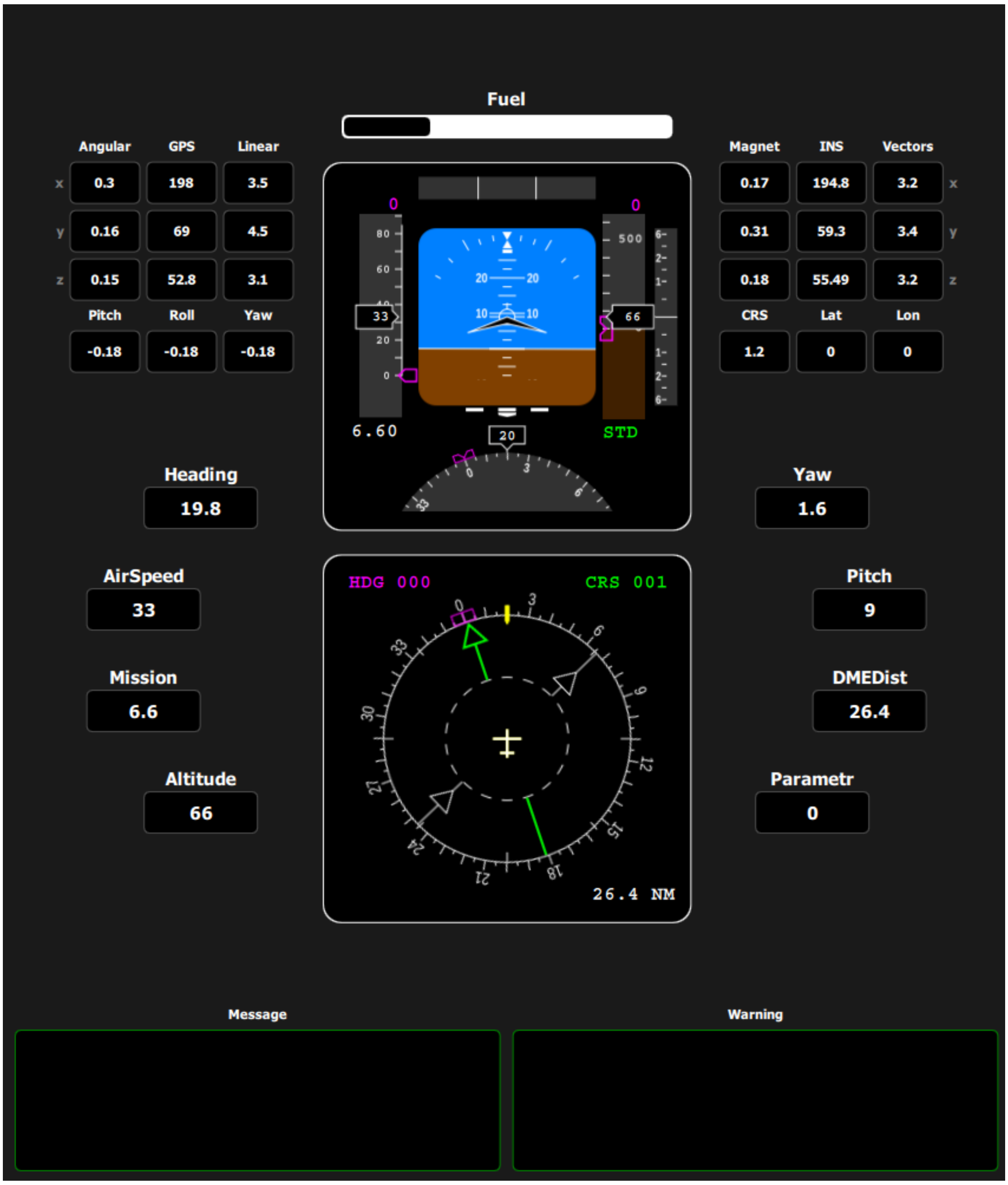

Fig. 4.4 - UAV indicators monitoring window

In this part, there are windows for displaying warnings and messages that will inform the operator about the correct or incorrect operation of a particular sensor, the completion of a mission, the beginning and end of a flight, etc. (Figure 4.4).

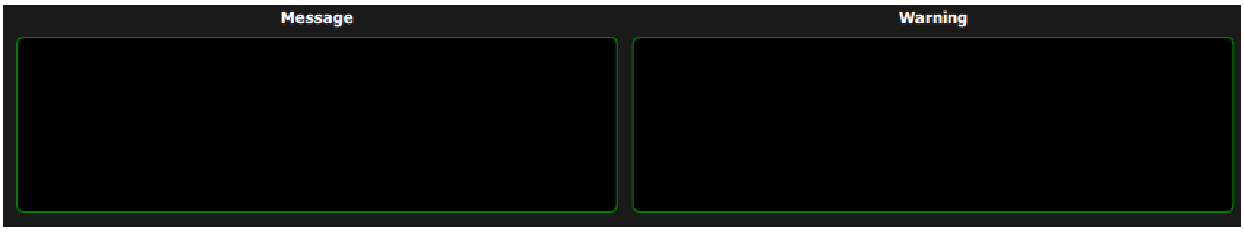

Fig. 4.5 - Warning and message windows

Two widgets are concentrated in the center, which are built on the basis of an electronic direction indicator (Fig. 4.5) and an electronic horizontal position indicator (Fig. 4.6), they display all the necessary parameters based on the UAV sensors, as in the cockpit of a conventional aircraft, which is clearly can help you determine the direction or positions of the aircraft

Fig. 4.6 - Electronic Direction Indicator (EADI)

Fig. 4.7 - Electronic Horizontal Position Indicator (EHSI)

On the right side of the interface there is a toolkit for building a flight task and looks like this - Fig. 4.7.

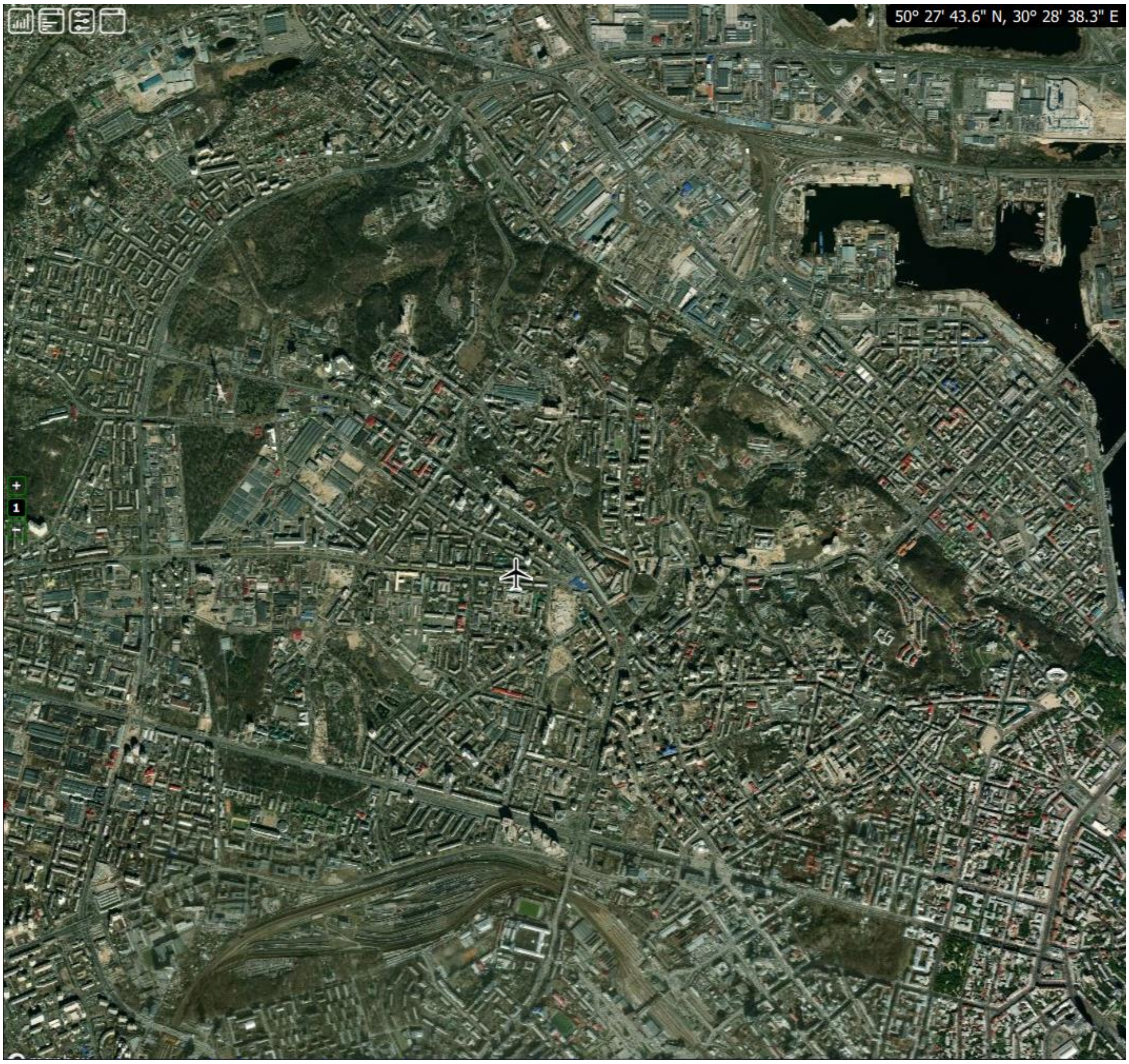

Fig. 4.7 - Window for building a flight task

As a background, you can use satellite images or a vector map (Fig. 4.8) showing most of the available infrastructure objects on it.

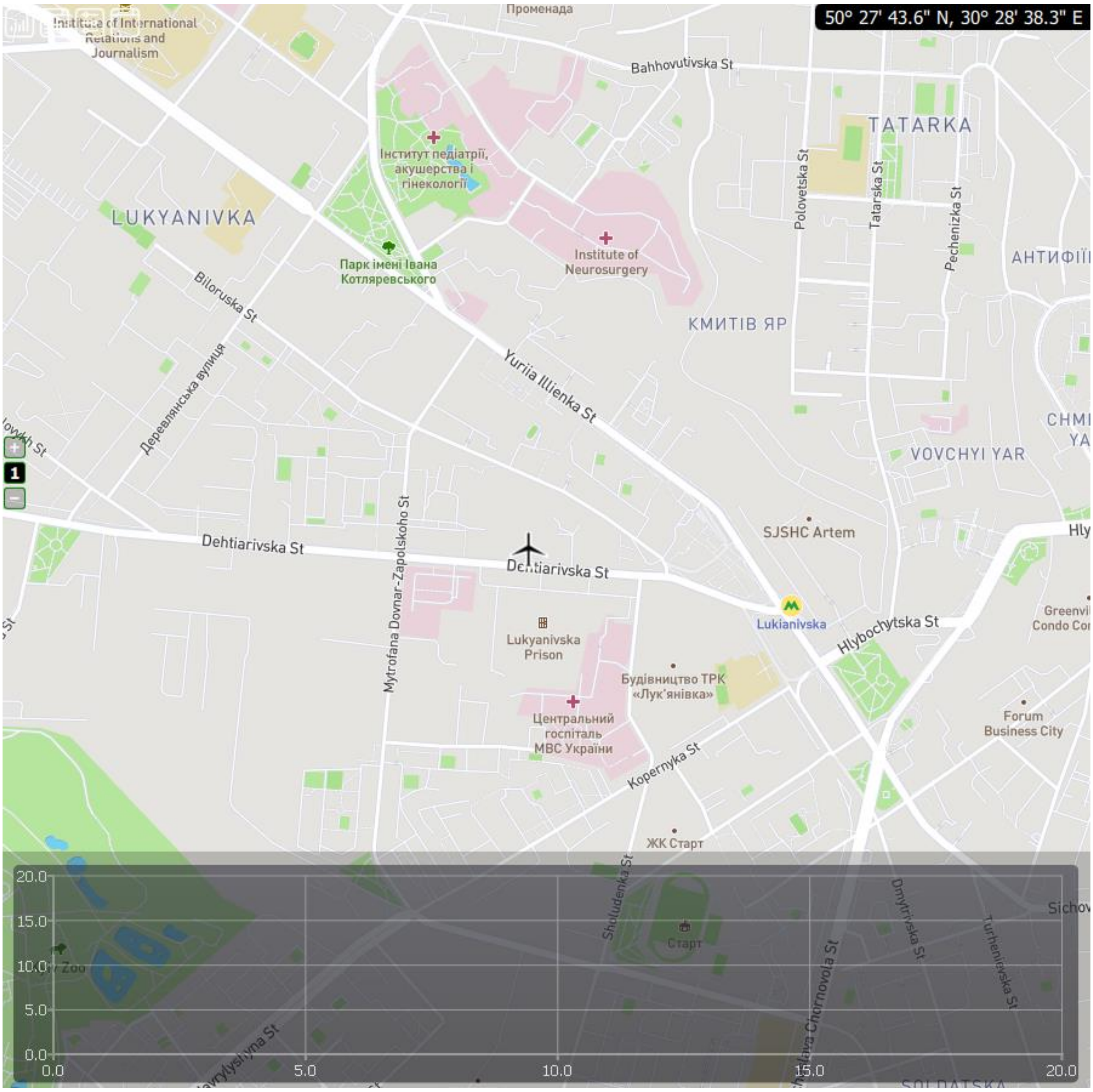

Fig. 4.8 - Vector map type

Vector map is used to build a flight task, mainly if prohibited areas are pre-mapped on the map (Fig. 4.9), which are hard to see on satellite images.

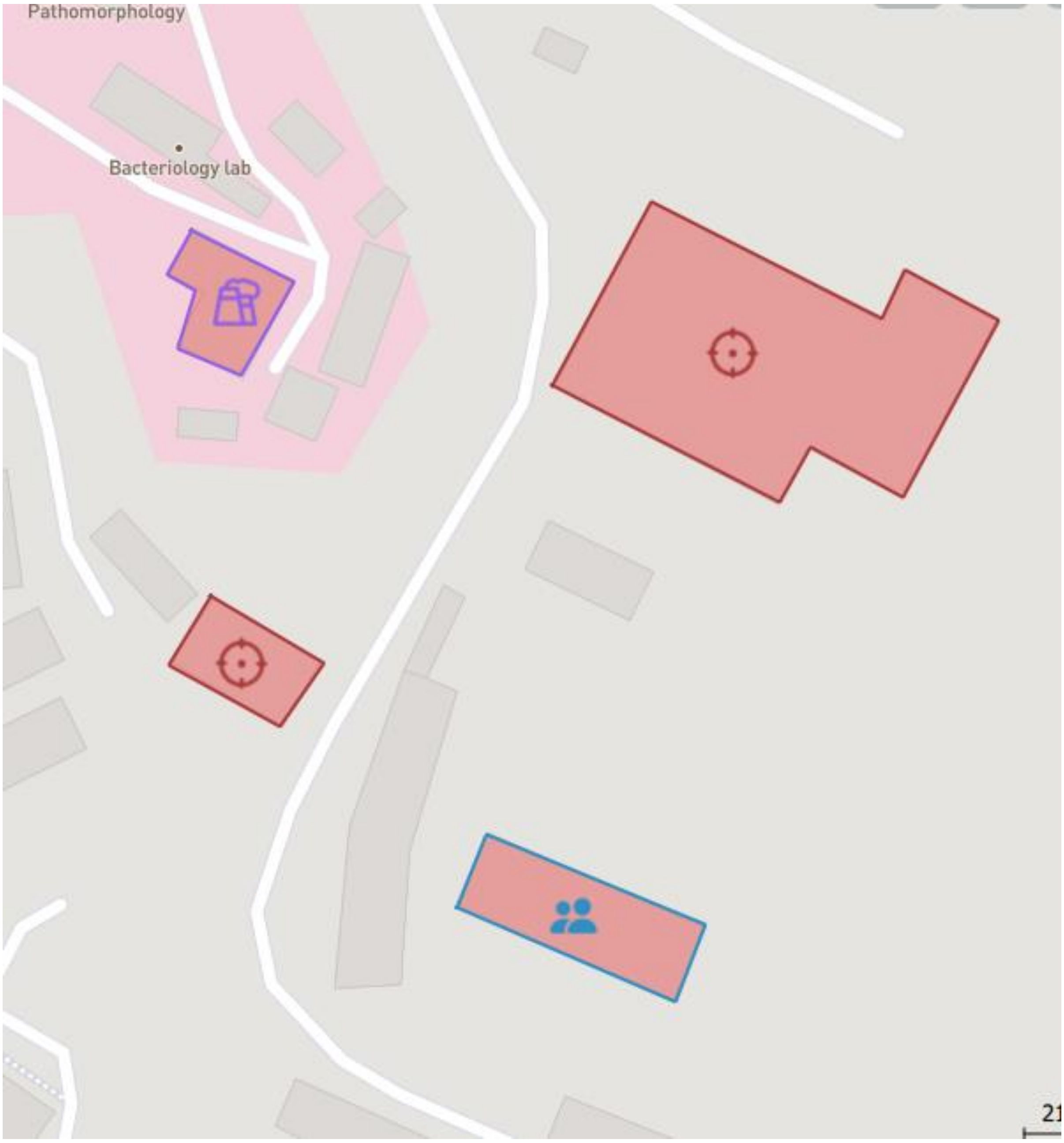

Fig. 4.9 - Prohibited zones on the vector map

In our case, we use satellite data, since in the current realities, objects can change their location very quickly and vector maps can become outdated just as quickly, with the help of images, we can correct the route with minimal risks for the UAV if melons are provided without delay and the map of the area will not have time to become outdated.

A marker is marked on the map in the form of an airplane, it is also the beginning of the flight task, if the launch type is “catapult”, we can launch at any point convenient for us, otherwise, we need a runway, which narrows the possible starting points.

After you have selected and set a marker on the map, you double-click to put points on the map, this is displayed on the screen using the Qt / qml program shell and you can correct and see the approximate route (Fig. 4.10)

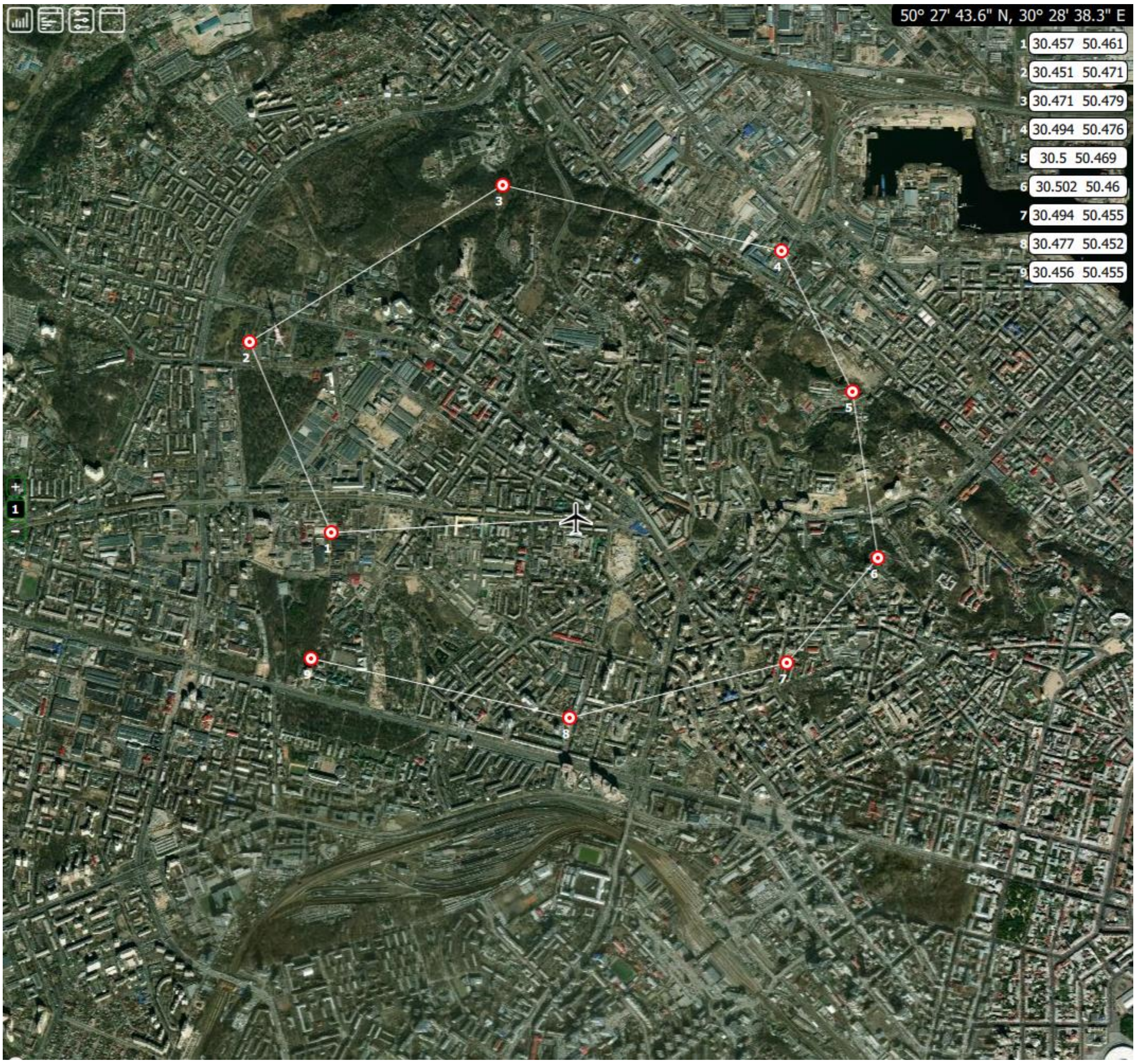

Fig. 4.10 - Building a flight task

As soon as we clicked on the screen with a double click, using an algorithm, the mouse position is converted into coordinates and saved into a model, which will later be part of the flight task structure and will be uploaded to the UAV software center.

In the right part of the window, the current position of the aircraft is visualized and points indicating their coordinates on the map, which we can delete if desired (Fig. 4.11)

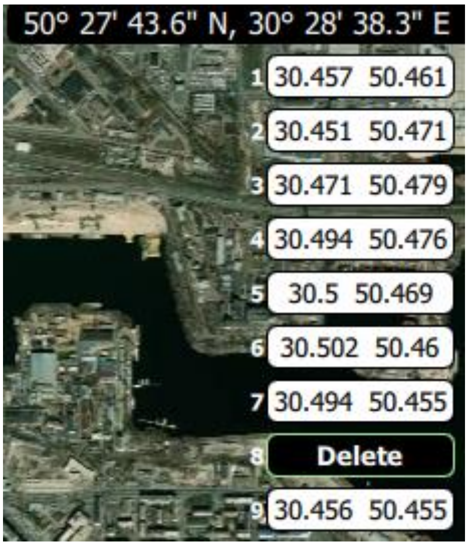

Fig. 4.11 - Auxiliary tools for building a flight task

In the upper left corner, where the toolbar is located (Fig.4.2), we can clear the work area, start transferring data from the UAV or open an additional window that will show us the altitude graph from the start of the flight mission to its end (Fig. 4.12)

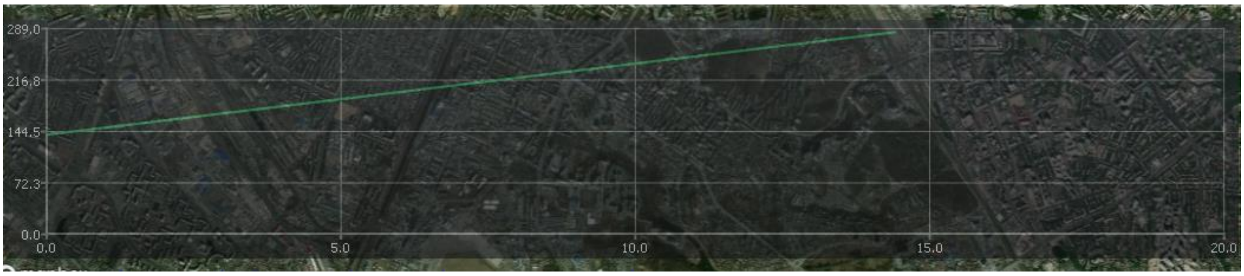

Fig. 4.12 - UAV height scale

CHAPTER V. ENVIRONMENTAL PROTECTION

5.1. Electromagnetic radiation in the modern world

Human activity generates an increase in the electromagnetic radiation level. This level of radiation can affect a person's life and affect their development. It can also affect the body's molecular level. The wide frequency ranges of this radiation can cause changes in the human body's molecular structure and affect the development of the next generation. The wide frequency ranges of radiation that humans receive can affect their development. This is why it is important that people are aware of the effects of this type of exposure.

Unwanted electromagnetic radiation and pickup found in various electronic data processing systems are potential sources of information disclosure through electromagnetic channels. Therefore, personal computers are sources of high-frequency electromagnetic radiation. As a result, the information contained in the computer and displayed on the monitor screen can be received at distances of several hundred meters. Today, one way to neutralize such leaks is to use a noise generator or completely shield the room with a solidly grounded metal sheet. However, the use of noise generators creates an additional unwanted electromagnetic environment in the protected space. This has a direct negative impact on employee well-being, health and ability to work.

The development of the latest so-called "non-lethal" weapon systems, whose principle of operation is based on the use of super-intense pulses of directed electromagnetic waves, is a priority military course for major countries. world. As a result, it is known as a highly effective directed energy weapon. As a result of its action, the surface of the human body is heated to 54°C in 2 seconds, resulting in the effect of pain shock. The creation of electromagnetic bombs, whose detonation leads to the creation of powerful electromagnetic impulses, leads to the possibility of rapid destruction of electronic devices and systems. One of his most dangerous is "electromagnetic" terrorism. This includes using pulsed electromagnetic energy as a damaging agent.

For radars based on the transmission and reception of electromagnetic waves, a very important task is the electromagnetic masking of objects in order to reduce the "visibility" of the radar and reduce its detection range. For the reasons mentioned above, one of the most important issues of our time is the shielding of electromagnetic fields.

In fact, living organisms are often affected by multiple electromagnetic fields with different frequency ranges. For example, when working on a computer, operators are exposed to different frequency ranges and types of electromagnetic fields (EMF). That is, the sum of the low-frequency magnetic field, the low-frequency electric field, the high-frequency electric field, the range of light, and the sum of the high-frequency electromagnetic field (HFMF) of X-ray radiation. Humans experience the same complex effects during solar flares. This is the case when he is further affected by the sum of the VEMF, which is the sum of the ionizing radiation and high-frequency magnetic field from the second day's geomagnetic disturbance.

5.2. Types of electromagnetic fields

Electrical constants and variable low-frequency fields. When biological structures are exposed to electromagnetic fields, low-voltage electric fields are almost always affected, except when the biological object accidentally comes into emergency contact with a high-voltage circuit. The effect of low-voltage electric fields is manifested in the appearance of electrophoretic phenomena. A constant electric field causes movement of stationary charged particles, reorientation, acceleration or deceleration of moving charged particles, depending on their polarity. Alternating electric fields increase the permeability of these particles across the membrane due to periodic changes in polarization at the permeation zone, accelerating the movement of charged particles in blood vessels with valve properties due to the presence of non-return valves.

Magnetic constant and variable low frequency field. Although the effects of magnetic fields have not been studied as much as those of electric fields, recently the use of magnetic fields in physiotherapy allows us to talk about their effects on biological structures. Several models have been proposed for the effects of magnetic fields. The orientation sequence can be viewed as the most probable model. Fine particles with magnetic properties due to ferrite inclusions and magnetic moments change their position in space. A change in orientation is observed in molecules of smallest dimension. This is because the molecules are the most mobile and free in low viscosity liquids.

high frequency electromagnetic field. When living tissue is exposed to HEMF, some tissue molecules are excited, ionized and dissociated, forming new charged micro particles. Due to the simultaneous action of the EMFs of the above groups, there is a joint concerted effect on living tissue rather than a simple summation of their effects, the effects reinforcing each other. Free micro- and macro-particles randomly arranged in a liquid medium orient themselves in the effective directions of the electric and magnetic fields.

Therefore, the degree of interaction between VEMF and biological structures increases sharply, increasing therapeutic efficacy or increasing detrimental effects.

5.3. Sources of electromagnetic pollution of the environment

EMP sources can be characterized by several criteria, the most common being frequency domain classification. The main divisions across the known radiation range:

Radio waves, infrared, visible spectrum, ultraviolet, X-rays, and gamma rays undergo additional fragmentation determined by the conditions of radio propagation. The radio sources can operate in the same frequency range or be tuned to specific frequency bands. With the help of electromagnetic waves, information can be transmitted in the form of radio signals with different carrier frequencies, widths of the frequency spectrum and types of modulation. In terms of frequency division, an EMP source is therefore characterized by its main operating frequency (the carrier frequency of the radio signal), the width and type of spectral characteristics of the radiated signal. The nature and width of the EMR spectrum depend on the instantaneous value of the electric field strength and the nature of its change over time. Most commonly used in modern radio engineering and amenable to analysis, harmonic oscillations are characterized by their instantaneous values of amplitude, frequency and phase. Information parameters can therefore be changes in amplitude, frequency and phase.

Natural EMP source. They are divided into two groups. The first is the Earth field.

Constant electric field and constant magnetic field. The second group is radio waves produced by cosmic sources (Sun, stars, etc.), atmospheric processes (lightning discharges, etc.). The Earth's natural electric field is created by excess negative charges on the surface. Its intensity is typically between 100 and 500 V/m. Storm clouds can increase electric field strengths to tens or hundreds of kV/m. His second group of natural his EMP sources is characterized by a wide frequency range.

During solar flares and storms, the human body experiences complex currents of electromagnetic fields. The main physical properties and duration of action of electromagnetic fields vary greatly. Long-term studies of the effects of EMF on biological structures have revealed numerous consequences of these effects. Each group of EMF.

Anthropogenic EMP sources.

wiring. The largest contributors to the residential electromagnetic environment in the 50 Hz industrial frequency range are the building's electrical equipment, that is, the cable lines that supply all apartments and other consumers of the building's life support system, and switch cabinets. and a transformer. In rooms adjacent to these sources, the level of magnetic fields caused by flowing currents typically increases with power frequency.

power line. Today, it can be considered a proven fact that exposure to electromagnetic fields from high-voltage power lines and other electrical distribution systems greatly increases the likelihood of leukemia, brain tumors and other dangerous diseases. Children are especially vulnerable to electromagnetic fields.

Active power line wires create industrial-frequency electric and magnetic fields in adjacent rooms. The distances these fields propagate from the wires of the line reach tens of meters.

The range of electric field propagation depends on the voltage class of the transmission line, the higher the voltage the larger the zone where the electric field level increases, but the size of the zone does not change during the operation of the transmission line.

The range of magnetic field propagation depends on the magnitude of the current flowing or the load on the line. Since the load on the transmission line can change several times both during the day and with seasonal changes, the size of the zone with increased magnetic field level also changes.

Electric and magnetic fields are very powerful factors that affect the state of all biological objects within their sphere of influence.

For example, insects in areas affected by the electric field of high-voltage lines show behavioral changes.

Increased aggression, fearfulness, decreased performance and productivity, and a tendency to lose the queen bee are observed in honeybees. Changes in behavioral responses are observed in beetles, mosquitoes, butterflies, and other flying insects, such as changes in direction of movement to the side of lower field strength. The shape and size of flowers, leaves, and stems often change, and additional petals appear.

Healthy people suffer from staying in areas of high voltage power lines for relatively long periods of time. Short-term (minutes) exposure may cause adverse reactions only in hypersensitive persons or in patients with certain types of allergies. years), a stay can lead to the development of diseases of the human body, mainly cardiovascular and nervous systems. In recent years, neoplastic diseases are often mentioned as sequelae.

Home appliances. Sources of electromagnetic fields in homes are various appliances such as refrigerators, irons, vacuum cleaners, electric ovens, and televisions. The electromagnetic environment of a home is influenced by the building's appliances, transformers, and cable lines. Household electric fields range from 1 to 10 V/m. However, you may encounter points such as: B. An ungrounded computer monitor.

Measurements of the strength of magnetic fields from domestic appliances show that their short-term effects are even stronger than when a person is near power lines for a long period of time. If the national standard for the permissible value of the magnetic field strength of the population from exposure to power lines is 1000 mG, then household appliances significantly exceed this value.

Computers. The operation of computer equipment involves electromagnetic emissions. This is a source of dangerous signals and can form an information leakage channel. Considering the widespread use of personal computers at work and at home, consider this his EMP source more closely.

The main components of a personal computer (PC) are:

system unit and various input/output devices:

keyboard, disk drives, printers, scanners, and so on. Each personal computer contains visual display information. Called - monitor, display. As a rule, it is based on devices based on cathode ray tubes. Personal computers are often equipped with surge protectors, uninterruptible power supplies, and other auxiliary electrical devices. All these elements form a complex electromagnetic environment at the user's workplace during PC operation.

The electromagnetic field generated by a personal computer has a complex spectral composition in the frequency range from 0 Hz to 1000 MHz, has electrical (E) and magnetic (H) components, and their relationship is very complicated. E and H are evaluated separately.

A study is being conducted in Ukraine on the general pattern of human reactions to impacts from EMR monitors. The results show that, among other violations of the functional state of the body, the most pronounced violations of the endocrine and immune systems occur. Deviating immune states, both immunodeficiency and autoimmune, are fundamental to the inconsistencies in processes that maintain homeostasis throughout the body.

Cellular. Cellular radiotelephones are one of the most rapidly evolving telecommunications systems today. Hundreds of millions of subscribers worldwide now use mobile communication services. The main elements of a cellular communication system are base stations and mobile radiotelephones. A base station (BS) maintains radio communication with a mobile phone (MRT) and makes his EMP sources on the BS and MRT in UHF range.

A key feature of cellular radio communication systems is the highly efficient use of the radio frequency spectrum allocated for system operation, "repeated use of the same frequency, use of different access methods". A good number of subscribers. This system uses the principle of dividing a given area into zones or "cells", usually with a radius of 0.5 to 10 kilometers.

Television and radio stations. Broadcast Radio Centers (RTCs) are located in specially designated areas and can occupy fairly large areas (up to 1000 hectares). By their construction, they contain one or more technical buildings in which radio transmitters are located and antenna fields in which up to dozens of APS are located. Antenna Feeding System "AFS" Contains an antenna used to radiate radio waves and a feeding line that feeds the radio frequency energy produced by the transmitter. The zone of possible undesirable effects of EMR produced by

China conditionally he can be divided into two parts. The first part of the zone is the area of the RRC itself, where radio transmitters and all services that ensure the operation of AFS are located. This area is protected and is only accessible to personnel specialized in the maintenance of transmitters, switches and AFS. His second part of the zone is the area adjacent to the MRC, which has unrestricted access and may be populated with various residential properties. In this case, there is a risk of exposing the resident population of that part of the zone.

High EMR values are observed within the region and often outside the sites of low-, medium-, and high-frequency (PRTS LF, MF, and HF) transmission centers. A detailed analysis of the electromagnetic environment in the RRC region shows the extreme complexity associated with the individual nature of the EMP intensity and distribution at each radio center. In this regard, such special investigations are performed for each individual OCP.

A widespread source of EMR in populated areas is radio transmission centers (RTTCs) that emit VHF and UHF ultra-high frequencies into the environment.

Satellite connection. Satellite communication systems consist of transmitting and receiving stations on Earth and satellites in orbit. The radiation pattern of a satellite station antenna has a prominent, narrowly directed main beam, called the main lobe. The energy flux density of the main lobe of the radiation pattern can reach hundreds of W/m near the antenna and can produce significant field strengths even at great distances. For example, a station PG1E operating at a frequency of 2.38 GHz and with a power of 225 kW at a distance of 100 km he produces 2.8 W / m2. However, the energy spread of the main beam is very small and occurs most in the area where the antenna is located.

There are two possible hazardous exposures:

- directly into the area where the antenna is located
- when approaching the axis of the main beam along its entire length.

Radar system. Radar stations are usually equipped with mirrored antennas and have a narrowly directed radiation pattern in the form of beams directed along the optical axis. Radar systems operate at frequencies from 500 MHz to 15 GHz, but individual systems can operate at frequencies up to 100 GHz. The electromagnetic signals they produce are fundamentally different from emissions from other sources. This is because the periodic movement of the antenna in space causes a spatial discontinuity in the radiation. Temporary discontinuities in irradiation are due to periodic behavior of the radar with respect to radiation. The operating time in different operating modes of radio devices can be calculated from several hours to a day. So for a weather radar with a 30 minute intermission, radiation, and a 30 minute break, the total operating time does not exceed 12 hours, although in most cases airport radar stations operate around the clock. increase. The width of the radiation pattern in the horizontal plane is typically a few degrees and the exposure time during inspection is tens of milliseconds.

Weather Radar can generate about 100 W/m2 PES per irradiation cycle at a distance of 1 km. An airport radar station produces a PES of about 0.5 W/m2 at a distance of 60 m. Marine radars are installed on all ships and usually have an order of magnitude lower transmit power than airfield radars, so the PES scans produced at distances of several meters do not exceed 10 W/m2 in normal mode.

Improved radar performance for various purposes and the use of highly directional omnidirectional antennas greatly increase EMP intensity in the microwave range, creating large areas of high energy flux density on the ground.

- Adverse Factors conditionally divide him into two groups.

- Non-Specific - These are factors that occur in this type of activity, but can also occur in other types of activity.

Non-Specific Hazards:

1 Pulsed X-ray radiation (tested by operator near monitor)

2. Influence of unfavorable microclimate environment. Temperatures rise with mobile radar devices, especially in the summer. The metal walls are heated and the equipment raises the temperature inside the cabin. Workers must control water and salt regimes, food, clothing must be breathable and vapor-permeable, and underwear made of natural fabrics must be worn.

3. Noise and vibration from equipment (diesel installations on mobile radar installations)

4. Harmful chemical contamination. These include products of incomplete combustion of fuels, with CO being the most harmful. Operating electronic equipment also produces nitrogen oxides, ozone (a powerful oxidant for the body), and anthropogenic pollutants (mercaptans, hydrogen sulfide, carbon dioxide, etc.).

5. High mental stress of staff.

6 High current action - electric shock hazard.

7. Violation of work and rest rules

Specific hazards:

Electromagnetic radiation is a specific hazard. Electromagnetic radiation under radar conditions is used and can be parasitic.

Used (should) - Coming from the antenna, anyone standing in the coverage area of the antenna is exposed to radiation (technicians working on setting up equipment when in contact with an open generator, a person sitting at a monitor, and a mobile station - respectively). In the area of effect of the antenna, not only the military, which is not part of the radar, but also all local residents are exposed to radiation.

Parasitic (shouldn't be, but they are) - come from various devices - from EMP generators, feeder paths. Applies to employees. Occurs when the airtightness is broken when radiation enters the room and affects personnel.

CHAPTER VI. LABOR PROTECTION

6.1. Dangerous and harmful occupational safety factors for unmanned aerial vehicles

This paper examines the process of creating a digital system for automatic control of unmanned aerial vehicles. An unmanned aerial vehicle is an aircraft that flies and lands without a pilot on board. Therefore, automatic controls should be designed so that a person has little contact with his UAV. The automated UAV control system considered in the paper ensures the accuracy and smoothness of UAV movements as controlled by an electric remote control. To ensure proper operation of the electrical equipment in this system, personnel must follow all electrical and safety instructions.

To avoid injuries, malfunctions, emergencies, occupational diseases and equipment failures, those involved in adjustments, integration and repair must follow clear instructions. Persons over the age of 18 who have passed a medical examination and have no medical contraindications, have undergone special training, accreditation and relevant certificates, have undergone introductory training, on-the-job training and fire safety training in labor protection, electrical maintenance systems are allowed to be used independently. Employees who maintain electrical systems should have appropriate electrical safety groups. Know and be able to apply safety rules as far as the performance of the work requires.

When setting up, testing, and debugging electrical equipment, the rules for operating electrical equipment, safety rules for operating consumer electrical equipment, and technical processes must be strictly adhered to.

When working with electrical equipment, there are many dangerous and harmful factors for the personnel who maintain it. Some of them:

- electric shock;
- falling while performing work at height;
- increased air mobility;

- increased level of static voltage;

- burns during the performance of work on the repair of power cables (heating of the cable mass);

- injury by rotating parts of electric drives, parts of machines and mechanisms;

- electric arc burns during short circuits;

- the electric field strength is more than 5 kV/m;

- step and applied voltage;

- increase or decrease in ambient temperature;

- traffic in the working area, during the location of substations and substations next to roads and other transport highways;

- insufficient lighting of the working area;

- action of chemicals (acetone);

- insufficient illumination of the working area.

Parts of tools that are isolated and used for servicing electrical equipment must be made of conductive materials.

When working in an explosive zone, the use of materials or tools that can cause sparks is prohibited.

For work in the dark period, for local lighting of the area where work is being carried out, battery lights with a voltage of up to 12 V in explosion-proof form are used in areas with an increased risk of explosion.

It is very important to observe safety regulations when using electrical equipment. Malfunctions found in electrical equipment should not be ignored. Such careless attitudes can lead to injuries of varying severity, and even death, especially to ourselves.

Occupational safety is greatly influenced by the environment in which electrical systems are operated. Aggressive gases and vapors can destroy insulation in electrical equipment, reduce electrical equipment resistance and create the risk of stress transfer to metal structures. It is affected by heat, humidity and conductive dust.

Rooms in which electrical equipment is operated fall into three main categories.

- Particularly Dangerous Facility;

- A facility that is not at increased risk.

Facilities with high risk of electric shock are characterized by the presence of any of the following conditions:

- Humidity (rooms where the relative humidity of the air does not exceed 60% and does not exceed 75%).

- Conductive dust (technical or other dust can adhere to wires and penetrate machines and equipment);

- Conductive floors (metal, earth, reinforced concrete, brick);

- Increased air temperature (+35 ° C and above in the long term, +40 ° C in the short term); possibility of contact.

A particularly hazardous space is characterized by the presence of one of the conditions that constitute a specific hazard. Or when two or more conditions that increase risk coexist.

Non-increased hazard facilities are characterized by no increased hazards or conditions that create special hazards (such as dry control rooms).

Analysis of electrical trauma distinguishes between four main causes of electrical injury. The main causes of electrocution deaths in Ukraine are organizational and technical.

Most Important Organizational Reason:

– Ineffective supervision – Departmental and official control over compliance with safety requirements.

- No or poor quality training on occupational health and safety issues.

- Lack or omission of health examinations for electrical personnel.

– Violation of the requirements of standards, norms related to the operation of electrical equipment; – Non-compliance with labor protection measures;

- Violation of technical regulations.

- Violation of regulations, planning and repair work.

- Inadequate Technical Supervision for Dangerous Work

Technical reasons include:

– Malfunction of Electrical Installations;

– Structural Defects in Equipment.

- Lack of personal protective equipment.

- Absence of signaling device.

Health and hygiene reasons include:

– Poor or unreasonable lighting.

- Increased noise level;

– Inadequate microclimate conditions;

- Presence of radiation.

Psychophysical reasons include:

- Worker misdemeanor due to fatigue.

- Discrepancies between the employee's psychophysiological or anthropometric data and the work performed.

An analysis of accidents at work shows that the risk factor for maintenance personnel of electrical equipment is electric shock. And the main cause of electric shock is the appearance of voltage where it should not be. The reason for this is the violation of the insulation of cables, wires and windings. Possibility of touching uninsulated parts carrying electricity. This happens when terminals and busbars are placed at improper heights. The formation of an electric arc between a conductive part and a person.

Every year in Ukraine, approximately 1,500 people die from electric current. The largest number of cases of electrocution, including those with fatal consequences, occur during the operation of electrical installations with a voltage of up to 1000 V, which is due to their distribution and relative availability for almost everyone who works in production. Cases of electrocution during the operation of electrical installations with a voltage of more than 1000 V are infrequent, which is due to the small distribution of such electrical installations and their maintenance by highly qualified personnel.

Analysis of accidents related to the action of electric current allows dividing the main causes into groups:

- accidental contact with live parts;

- voltage on metal parts of the equipment;

- mistakenly connecting the equipment under voltage during maintenance and preventive work on it;

- the occurrence of a step voltage on the surface of the earth on which a person is located

Each of the presented groups includes specific dangerous factors, namely:

- violation of the rules of installation, technical operation and safety of electrical installations;
- lack of reliable means of protection;
- imperfection of electrical installation design;
- performing electrical installation and repair work under voltage;
- malfunction of insulation of current-conducting parts of the system;
- wrongly connecting the equipment under voltage during regular maintenance work;
- low-skilled training by workers who use manual electric machines;
- use of cables and wires that do not meet production conditions.

6.2 Technological measures to reduce the impact of harmful production factors

The development of measures to reduce hazards implies the organization of labor protection management. As a result, the risk of injury, accidents, death, occupational diseases and emergencies can be reduced.

Order of the Ministry of Social Policy of Ukraine No. 2072 dated December 28, 2017 "Requirements for safety and health protection during production and use

The principles for ensuring the safety of activities can be characterized by the following groups of measures:

Technical Measures - technical measures that make it possible to ensure safe and hazard-free conditions for the performance of assigned tasks, the introduction of new equipment, devices and devices. Technical measures can be divided into two broad groups: Parts:

- Aid in isolating existing electrical systems
- Tool when working on live parts.

The first group of measures includes:

- Drive mechanical block to perform shutdown, remove fuse, disconnect end of power line.

- Earth installation (Earth tester switch or portable earth installation).

The second group of measures includes:

- Work on behalf of at least two of her workers with electrical protective equipment and ensure that the safe areas of the workers are monitored.

Regulatory and methodological measures include:

- Development of manuals and recommendations.
- Development of regulatory frameworks;
- Development of educational methods.
- Development of H&S section in job description.

Organizational activities include:

- Management of the technical state of equipment.
- Control of compliance with the requirements of official documents on labor protection.
- Providing Appropriate Safety Signage.
- Provide individual and collective protection measures for workers.

Sanitary and sanitary measures include:

- Controlling the effects of factors of production on workers' health.
- Plan of measures to improve sanitary and sanitary conditions;
- Certificate of sanitary and technical conditions of working conditions;

Socio-economic measures include:

- Social insurance of employees by employers
- Financing of labor protection measures.
- Compensation of workers by employers in case of amputation.

Treatment and preventive measures include:

- Health care of workers at work.
- Medical assistance for victims of occupational accidents.
- Conducting (preliminary and periodic) health examinations of employees.

Scientific events include:

- Accident location and response plan.

- Evaluation of the effectiveness of labor protection controls.

- Emergency simulation and development of measures to avoid it.

The development of measures to reduce hazards implies the organization of labor protection management. As a result, the risk of injury, accidents, death, occupational diseases and emergencies can be reduced.

Order of the Ministry of Social Policy of Ukraine No. 2072 dated December 28, 2017 "Requirements for safety and health protection during production and use

The principles for ensuring the safety of activities can be characterized by the following groups of measures:

Technical Measures - technical measures that make it possible to ensure safe and hazard-free conditions for the performance of assigned tasks, the introduction of new equipment, devices and devices. Technical measures can be divided into two broad groups: Parts:

- Aid in isolating existing electrical systems
- Tool when working on live parts.

The first group of measures includes:

- Drive mechanical block to perform shutdown, remove fuse, disconnect end of power line.
- Earth installation (Earth tester switch or portable earth installation).

The second group of measures includes:

- Work on behalf of at least two of her workers with electrical protective equipment and ensure that the safe areas of the workers are monitored.
- Industry regulations for electrical safety. Cross-industry prescriptive electrical safety legislation does not preclude the development of industry-specific NAs where appropriate. At the same time, sectoral NAs must not interfere with cross-sectoral NAs to reduce safety levels.
- Corporate regulatory action on electrical safety issues. Basically, these are instructions on the safe maintenance of electrical installations and the execution of work on them, developed and approved according to current requirements.

According to the State Standards for Electrical Safety and the Regulations for the Arrangement of Electrical Installations, the nomenclature of types of protection against electric shock includes the following means and methods:

He can distinguish three systems of means and means for ensuring electrical safety.

- system of electrical protection devices;
- Systems of organizational and technical means and means.

Main technical measures and measures to ensure electrical safety:

- Isolation of live parts.
- Protective disconnection of electrical networks;
- Equipotential coupling;
- Compensation for capacitive ground fault currents;
- Live parts not available.

Insulation of live parts. Ensures the technical operability of electrical installations, reduces the possibility of falls of persons, short circuits between the ground of electrical installations and the body, uninsulated charging of electrical installations powered by networks separated from earth It reduces the current that flows through a person when the part is touched. A phase with damaged insulation is present.

DSTU B V.2.5-82: 2016 "Electrical safety in buildings and structures. Requirements for protective measures against electric shock" distinguishes between insulation.

- also - protects against electric shock if insulation is damaged.
- double — Consists of work and supplements.
- Reinforced - Improved working insulation that offers the same protection as Double.

Safe separation of electrical networks. The total resistance of the insulation of the wires of an electrical network to earth and the capacitive component of the earth leakage current depend on the length of the network and its branches. As network clutter increases, capacitance increases and resistance decreases. Isolating such a large network into separate electrically isolated components using a transformer with a conversion factor equal to 1 increases the insulation resistance and reduces the capacitance, thus reducing the safety level is improved.

Equipotential bonding. This reduces the contact voltages that can occur on the stage during the operation of electrical installations or when people are exposed to these voltages in other situations. serve the purpose. Equipotential bonding occurs when the potential of a supporting surface on which a person can stand is raised to the potential of a live part that can be touched.

Compensation for the capacitive part of the ground fault current. Current in single-phase circuits, current through a person, is estimated by active and capacitive components. The capacitance of each core of a 6...35 kV overhead line network is approximately 5000...6000 pF/km and the capacitive current per 1 kV network voltage and 1 km network length is 2.7...3.3 mA. A network of wooden supports. For networks on metal supports, this current increases by 15%. In large branch networks, the capacitive portion of the current flowing through a person can exceed the active portion and can determine the severity of an electric shock to a person.

Prevent access to live parts. Statistics on electric shock show that the majority of electric shocks are associated with contact with live parts of electrical equipment (approximately 56%). For installations up to 1000, the main measures to keep live parts inaccessible are protective fences, closed switching devices (package switches, complete starting devices, remote electromagnetic devices for controlling power consumers, etc.) is used. Insulated live parts that are protected from accidental contact beyond the reach of tools, various height adjustments, third-party access restrictions to the electrical room, etc.

System of electrical shielding equipment:

DNAOP 1.1.10-1.07-01 "Rules for using electric shielding gadgets" (hereinafter the Rules) is a legitimate regulatory document, which lists the protecting gadgets, necessities for his or her design, scope and requirements of tests, the system to be used and storage, equipping with shielding gadgets for electric installations and manufacturing crews. The method of safety utilized in electric installations have to meet the necessities of present day nation requirements, technical situations for his or her design, etc.

Electrical safety method is divided into insulating (insulating rods, clamps, pads, dielectric gloves, etc.), shielding (fences, shields, screens, posters) and shielding (goggles, helmets, protection belts, gloves for hand safety).

System of organizational and technical measures and method:

The most important organizational and technical measures and method for the prevention of electrical accidents are regulated via way of means of DNAOP 0.00-1.21-98 "Rules for the secure operation of electrical installations of consumers", in step with which the duty for the company of secure operation of electrical installations rests with the owner.

By law, have to:

- the primary organizational and technical measures and method for the prevention of electrical accidents are regulated via way of means of DNAOP 0.00-1.21-98 "Rules for the secure operation of customer electric installations", via way of means of which duty for the company of secure operation of electrical installations rests with the owner;

- create and personnel an electrical provider in step with needs;

- to create such situations on the corporation that the personnel who're answerable for the protection of electrical installations, according with the present day necessities, perform their inspection and checking out in a well timed manner;

- increase and approve activity commands for electric provider employees and commands for secure overall performance of labor in electric installations, considering their characteristics.

6.3. Calculation of contour protective grounding for electrical installation

General electrical safety requirements must comply with DSTU 7237: 2011. A system of occupational safety norms. electrical security. General requirements and nomenclature for types of protection. Protective earth is used to protect against electric shock. The purpose of protective earthing is to reduce the current flowing through a person (Il) who contacts the chassis of the grounded diagnostic equipment when there is U_{cont} (contact voltage) as a result of damage or supporting parts.

Laboratory circuit calculations are reduced to determining the number of vertical grounding devices and the length of the connecting bar. The grounding consists of a tubular vertical grounding device, connected with a metal strap. The protective earth resistance must meet the requirement of R3 <. 4 ohms for systems with low leakage current and voltages up to 1000 V.

Finding the resistance of the ground circuit

1. Under good conditions, the resistance of a single earthing device is determined by the formula:

$$R_{ст} = 0.366\frac{p}{l}\left(lg\frac{2l}{d} + \frac{1}{2}lg\frac{4H+l}{4H-l}\right), \qquad (1)$$

where we will choose a rod as a grounding device.

Length: l = 1.5 (m)

Diameter: d = 0.016 (m)

The distance from the surface to half the length of the rod: H= 0.85 (m)

Specific resistance of the grant: p= 102 Ohm*m

Substituting the data into formula 1, we get the following values:

$$R_{ст} = 0.366\frac{10^2}{1{,}5}\left(lg\frac{2*1{,}5}{0{,}016} + \frac{1}{2}lg\frac{4*0{,}85+1{,}5}{4*0{,}85-1{,}5}\right) = 60 \text{ Ом} \qquad (2)$$

The number of single grounding devices n is calculated by the formula:

$$n = \frac{R_{CT}}{r_{к.з} * \eta_{CT}}, \qquad (3)$$

where: rk.z. - the value of contour grounding, which normalizes, according to PUE-86

rk.z. = 4 ohms;

ὴст - - coefficient of use of a single earthing conductor for rods;

ὴст = 0.66.

According to the following data, we get:

$$n = \frac{R_{ст}}{r_{к.з} * \eta_{ст}} = \frac{60}{4*0{,}66} = 22 \text{ шт} \qquad (4)$$

The resistance of the connecting strip connecting single grounding devices:

$$R_{пол} = 0.366\frac{p}{l}\ lg\frac{2*l^2}{b*H}\ , \tag{5}$$

where: l is the length of the strip;

l=a*n=79.2 m;

a- the distance between the rods;

a=3.6 m;

H - the depth of laying the strip;

H=0.1 m.

$$R_{пол} = 0.366\frac{10^2}{79,2}\ lg\frac{2*79,2^2}{0,04*0,1} = 3\ Ом \tag{6}$$

The resistance of artificial contour grounding is determined by the formula:

$$R_{к.з.} = \frac{R_{ст} * R_{пол}}{R_{ст} * \eta_{пол} + n * R_{пол} * \eta_{ст}}\ , \tag{7}$$

where: ὴ - the coefficient of use of the connecting strip in the circuit of vertical electrodes;

ὴpol = 0.4

$$R_{к.з.} = \frac{60 * 3}{60 * 0,4 + 22 * 3 * 0,66} = 2,66\ Ом \tag{8}$$

The calculated value (the resistance of the grounding circuit does not exceed 4 Ohms, therefore it meets the requirements of electrical safety.

6.4. Ensuring fire safety during operation of electrical equipment

General electrical safety requirements must comply with DSTU 7237: 2011. A system of occupational safety norms. electrical security. General requirements and nomenclature for types of protection. Protective earth is used to protect against electric shock. The purpose of protective earthing is to reduce the current flowing through a person (Il) who contacts the chassis of the grounded diagnostic equipment when there is Udot (contact voltage) as a result of damage or supporting parts.

Laboratory circuit calculations are reduced to determining the number of vertical grounding devices and the length of the connecting bar. The grounding consists of a tubular vertical grounding device, connected with a metal strap. The protective earth resistance must meet the requirement of R3 <. 4 ohms for systems with low leakage current and voltages up to 1000 V.

Finding the resistance of the ground circuit

1. Under good conditions, the resistance of a single earthing device is determined by the formula:

Portable dry chemical extinguishers VPS-6, VPS-10, VP-2, VP-2B, VP-8B, VP-5, VP-10 are intended for extinguishing fires in energized electrical installations. The Fire Extinguisher VP-6 (Fig. 6.1) is intended to extinguish various classes of solid, liquid and gaseous substances depending on the type of powder used in the extinguisher. Not recommended for fire extinguishers that may fail if exposed to powder. (b) Computer equipment, etc.

Fig. 6.1 - Powder fire extinguisher VP-6

A fire extinguisher consists of a body, charge (powder), suction pipe, gas cylinder, gas pipe with aerator, pressure gauge, transport handle, release lever, hose and fuse.

6.5. Safety instructions for the operation of electrical equipment

1. The instructions apply to all departments of the company.

2. According to these instructions, the personnel shall be trained before starting work (initial training), after which he shall be trained every three months (retraining).

3 Owners must insure their staff against accidents and occupational diseases.

4. Failure to comply with this instruction will subject staff to disciplinary, material, administrative and criminal liability.

5. Persons under the age of 18 who have passed a medical examination, have no contraindications, have obtained special training, certification and relevant certificates, and have received introductory training, on-the-job training and training in occupational safety. It is permissible to maintain the electrical system independently.

6. Appropriate electrical safety groups are required for employees who service electrical equipment.

7. The employee's knowledge verification certificate is a document certifying the right to work independently in electrical installations in positions designated by the profession.

8. When performing official duties, employees must carry a knowledge test certificate. An employee cannot work without a certificate or with an expired certificate for knowledge verification.

9. Written exam pass certificates will be replaced if there is a transfer or no vacancies.

Safety Requirements Before Working:

1. Check and wear personal protective equipment (special clothing, special shoes, etc.). Electrician's overalls should be tight-fitting and closed, as the hem and sleeves can get caught in mechanisms and moving parts of the machine. A hat must be worn on the head.

2. Inspect the workplace to check the proper operation of the ventilation system, the absence of malfunctions in the operation of electrical equipment requiring maintenance, the availability and maintainability of means of fire extinguishing, means of collective protection, the availability of tools necessary for the work.

3. Clear the work area by bystanders, remove unnecessary objects and materials from the work area, delineate the work area, and post safety signs.

4. Before undertaking any high-risk work to be carried out pursuant to an order or permit order, ensure that the documentation is properly prepared, receive targeted instructions, take action. Regulation requirements for the safe operation of consumer electrical installations.

Safety requirements during work:

1. It is forbidden to open switch cabinets, devices individually, repair electrical devices, open (remove) locks and protective devices.

2. Use electrical protective equipment as required, if indicated. Protective equipment must be tested and have a special stamp indicating that the test has been carried out.

3. Electrical personnel working near live parts should position these live parts only on one side in front of them. Working with live parts behind or on either side of the operator is prohibited.

4. Approved list for work with or without voltage disconnection performed by an electrician at a fixed location during one shift according to the regulations for electrical equipment up to 1000 V. Work done to order.

5. All secondary windings of current and voltage measuring transformers must be permanently grounded when working on circuits of measuring devices and relay protective devices.

6. It is not permitted to remove the protection of parts of an electric motor that rotate while the electric motor is running.

Post-Work Safety Requirements:

1. Turn off electrical equipment and devices used during work.

2. Collect parts, materials, tools and devices, bring them into proper condition (clean, wipe) and remove tools and devices at designated locations.

3 Clean the workplace, collect trash in the trash can, and take it out of the room to the designated area.

4. Take off the work clothes and other personal protective equipment used during the work and store them in the designated place.

Conclusion:

1. The main legislative act on labor protection is the Ukrainian law. The Population and Labor Law (KZpP) and the State Intersectoral and Sectoral Normative Law bind all state and non-state institutions throughout the Ukrainian territory.

2. Accumulated statistical information shows that electrocution is one of the main causes of electrocution, so due care should be taken to establish and comply with occupational safety regulations when working with electricity. It is important. Care is taken to calculate the contour grounding of areas where electrical equipment is located.

3. Consider the main groups of precautions to avoid injury. Indicates measures and countermeasures to prevent electric shock, injury, and accidents. The most important technical and organizational measures for fire protection were considered. Consider the structure of a fire extinguisher, which is the primary extinguishing medium.

4. The basic procedures for operating various types of electrical equipment are described and details are considered for creating a regulatory framework.

CONCLUSIONS

In this work we have considered prediction and routing modules, neither of which are part of the traditional concept of planning and control modules. However, with our proposed broader understanding of the planning and control structure, forecasting and routing create inputs for traditional traffic planning. Therefore, they are included in the broader planning and control structure.

Traffic forecasting is abstracted to a two-level classification of behavior and trajectory generation problems. Our proposed approach is path-level routing, according to which the UAV follows the UAV to its destination through sequences of defined trajectories.

In the course of writing the work, an interface was developed to build a flight task that can be used to load, track key metrics from the UAV, and adjust the missions of the flight task.

Advanced QT/Qml frameworks were used, allowing the software product to be used on different operating systems, which adds flexibility in the use of system components.

There were also developed:

- Flight task construction model flowcharts;
- Algorithms for correcting the UAV route;
- A method for structuring and loading flight task missions;
- A method for structuring and reading parameters from the UAV;
- Satellite substrate interface for correcting build points.

The developed interface and flight task routing methods showed high reliability, usability and good results.

REFERENCES

1. Paden, B., Cap, M., Yong, S. Z., Yershow, D., and Frazzolo, E. 2016. A survey of motion planning and control techniques for self-driving urban vehicles. IEEE Transactions on Intelligent Vehicles, 1(1) p. 33-55. DOI: 10.1109/ TIV.2016.2578706.

2. Buehler, M., lagnemma, K., and Sanjiv, S. (eds.). 2009. The DARPA Urban Chal-lenge: Autonomous Vehicles in City Traffic. Springer Tracts in Advanced Ro-botics. DOI: 10.1007/978-3-642-03991-1.

3. Montemerlo, M., Becker, J., Bhat, S., Dahlkamp, H., Dolgov, D., Ettinger, S., Haeh-nel, D., Hilden, I., Hoffmann, G., Huhnke, B., Johnston, D., Klump, S., Langer, D., Levandowski, A., Levinson, J., Marcil, J., Orenstein, D., Paefgen, J., Penny, I., Petrovskaya, A., Pflueger, M., Stanek, G., Stavens, D., Vogt, A., and Thrun, S. 2008.

4. Junior: The Stanford entry in the urban challenge. Journal of Field Robotics: Special Issue on the 2007 DARPA Urban Challenge, 25(9), p. 569-597. Gindele, T., Brechtel, S., and Dillmann, R. 2010. A probabilistic model for estimating driver behaviors and vehicle trajectories in traffic environments. In Proceedings of the 13th International IEEE Conference on Intelligent Transportation Systems (ITS), Madeira Island, Portugal, p. 1625 - 1651. DOI: 10.1109/ITSC.2010.5625262.

5. Aoude, G. S., Desaraju, V. R., Stephens, L. H., and How, J. P. 2012. Driver behavior classification at intersections and validation on large naturalistic data set. IEEE Transactions on Intelligent Transportation Systems, 13(2), 724-736. DOI: 10.1109/tits.2011.2179537.

6. Lefevre, S., Gao, Y., Vasquez, D., Iseng, H. E., Bajsy, R., and Borrelli, F. 2014. Lane keeping assistance with learning-based driver model and model predictive control. In Proceedings of the 12th International Symposium on Advanced Vehicle Control, Tokyo, Japan.

7. Gadepally, V., Krishnamurthy, A., and Ozguner, U. 2014. A framework for estimating driver decisions near intersections. IEEE Transactions on Intelligent Transportation Systems, 15(2), p. 637-646. DOI: 10.1109/TITS.2013.2285159.

8. Gadepally, V., Krishnamurthy, A., and Ozgüner, U. 2016. A Framework for Estimating Long Term Driver Behavior. arXiv, 2016; arXiv:1607.03189. 19.

9. Bonnin, S., Weisswange, T. H., Kummert, F., and Schmuedderich, J. 2014. General behavior prediction by a combination of scenario-specific models. IEEE Transactions on Intelligent Transportation Systems, 15(4), p. 1478-1488. DOI: 10.1109/TITS.2014.2299340.

10. Kumar, P., Perrollaz, M., Lefevre, S., and Laugier, C. 2013. Learning-based ap. proach for online lane change intention prediction. In Proceedings of the IEEE Intelligent Vehicles Symposium (IV 2013), Gold Coast City, Australia, p. 797-802. DOI: 10.1109/IVS.2013.6629564.

11. Hsu, C. W., Chang, C. C., and Lin, C. J. 2003. A Practical Guide to Support Vector Classification. Department of Computer Science, National Taiwan University.

12. Krizhevsky, A., Sutskever, I., and Hinton, G. E. 2012. Imagenet classification with deep convolutional neural networks. In Advances in Neural Information Processing Systems (p. 1097-1105).

13. Medsker, L. R. and Jain, L. C. 2001. Recurrent neural networks. Design and Ap-plications, 5.

14. Sak, H., Senior, A., and Beaufays, F. 2014. Long short-term memory recurrent neural network architectures for large scale acoustic modeling. In Fifteenth Annual Conference of the International Speech Communication Association.

15. Dilkstra's Algorithm. https://en.wikipedia.org/wiki/Dijkstra's algorithm. 103

16. A° Algorithm. http://web.mit.edw/eranki/www/tutorials/search/. 103

17. https://en.wikipedia.org/wiki/Geographic_coordinate_system

18. Rasmussen, C. E. 2006. Processes for Machine Learning. The MIT Press.