Design and Development of Efficient Guidance System Using Multi-functional Robot with Quadcopter

Moustafa M. Kurdi, Aliaksei K. Dadykin, and Imad A. Elzein
Belarusian National Technical University, Minsk, Belarus
Email: mostafa.alkirdi@aut.edu, alex_05_07@rambler.ru, imad.zein@liu.edu.lb

***Abstract*—This paper introduces the design and development of QMRS. QMRS (Quadcopter Mobile Robotic System) is a real-time obstacle avoidance capability in Belarus-132N mobile robot with the cooperation of quadcopter Phantom-2. The main objective of this research paper is to identify the method involving the use of vision and image processing system from both robot and quadcopter; analyzing path in real-time and avoiding obstacles based-on the computational algorithm embedded inside the robot. In addition, it focuses on the full coordination between robot and quadcopter by designing an efficient wireless communication using WIFI. QMRS increases the efficiency and reliability of the whole system especially in robot navigation, image processing and obstacle avoidance due to the help and connection among the different parts of the system.**

***Index Terms*—quadcopter mobile robot system, quadcopter, multi-functional mobile robot, image processing, wireless communication**

I. Introduction

A robot is an electro-mechanical device designed to accomplish variety of tasks in different aspects of our life.

Service robots mainly designed to serve humans in multilateral sectors of education, medical, military, security, emergency cases, entertainment, research, production and agriculture [1].

Unmanned Ground Vehicles (UGV), often called ground robots, which are used both in military and civilian purposes, for the protection and rescue of people in the performance of tasks in life-threatening conditions. Generally, these ground robots used to produce work with explosive ordnance and mine clearance, reconnaissance, search and rescue operations, inspection of buildings and infrastructure, patrolling as well as freight traffic.

Today, Unmanned Ground Vehicles have the ability to self-navigation, since they are based on data received from the onboard sensors, image processing and GPS. Unmanned Ground Vehicle (UGV) is able to detect static and moving obstacles and find the best and shortest path to get through a number of given points to the target.

There are many obstacles (rock, big stones, buildings, mountains, cars and civilians) at outdoor environment which considered as a problem for each mobile robot. To overcome this dilemma, we designed and developed a Quadcopter Mobile Robotic System for agriculture purpose application to help emergency situations (in the liquidation of the threat of explosion, poisoning, fire-fighting and in agriculture for spraying pesticides). The method involves using domestic serial chassis mini-tractor Belarus-123N includes different functions like capturing real world data using digital image processing used to detect its obstacle which is found in its path. To increase the efficiency of mobile robot, we use Phantom-2 Vision Quadcopter to help the mobile in navigation and in direction.

Quadcopter Mobile Robotic system is real-time obstacle avoidance represented by using an effective wireless communication between Mobile Robot and Quadcopter. There are two mechanisms to communicate with the robot and quadcopter (wireless communication using Wi-Fi and wired technology channel up to 10 meters for configurations) [2].

For detecting and avoiding obstacles in their paths, robots should be able to monitor and adapt their surrounding by embedding system to analyze its view and environment [3]. Distinctive cameras from both Mobile Robot and Quadcopter and sensors are used to detect obstacle [4].

In regards to that, we are designing a Quadcopter Mobile Robotic system which performs multiple operations like motion in different direction, avoid and detect obstacles, perform different tasks (fire-fighting and removable arm).

For navigation and position, mobile robot has to solve two problems: To determine the current location, and build path of the upcoming journey, free from obstacles.

The first problem is solved by a system of visual image positioning from robot and quadcopter. Image with moving robot is analyzed to highlight specific points of their unique ensemble allows for the repeated analysis of the image, the new range of travel, to reliably determine its location. The problem of detection of obstacles encountered on the way of movement of the robot is very typical. However, robots copes with this task stereo video camera. Depth map construction space in front of the stereo cameras, and accordingly, in the way of movement of the robot, allows the robot to choose the path free of obstacles directions.

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This article is concentrating on an international project (Belarus, Kazakhstan and Azerbaijan) to create a multifunctional Quadcopter Mobile Robotic system based on the chassis serial domestic mini-tractors and commercial quadcopter to introduce the concept of controlling such a robot using wireless communication [5].

II. Remote Control Mobile Robot

Modern robotics were introduced in the 60-70th of the last century as a response to the overall automation of requests when the resulting compound manned manipulators systems of numerical control machine tools and other technological equipment were automatic machines of a new type. They were robots with programmed control - the first generation of robots.

The success of the first robot has caused the rapid growth of demand for them, and therefore the requirements for their abilities. They began to develop robots with combined control, in which the control software is complemented by the management of the human operator - robots intermediate one and a half generation supervisory, and then the interactive controls.

In those years, the first step began to make the theory of adaptive management. One of the first machines with this control became adaptive robots. This second-generation robots, equipped with sensory.

With the development of adaptive control systems which were used in these methods of artificial intelligence. When these technologies are taken determines the position in the algorithmic maintenance management systems, formed a new third-generation robots - intelligent robots.

Conventionally, all mobile robot remote control methods can be divided into the following groups:

- Automation level (manual, semi-automatic, automatic transmission)
- Data transmission and processing method (wired, wireless (Wi-Fi), the combination)
- Navigation method (GPS, GSM, cameras, gyroscopes, accelerometers, sonar).

A. *Mobile Robot Control Modes*

At present, almost all unmanned (terrestrial, aerial, underwater) mobile systems have three control modes:

- Manual (all the functions are carried out by the operator of the mobile complex)
- Semi-automatic (part of the functions performed apparatus of the operator)
- Automatic (all functions are performed by the device).

1) Manual Mode: In this mode, remote manual control changes the direction of movement of the robot, which is often all, is one or two joysticks connected to the computer. The operator, sitting in the mobile control station in front of a computer screen, can "see" what is in front and to the side, and also determine the distance to objects, the depth of the ditches and the slope of the surface, using located on the mobile robot cameras, laser rangefinders, machine inclination sensors and other sensors is controlled via the radio or wire.

2) Semi-automatic Mode: In the semi-automatic, robot controller can automatically move to the object, and for the control takes the operator, or on the contrary, the operator responsible for the movement of the robot to the object and then puts the robot in automatic mode. Also, when operating in automatic mode and the situation occurs robot can send a signal to the control panel that the operator must be involved.

3) Automatic Mode: The greatest importance will certainly have modern methods of automatic control. The most typical of the mobile robot are management techniques, based on:

- Biological Principles
- Inductive method of self-organization models
- Robust control
- Discrete Time Model
- Fuzzy models
- Adaptive Resonance

B. *Belarus 132N Mobile Robot*

During the stage of designing and implementing the mobile robot, we address reliability and simplicity of design of the robotic system. We use platform chassis of tractors "Belarus-132N" [5]. Unmanned Ground Robot

Belarus-132N is an international project (Belarus, Kazakhstan and Azerbaijan) is a four-wheeled small-size unmanned ground terrain vehicle, dimensions 120 x 120 x 180 cm (length, width and height respectively), weighing about 500 kg.

The power and traction, originally designed for plowing the soil, it is sufficient to ensure that the movement of the trolley up to 500 kg, or clearing blockages with regular attachments.
Physical specifications allow to transport it in simple and small vehicle with a medium wheelbase or a conventional single-axle trailer. General view of the current prototype robotic system with the original attachments designed for firefighting, is shown in Fig. 1.

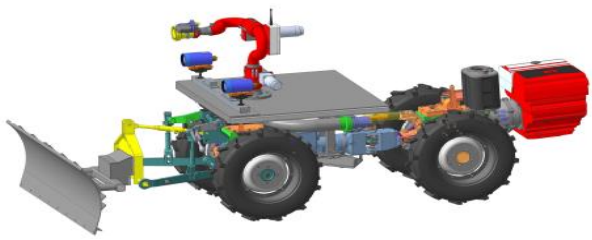

Figure 1. General view of the Belarus 132N robotic system.

The Belarus-132N Mobile Robot consists of the following systems and components: a video system for driving, positioning and navigation; mechatronic motion control system; on-board computer; telecommunication systems with a remote control unit; staff attachments.

The Belarus-132N Mobile Robot has two controls for operations such as remote control and semi-automatic control. The first one uses both wireless and wired technology to control the robot by an operator. The second one uses on-board video processing system for navigation and positioning.

Belarus-132N Mobile Robot has four types of motion control.

- *Driving forward* on the route.
- *Turning Left or Right*
- *Return with rotation*
- *Driving backward* (blind movement)

III. QUADCOPTER

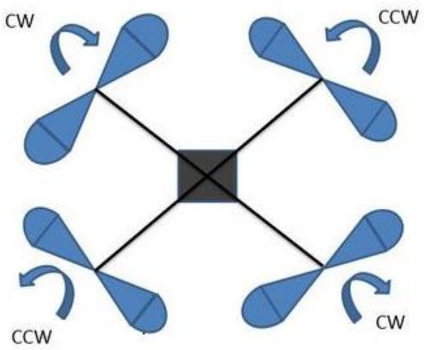

Figure 2. Rotating of rotors per axis of quadcopter.

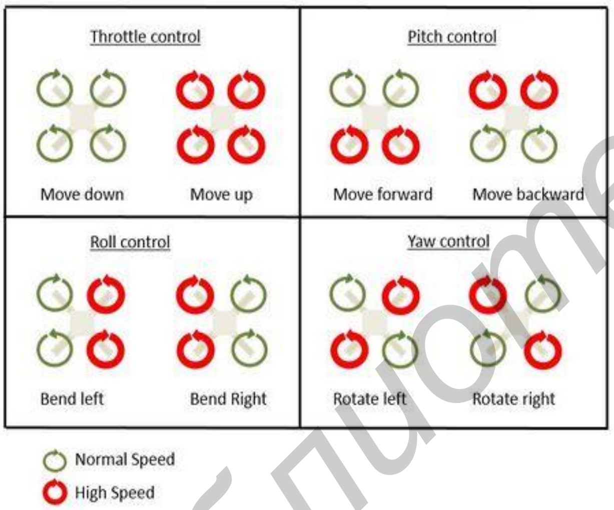

Figure 3. Different control mode related to the movement of quadcopter.

A **quadcopter** or quad-rotor is a multi-rotor helicopter that is departed and landed by four rotors. Quadcopter is a small Unmanned Aerial Vehicle (UAV) has significantly increased in recent decades. Quadcopter is one of the most successful vertical take-off and landing vehicle with autonomous flight control and stable hovering capabilities. These features have significantly increased the uses of Quadcopter in all researches in the universities including Electrical, Mechanical, Computer science, and Control system, Real-Time Embedded Systems, Robotics and Navigation.

The UAVs are usually used for military, research or civilian operations. The main applications in civilian operations are search and rescue operations, agriculture, fire control, search and rescue operations and inspection of critical areas [6].

A Quadcopter (Quad-rotor helicopter) is a multi-rotor aerial vehicle that is taken-off and lands by four rotors. It has two rotors per axes and each of the axes is aligned with the other where two rotors run clockwise (CW) and two rotors counter-clockwise (CCW) as shown in Fig. 2.

A wireless remote control is used to interact with the flight controller system for changing the flight path.

Quadcopter uses the Stable Mode. In this mode, data from accelerometer and gyro sensor is combined to calculate the quadcopter angle. Once the remote control stick is moved to non-idle location, the quadcopter angle is changed accordingly and held at the angle as shown in Fig. 3.

A. *Phantom-2 Vision Quadcopter*

Figure 4. General view of phantom-2 vision quadcopter.

TABLE I. SPECIFICATION OF PHANTOM-2 VISION QUADCOPTER

Battery	5200mAh LiPo
Weight	1160g
Hover Accuracy	Vertical: 0.8m; Horizontal: 2.5m
Max Yaw Angular Velocity	200 °/s
Max Tilt Angle	35 °
Max Ascent / Descent Speed	Ascent: 6m/s; Descent: 2m/s
Max Flight Speed	15m/s (Not Recommended)
Diagonal Length	350mm
Tilting Range of Gimbal	0 °-60 °
Operating Frequency	5.728GHz - 5.8GHz
Receiver Sensitivity (1%PER)	-93dBm
Working Voltage	80 mA@6V
Resolution	14 Megapixels
Sensor size	1/2.3"
Transmitter Power	7dBm
Power Consumption	5W

The specifications of Phantom-2 Vision Quadcopter are shown in the Table I.

Phantom-2 Vision Quadcopter is a lightweight, multi-functional integrated aircraft and camera with a camera remote-control by DJI VISION APP as shown in Fig. 4. Its range extender increases Wi-Fi distance to 300 m. Due to its reliability, Phantom-2 Vision Quadcopter use antivibration camera platform with single axis stabilization. It operates at low-voltage protection with virtual radar aircraft locator on mobile device. The image processing uses HD Video Recording (1080/p30 or 1080/60i) and save the sequence of image in JPEG picture formats.

IV. Proposed Work

Development and construction of Quadcopter Mobile Robotic Systems (QMRS) consists of two parts: Mobile Robot and Quadcopter. The robot is equipped with sensors and cameras used for surveillance operation in outdoor environment area. For surveillance we use image processing concepts. Image processing systems receive data from a variety of cameras and from Quadcopter to determine the distance to an object (obstacle) with the captured output to an external computer [7] to increase efficiency as shown in Fig. 5.

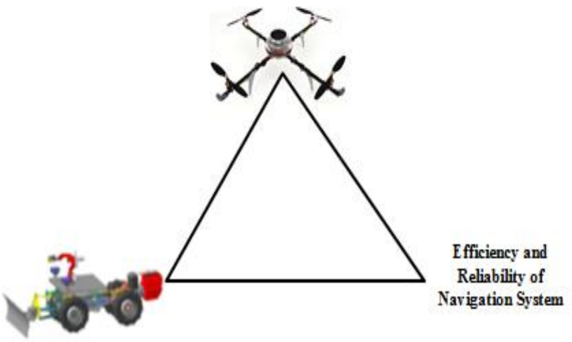

Figure 5. General view of quadcopter mobile robotics system (QMRS).

Thus, the present project of Quadcopter Mobile Robotic System has four main levels of computing modules: an external computer (user); on-board computer; multi-channel controller actuators; quadcopter. Each module was necessary to define the specification of functions, commands to initialize them, the service information data and inter-module interfaces [5].

A. Quadcopter Mobile Robotic System (QMRS)

Automatic detection and tracking of objects observed in a sequence of images is an actual problem, often occurring in the development of navigation systems manned and unmanned aircraft. The Quadcopter Mobile Robotic System consists of Quadcopter and Mobile robot by using image processing to determine the optimal route for mobile robot.

An essential requirement for the developed algorithm is the ability to implement it in the onboard data processing systems, enough effective approach to the automatic detection of objects in the conditions of uncertainty of the location and orientation.

B. Algorithm of Coordination QMRS System

The Quadcopter Mobile Robotic System detects, tracks any moving or stable objects in outdoor environment by using image processing system [8].

Each noticeable object in outdoor environment has following properties:

- Identifier - a unique number assigned to the new object detection. Number assigned to this object as long as there is no decision on the loss of the object;
- Coordinates the left edge of the object.
- Coordinates the top edge of the object.
- Width.
- Height
- Life Time - the number of frames of a video sequence in which the object was present since the first detection
- Object type.

The algorithm of QMRS system depends mainly on information from both quadcopter and mobile robot in order to increase efficiency [9].

Model of obtaining information from the environment must satisfy the following requirements:

- The availability of real resources (material, qualification) for its implementation.
- Corresponding to the relevant tasks.

On the basis of available material, qualification and other resources and by solving the main problem of obtaining the information model of the environment, we proposed the following models of sub-task and the corresponding script to solve it: "Investigation of area by a group of mobile robots by drawing up (specification) the plan, laying the route and implementation of navigation."

The composition of the group of robots involved of one main (or base) mobile robot (MBR) with quadcopters/s on board.

The algorithm of solving the problem and specification of functions of robots:

- MBR has modes of remote, semi-autonomous and autonomous control. On board carries the server on which the loaded geographic information system (GIS) with a digital map of the site location. (Similar map launched on computer operator remote PC). MBR has the GPS - receiver, which determines current coordinates on map; XY rotary video system that allows MBR and computer operator to control the movement and "to look round" during the stop, and other sensors of the current situation.
- The operator can control the MBR remotely (receiving video data from the board) or in semi-automatic mode, by specifying a point on a digital map, which must arrive, or reference point in the video frame in the direction of which it is necessary to move (or concerning which it is necessary to perform the movement). Data from the GPS-receiver is constantly updated, are linked to a digital map and compared with video analytics.
- In the simplest case, the quadcopter plays a supporting role by duplicating the rotary video system onboard the MBR. If necessary (or on command from the remote control) the quadcopter takes off and hovers over the robot at a height of 15-20 meters. Video data from quadcopters transmitted to the MBR server wirelessly, which increases visibility and allows operating

effectively the movement of remote control mode, and also serve for updating the situation on a digital map of the district site area. On command quadcopter performs automatic landing aboard. On board, the automatic problem-solver works quadcopters and connects to a source of recharging batteries.

In more complex version, on board is not one, but two quadcopters are in series one after another; according to the team circled they perform a predetermined portion of the perimeter, and return back to the MBR. Thus, the MBR receives much more information about the ground situation, but its automatic processing algorithms respectively increase dramatically, and there is a need for an exchange of information between the current quadcopters.

- Mobile robots can be controlled remotely by the operator, remotely or autonomously MBR. Optionally they can be equipped with video cameras, GPS, other sensors, and technological equipment such as manipulator. The simplest examples of the application - the automatic following of the MBR and the management of transmission of wireless communication or transferring the video picture from hard-to-reach places on the MBR to the operator. In more difficult situation - MBR distributed on the territory according to the given program, specified coordinates with elements of autonomous control.

As a result, the model of the information environment will be presented by a digital map of the area with the updating according to the various data (video, acoustic, radar, with elements of augmented reality- Pokemon Go, and others.).

C. *Mobile Robot and Quadcopter Communication System*

Communications and communications protocols will play an important role in mobile robot systems able to address real world applications [10] as shown in Fig. 6.

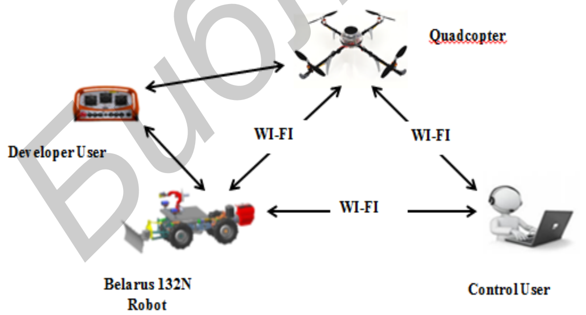

Figure 6. Communication and transmission of data among different parts of Quadcopter Mobile Robotic System (QMRS).

A mobile robot system might employ communications in any or all of the following modes:

- Between a robot and control user to send command tasking from the user to the mobile robot and to receive back from the robot system status and environmental data.
- Between a quadcopter and control user to send command from the user. Quadcopter synchronizes with user control to see what the camera located at quadcopter records. The user use joystick or remote control in order to direct the quadcopter in space.
- Between robot and quadcopter in a hybrid robot system to support both planning and coordinated execution of cooperative behaviors between robots i.e. mobile robot and quadcopter.
- Between robot and the robotic system developer, to eliminate errors and increment implementation productivity and efficiency by providing software downloading and system debugging implements to exercise and validate hardware as well as software.
- Between quad-copter and the robotic system developer, to eliminate errors and increment implementation productivity and efficiency by providing software downloading and system debugging implements to exercise and validate hardware as well as software.

V. Conclusion and Future Work

The objective of this project is to design a communication network for hybrid robots (QMRS) to transmit real-time video back to a host computer for monitoring and controlling purpose. The choice of using WI-FI to develop the communication system resulted in a system that is capable of transmitting data within a local wireless network.

QMRS (Quadcopter Mobile Robotic System) is a real-time obstacle avoidance capability in Belarus-132N mobile robot with the cooperation of quadcopter Phantom-2. The article identifies the method that use vision and image processing system from both robot and quadcopter; analyzing path in real-time and avoiding obstacles based-on the computational algorithm embedded inside the robot.

The next step of the future work will involve positioning and navigation of mobile robot in a merging cooperation of quadcopter in an unknown environment by using digital map, GPS, image processing, and sensors.

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Moustafa M. Kurdi received the BE degree from the Department of Computer Engineering, Beirut Arab University, Lebanon, in 2002, and the MBA degree from the Department of Business Management, Lebanese International University at Lebanon, in 2010. He is presently a Ph.D. candidate at the Electrical and Computer Engineering Department of Belarusian National Technical University, studying control, system analysis and data processing.

Currently, he is coordinator of faculty of applied sciences, American University of Technology (Lebanon). He has more than 10 years of academic teaching experience in the fields of computer, software and networking engineering.

Mr. Kurdi is member of IEEE. His current research interests include robotics, computer vision, intelligent mobile robots, navigation system, image watermarking, and design automation.

Imad A. Elzein is an electronics and computer engineer who obtained his undergraduate and graduate level degrees in electronics and computer engineering from Wayne State University, Michigan, USA in 2004.

Currently, he is an Assistant Professor at the computer Science and Information Technology Department, School of Arts and Sciences, Lebanese International University (Lebanon).

Imad has more than 17 years of solid hands-on experience in the design, testing, and analysis of electronics, telecommunication, and networks engineering environments coupled with more than 7 years of academic teaching experience in the fields of electrical and networking engineering. His research of interests is in the fields of Renewable Energy, Network Design, and Robotics.

Aliaksei K. Dadykin received the military degree from Minsk Suvorov Military School, in 1975, and Master degree, Phd in Automated Control Systems from Minsk High Engineering Military School of anti-aircraft missile defense with honors, in 1980 and 1989 respectively.

Currently, he is a chairman of the scientific meeting of the International Institute of Distance Education (MIDO) BNTU, the member of the Council on thesis defense at BNTU, and an associate professor of the Department of Information Systems and Technology National Technical University.

He is the author of 40 research works. He has 5 inventor's certificate. His current research interests include 4-wheel mobile robots, system analysis, management and information processing, and design automation.