

Design and Implementation of Mobile Ground Base Station for UGV

Paweł Iwaneczko, Karol Jędrasiak, Krzysztof Daniec, and Aleksander Nawrat

Institute of Automatic Control, Silesian University of Technology,
Akademicka 16, 44-100 Gliwice, Poland

Abstract. The purpose of this article is to present the designed and implemented Mobile Ground Base Station for UGVs. It was designed by the team from Silesian University. The MGBS (Mobile Ground Base Station) was tested using two different types of loopbacks: SIL (Software In the Loop) and HIL (Hardware In the Loop). After performing tests in virtual reality the MGBS was tested in the integration with the real UGV object. All tests were passed successfully.

Keywords: mobile ground base station, UGV, tele-operation, UGV control.

1 Introduction

Mobile ground base station (MGBS) is a system, that allows the operator to manage and remote control of the unmanned ground vehicle (UGV). In addition to manual control of the object, operator can watch the live on-board cameras and telemetry data view in the same time. Thanks to this person who control the object can faster and more accurately make a decision related to the specific task of the UGV. Unmanned ground vehicles are often used to recognize the area where there is a risk of loss of life or for recognition the enemy objects. UGV are also often used to search for and evacuate the wounded from the battlefield and for transporting ammunition or weapon systems to the soldiers. For this purpose, the base station must have a functionalities such as: monitoring and management of the UGV and UAV, display of the video stream from the object on-board cameras in real time, emergency remote manual control, it should have a touch display screen and dedicated key panel to operate the system functions. It should be noted, that MGBS should be highly mobile, should have a reinforced casing structure, should provide a secure encrypted communication with the environment and be easy to use with gloves.

2 Design

Most of mobile ground base stations solutions is based on the case structure [1-6]. In the article [7] and [8] author is connecting virtual reality to the ground base station to perform software simulation.

Construction of the mobile ground base station is based on the case structure. Casing is made of reinforced material. The case is equipped with a touch-screen monitor with high brightness, which is built-into the lid of the case. The key panel consists of 17 function keys, 3 function switches and emergency stop key. Case also includes 2 manual controllers (joysticks). Power switch of the case is protected with the key lock (ignition). Case is presented on the fig. 1 in two options: a shows the opened view, and b shows the closed case.



Fig. 1. Mobile Ground Base Station view: a) opened, b) closed

Under the keyboard panel there is placed dedicated electronic which is responsible for a stable and reliable work of all system components. Electronic system supports up to 40 digital input keys (including built-in LEDs) and up to 16 input analog joysticks. It is connected to a separate electronic module, with GPS sensor, and a separate radio link module (RF 869 MHz), which are used to communicate with and navigate the APG or a group of objects [13]. On the top left of the keyboard panel are installed four expansion ports for connecting the external antennas or mobile devices. Basic microcontroller controls the input ignition, which turns on power supply for all components, and holds it until all other parts is not turned off. Internal gel rechargeable battery (12V) have a system protection against too deep discharge and it can be charged from external AC power socket. Above the power socket is installed 5 LEDs that indicate the percentage of battery level, which is fully checked by the dedicated voltage measuring system. The battery must be charged with a constant current and constant voltage. Inside of the case there is also installed Wi-Fi router, an industrial PC computer and high brightness LCD monitor. It can be separately switched on/off to manage energy savings. All these components are shown in fig. 2.

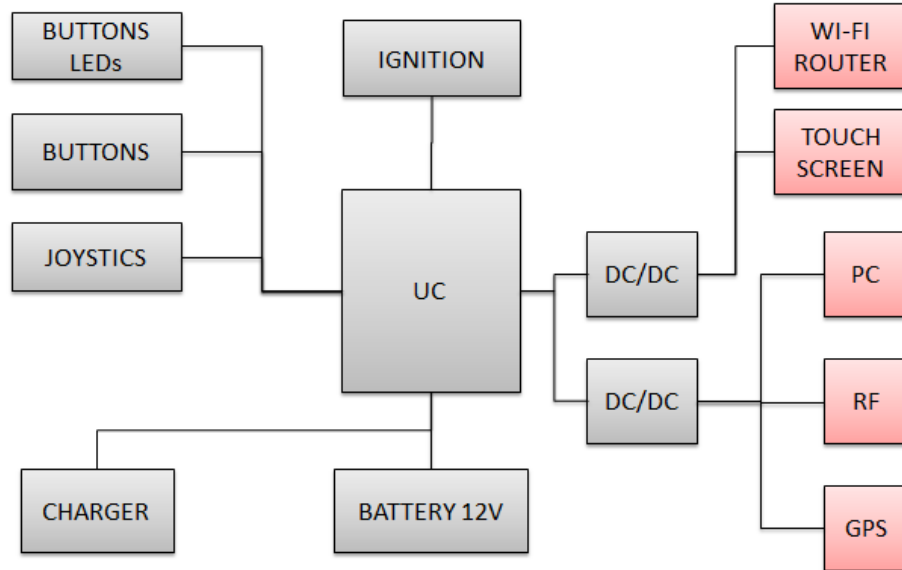


Fig. 2. Internal components connection schema

3 Functionality and Operation Instruction

The main functionality of the MGBS is the remote control of APG platform. For this reason case can be turned on in two modes. The first mode is without operator panel, which implicate the power saving. This is because the fact, that the PC, touch screen and Wi-Fi router, which consume the most energy, are switched off. The secondary functionality of the MGBS is the management of the APG platform. In this mode operator can use the control application to:

- show the location and azimuth orientation of the UGV,
- visualize the cameras,
- visualize the telemetry data on charts or dedicated sensor gauges,
- manage the unmanned objects,

3.1 UGV Control without Operator Panel

The UGV control mode without operator panel was designed for intuitive remote control of unmanned APG object and was highly simplified. After turning the ignition switch on (fig. 3.5), dedicated electronics that manages the power of all system components - starts the radio link module, GPS module and input/output module, which handles keys and the joysticks. Active key panel components is as follow:

- emergency stop switch – that stops all APG control systems, and its default value is opened (fig. 3.1),

- operator panel enable switch – that runs and stops industrial PC computer, touch screen and Wi-Fi router (fig. 3.2),
- auto/manual switch – which switches automatic control mode to remote control mode (fig. 3.4),
- manual control joystick – that allows the operator to remote control of the UGV (fig. 3.25).



Fig. 3. Keyboard panel with footnotes

3.2 UGV Management with Operator Panel

The UGV control mode with operator panel was designed for management the unmanned APG object. When operator switches the operator panel switch on (fig. 3.2), there will be launched all most energy consuming components of the case system: industrial PC computer, Wi-Fi router, and LCD touch screen. When operator switches the ignition switch off (fig. 3.5), when PC computer is turned on, the power LEDs are blinking for 10 seconds to inform the operator, that system on the PC is not closed properly. In this mode all keys and joysticks are enabled and are used to handle the PC operator application:

- zoom in button – this button is responsible for map control zooming in, alternatively with a camera zooming in (fig. 3.10),

- zoom out button – this button is responsible for map control zooming out, alternatively with a camera zooming out (fig. 3.19),
- left joystick – this joystick is used for move horizontally and vertically the map control, alternatively with rotating camera view (fig. 3.20),
- first camera button – toggles on/off the video stream window from the front APG camera (fig. 3.11),
- second camera button – toggles on/off the video stream window from the PTZ observation camera (fig. 3.15),
- LIDAR workspace button – changes the active workspace to LIDAR sensor view (fig. 3.21),
- map workspace button – changes the active workspace to navigation map control view (fig. 3.7),
- gauges workspace button – changes the active workspace to gauges control view (fig. 3.8),
- diagnostics workspace button – changes the active workspace to diagnostics chart control view (fig. 3.9),
- object trace button – toggles on/off the buffered trace of the unmanned object on the navigation map control (fig. 3.12),
- map LIDAR button – toggles on/off the LIDAR sensor view of the UGV on the navigation map control (fig. 3.16),
- track object button – toggles on/off tracking the object on the map, what means that the map automatically changes its position, so that the object is still visible in the middle of the screen (fig. 3.22),
- add waypoints button – changes the tap on the screen mode to adding a new waypoint (GPS location) on the navigation map (fig. 3.14),
- remove waypoints button – changes the tap on the screen mode to removing the waypoint from the navigation map (fig. 3.18),
- undo button – undoes the last 3 edits on the map waypoint mission (fig. 3.24),
- mission switch – toggles on/off the right mission panel, where operator can choose and show on the map one of the saved missions (fig. 3.3),
- up button – up navigation button, which is used to select previous mission from the opened mission panel (fig. 3.13),
- down button – down navigation button, which is used to select next mission from the opened mission panel (fig. 3.17),
- select button – accept button, which is used to send the selected mission from the mission panel to the unmanned object (fig. 3.23).

In order to maintain the integrity of the graphical user interface, last four of the above described buttons have alternatively functions in the diagnostic workspace. This allows the operator to intuitively and quickly, using the keyboard, even with thick gloves, to select multiple of telemetry data on real time chart.

Most of functions are binded both to keys described above and to the icons, which are added to the visualization of the PC operator application (PCOA). Industrial computer has installed Windows 7 Embedded system, and the operator application is implemented in C#.NET language using the WPF and DirectX components.

Visualization of the PCOA is divided into 4 separated workspaces with different components and 2 independent windows. Those four workspaces are:

- navigation map workspace – that visualizes the UGV object on the map in its GPS coordinates, and allows operator to manage the unmanned object autonomous route (fig. 5),
- LIDAR gauge workspace – that visualizes the *Light Detection and Ranging* sensor, which is installed in the front of the APG platform (fig. 4.a),
- telemetry gauges workspace – that visualizes: the left crawler speedometer, right crawler speedometer, main speedometer, horizon gauge, compass gauge, oil and engine temperature gauges, accumulator voltage gauge and fuel level gauge (fig. 4.b),
- diagnostic chart workspace – that allows to visualize all telemetry data on the one real-time chart (fig. 4.c).



Fig. 4. Telemetry workspaces: a) LIDAR gauge, b) telemetry gauges, c) diagnostic charts

PC operator application includes two management icons layer. Main layer is located in the top-left corner of the screen, it is visible on each of the workspaces in front of the all controls and displayed windows (fig. 4, 5), and it is used to management the active workspace and open camera windows. The second icons layer is closely linked to the navigation map. Icons located in the main management layer are as follows:

- first camera icon – toggles on/off the video stream window from the front APG camera (fig. 5.1),
- second camera icon – toggles on/off the video stream window from the PTZ observation camera (fig. 5.2),
- LIDAR workspace icon – changes the active workspace to LIDAR sensor view (fig. 5.3),
- map workspace icon – changes the active workspace to navigation map control view (fig. 5.4),
- gauges workspace icon – changes the active workspace to gauges control view (fig. 5.5),
- diagnostics workspace icon – changes the active workspace to diagnostics chart control view (fig. 5.6),
- battery control – shows the battery percentage level of the case electronic systems (fig. 5.8).

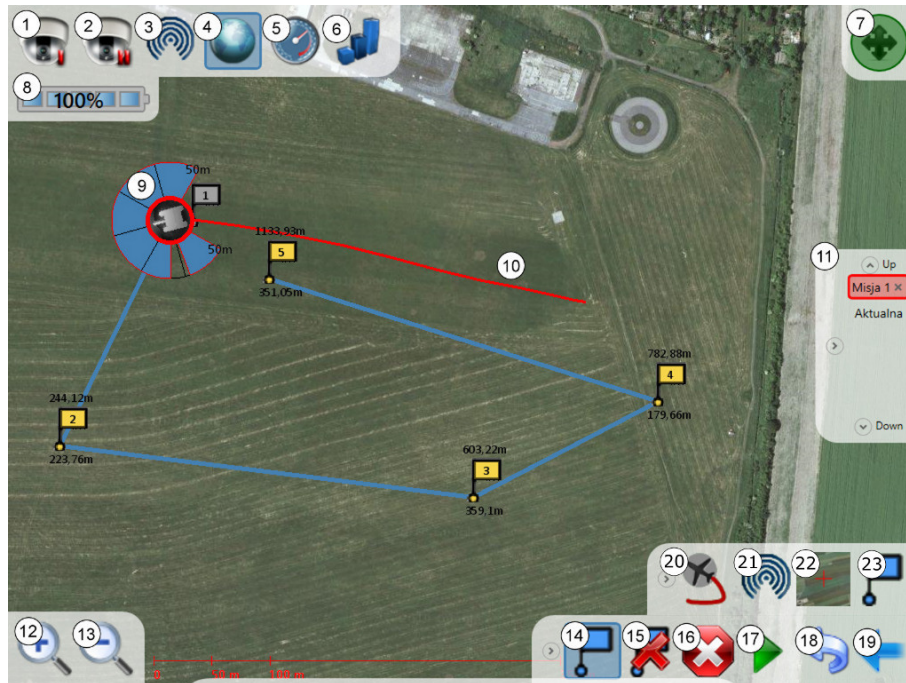


Fig. 5. Navigation map control view with footnotes

Icons located in the map navigation management layer are as follows:

- map movement icon – toggles on/off the possibility of moving the map view (fig. 5.7). Operator can move the map view by grabbing and dragging the touch screen in the clear area of map images
- mission menu – allows the operator to select and show one of the previously saved missions on the map (fig. 5.11). Mission menu contains: horizontal arrow - which is used to toggle the visibility of the menu, missions list, and up and down arrows - which are used to scrolling the missions list. The last mission from the list is an actually edited mission, which operator can create and save on the computer by sending it to the UGV object,
- zoom in icon – this icon is responsible for map control zooming in (fig. 5.12),
- zoom out icon – this icon is responsible for map control zooming out (fig. 5.13),
- add waypoints icon – changes the tap on the screen mode to adding a new waypoint (GPS location) on the navigation map (fig. 5.14),
- remove waypoints icon – changes the tap on the screen mode to removing the waypoint from the navigation map (fig. 5.15),
- abort mission icon – cancel and delete the currently executed mission from the UGV (fig. 5.16),
- send mission icon – sends actual selected mission from the mission menu to the UGV (fig. 5.17)

- undo icon – undoes the last 3 edits on the map waypoint mission (fig. 5.18),
- UGV menu icon – shows the UGV management icons (fig. 5.19),
- object trace icon – toggles on/off the buffered trace of the unmanned object on the navigation map control (fig. 5. 20). Buffered trace is shown in the fig. 5.10,
- map LIDAR icon – toggles on/off the LIDAR sensor view of the UGV on the navigation map control (fig. 5.21). Map LIDAR sensor is shown in the fig. 5.9,
- track object icon – toggles on/off tracking the object on the map, what means that the map automatically changes its position, so that the object is still visible in the middle of the screen (fig. 5.22).
- waypoints menu icon – shows the waypoints management icons (fig. 5.23).

Tracking the UGV on the map, while the object changes its coordinates, is shown in the fig. 6. When tracking is disabled the map don't changes its position automatically (fig. 6.a-b). When tracking is enabled the map automatically changes its position, so that the object is still visible in the middle of the screen (fig. 6.c-d). It is possible to select and track objects according to the algorithms presented in [9,10].

Operator application also includes management layer of the diagnostic chart workspace, which is almost identical as mission menu in navigation map workspace. The only difference is the possibility of select multiple chart data series from the telemetry list (fig. 4.c).



Fig. 6. Tracking object views

In addition to the four separate workspaces, the application allows the operator to run two independent windows. These windows are visible on top of other controls, can be minimized, maximized, resized and moved by the operator to a convenient position on the screen (fig. 7). These windows displays live video stream from two cameras placed on the APG platform. The stream can be also archived as an evidence [11,12].



Fig. 7. Cameras view on different workspaces

4 System Integration with Environment

MGBS case system is integrated with the real UGV object and with the Prepar3D® Lockheed Martin simulation software. This is because the control application software have to be well-proven and reliable. To provide a good verification of all functions of the control application, it was implemented in three ways, to integrate with: *Software In the Loop* (SIL) simulation, *Hardware In the Loop* (HIL) simulation and with the real UGV object.

4.1 HIL and SIL Integration with the Prepar3D® Lockheed Martin Simulation Software

Software In the Loop (SIL) simulation controls a physical process model (the simulator) using the software, which is a model of the regulator, and it's running on the same hardware platform. In the *Hardware In the Loop* (HIL) simulation process involves a real regulator, which communicates with the simulator through the appropriate interfaces. In both SIL and HIL loops – control application is executed on the mobile ground base station (MGBS), and it is used to manage the unmanned APG object, that is simulated on the other computer using the Prepar3D® simulation software. Control and management of the simulated model on the second computer is provided by control application, which was implemented so as to simulate the real object control systems. Communication interface between the MGBS operator application and Prepar3D® control software is based on 2.4 GHz wireless technology (fig. 8). The hardware simulation includes all electronic devices in the case, in particular the keyboard panel and microcontroller, which are connected with PC industrial computer by serial port. The difference in the SIL simulation is that the keyboard is not connected to the PC and it is displayed on the touch screen in the extending bottom menu.

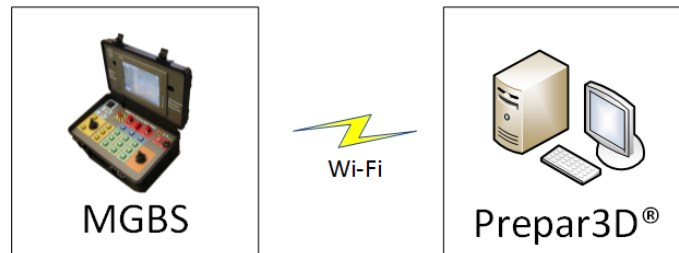


Fig. 8. HIL and SIL simulation

4.2 Integration with the Real Object

Communication between the mobile ground base station and the real unmanned ground vehicle object is also based on 2.4 GHz wireless technology. In the real object integration, case system parts are used for manual control of APG as well as for management of the autonomous control mode of the vehicle. All control systems of the UGV are implemented on a dedicated electronics systems. The control system of the APG consists of four electronic modules, where on each microcontroller is working an μ COS operating system. All modules communicate with each other via CAN bus (fig. 9). One of the modules is responsible for Ethernet connection with environment and is used as management unit and as link between the base station and APG control systems. Implementation of this module is very similar to SIL and HIL control application, with the difference, that first one is implemented in C language, and the second one in C# .NET language.

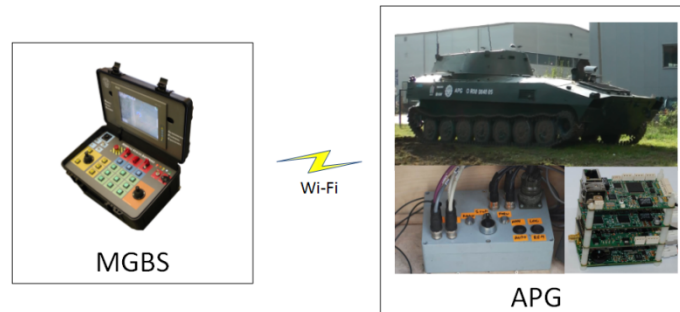


Fig. 9. Real object and MGBS integration

5 Tests

The work of all MGBS components and the integration with environment, as it was mentioned in the chapter 5, have to be well-proven and reliable. In order of that, tests were performed using the real object as well as simulated object in Prepar3D® Lockheed Martin simulation software. Unfortunately, not all of the MGBS functionalities can be identically mapped by the simulator and the real object, so all the tests performed in the simulation were also repeated on the outside training area with real UGV.

5.1 Control of the UGV Object Simulated in the Prepar3D® Lockheed Martin Software

Control and management tests of the simulated object, using the Prepar3D® Lockheed Martin simulator, were performed in the laboratory room in combination of the MGBS with the desktop PC computer (fig. 10). Tests were performed both in the SIL simulation loop – without using the operator key panel and microcontroller in the case, and in the HIL simulation loop – with all electronic components, which are located in the case. Most of performed tests in this mode was related to the visualization of the MGBS software and the correct interpretation of incoming telemetry data. Performed tests:

- visualization of the LIDAR control on the map and separate workspace,
- telemetry data displayed on the chart control,
- navigation of the map control (moving and zooming),
- waypoints management,
- mission creation, edition and sending it to the object,
- animation of the gauges needles,
- tracking object on the map,
- show trace of the object.



Fig. 10. Control and management the UGV object in simulation software

5.2 Control of the Real Object

Tests, that was performed in the integration with the real object was also performed in simulation mode, but only the real object test can correctly verify the functionalities associated with the management and control of autonomous systems. All driving test using the APG platform were performed on the outside training area (fig. 11). It was very important to keep all necessary precautions, and perform all tests away from the people. Performed tests:

- manual control,
- autonomous control,
- obstacle avoidance,
- camera video stream,



Fig. 11. Control and management the real UGV object

6 Conclusions

The article presents design, implementation and operation instruction of mobile ground base station for unmanned ground vehicles. The MGBS (*Mobile Ground Base Station*) was tested using two different types of loopbacks: SIL (*Software In the Loop*) and HIL (*Hardware In the Loop*). After performing tests in virtual reality the MGBS was tested in the integration with the real UGV object. All tests were passed successfully.

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