# Future Unmanned System Design for Reliable Military Operations

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***Abstract***

*In this paper, we propose the remote control station in order to guarantee and increase the efficiency of combat abilities using unmanned ground vehicle (UGV). Our remote control station is capable of sending a variety of messages designed for carrying out the skillful movement for collaboration among UGVs. Also, we present the core components of unmanned ground vehicles to efficiently carry out the sophisticated and primary missions provided by remote control station in future combat field. The proposed UGV is consisted of many sophisticated-designed systems such as navigation, obstacle detection sensor, wheel activator for vehicle control and network devices for communication. The developed system, named UGV and remote control station, is easy to operate and enable significant reduction in station operator workload by utilizing an intuitive graphic user interfaces for UGV navigation and allowing a single station operator to command multiple UGVs simultaneously. To verity the effectiveness of our proposed system, we conduct a great many remote operating tests in the real environment. In the consequence of the operation test, we expect that the remote control station and UGV play an important role in the future military operation.*

***Keywords:*** *Unmanned system, Unmanned ground vehicle, Remote control station, Military operation, Future combat, Intelligent control*

## 1. Introduction

An unmanned ground vehicle (UGV) is actively being developed for both civilian and military use to mainly perform dirty and dangerous activities [1-4]. Predominantly these vehicles are used to replace humans in hazardous. Lately UGVs are the focus of many research projects for both military and civilian applications [5-8]. The UGVs are used in different kind of applications like military, surveillance, security service, riot control, hostage situation, police, law enforcement, border patrol, etc. Examples are explosives and bomb disabling vehicles. UGVs, in varying sizes to meet mission capability requirement, are today saving lives and providing critical supporting capabilities in current military operations worldwide. They work more effectively in environmental extremes such as heat, cold, or nuclear, chemical and biological contamination in the warfare. Thus, UGV can be used to augment the soldiers' capability in the field of military operations. In general, a UGV is controlled by a human operator at a remote location via a communications link [9-12]. All cognitive processes are provided by the operator based upon sensory feedback from either line-of-sight visual observation or remote sensory input such as video cameras. Using the multiple sensor of UGV, the operators are provided with the ability to directly obtain and view critical information in a timely manner, and especially to obtain this information from areas that would be considered to be high risk before the advent of UGVs [13-17]. In this paper, we propose the key software module of remote control station in order to guarantee

and increase the efficiency of combat ability using UGVs. Also, we present the core components of UGV to efficiently carry out the sophisticated and primary missions provided by remote control station in future combat field. To verity the effectiveness of our proposed system, we conduct a great many remote operating tests in the real environment. In the consequence of the operation test, we expect that the remote control station and UGV play an important role in the future military operation.

Section 2 describes the software components of remote control station and well-formed core devices of UGV. Section 3 shows the implementation results. Finally, the main conclusions are presented in Section 4.

## 2. Remote Control Station and UGV for Reliable Military Operations

### 2.1. Remote Control Station

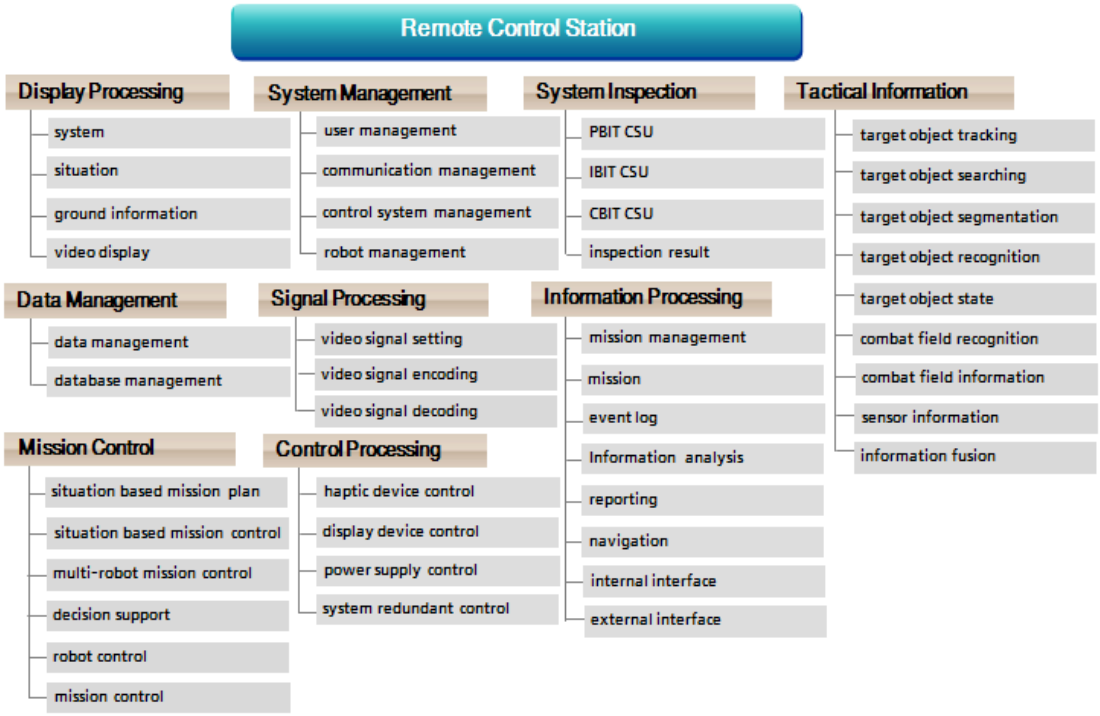



**Figure 1. Proposed Software Components of Remote Control Station**

In this paper, we present remote control station and its software architecture which is made of fine 9 software components, that is, display processing, system management, data management, control processing, information processing, system inspection, signal processing, tactical information and mission control to efficiently control UGV in the future combat fields. In tactical information component, object searching, target tracking, and information fusion methods are presented for combat field recognition as correctly as possible in timely manner. In addition, specially coordinated system inspection component which is functionally and systematically provided by built-in-test (BIT) for reliable operations is designed for continuous performance. The UGVs conduct an extensive mission receiving and reviewing continuously. After confirming the mission provided by remote control station, they accomplish that mission to match the combat situation. In mission control component,

situation based mission plan and decision support method utilized by tactical information are also presented for tactical and collaborate movements of UGVs. Using these critical software components of remote control station, the proposed UGV can perform the given military operations safety and reliably in the real field. Detail software components of remote control station are presented in Figure 1.

In our remote control station, we designed the 2-tier database structure using main memory database management system (MMDBMS) and generally used DBMS. Using the MMDBMS, uplink information which are comprised of the robot status data as well as robot captured video and sensor data are stored and processed quickly, as shown in Figure 2.

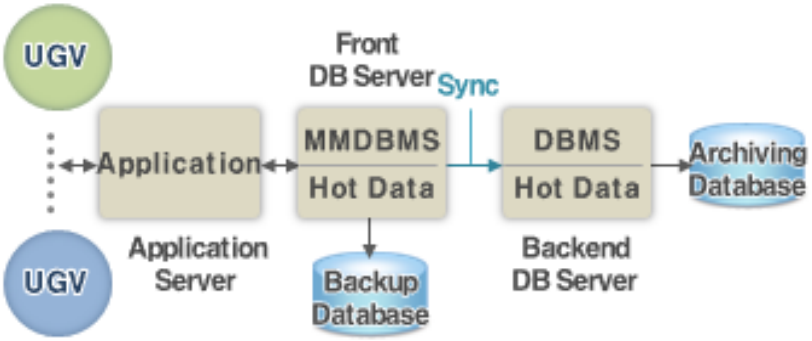



**Figure 2. High Speed Data Storing and Processing using Main Memory Database Management System**

We present the network based command message creation mechanism for operating UGV, as shown in Figure 3. When messages generated by control command are created, the system watchdog counter for ensuring the message generation precisely and bit-based variable data encoding which is designed for decreasing the message overhead using dynamic message packet field length are utilized. Using proposed encoding method, the link budget is minimized in terms of time delay between remote control station and UGV. The packet priority to enhance the stability and control efficiency of control command are applied in network message structure. Using this priority method, we can efficiently handle the higher priority message primarily when the network status is unstable.

An increasing amount of attention has been paid to improving reliability, availability, and safety in most autonomous control systems such as remote control station. For instance, as control systems in the field of aerospace, electric power, and automobiles become more complicated, more rigorous research for Fault Detection and Diagnosis (FDD) has been conducted. For this reasons, a fault tolerant state estimation and diagnosis method with high reliability using heartbeat signal is developed for the reliable operations of remote control station in combat fields. In order to detect the system fault, master and slave units are used and continuously transmit the 1 bit data, named heartbeat signal, with each other, as shown in Figure 4. We consider a standby-redundant model of two units, where we operate that one unit is operative and the other unit is in standby. If the operative unit fails at a certain time, a unit in standby is put into operation and the repair of the failed unit begins.

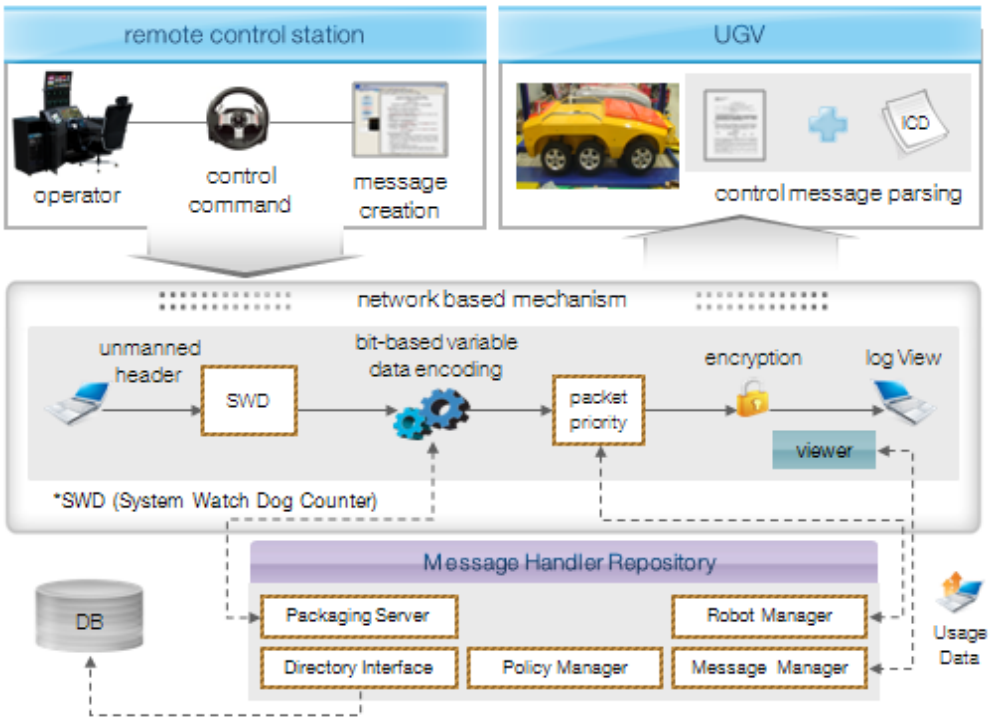



**Figure 3. Network Based Command Message Creation Mechanism for Operating UGV**

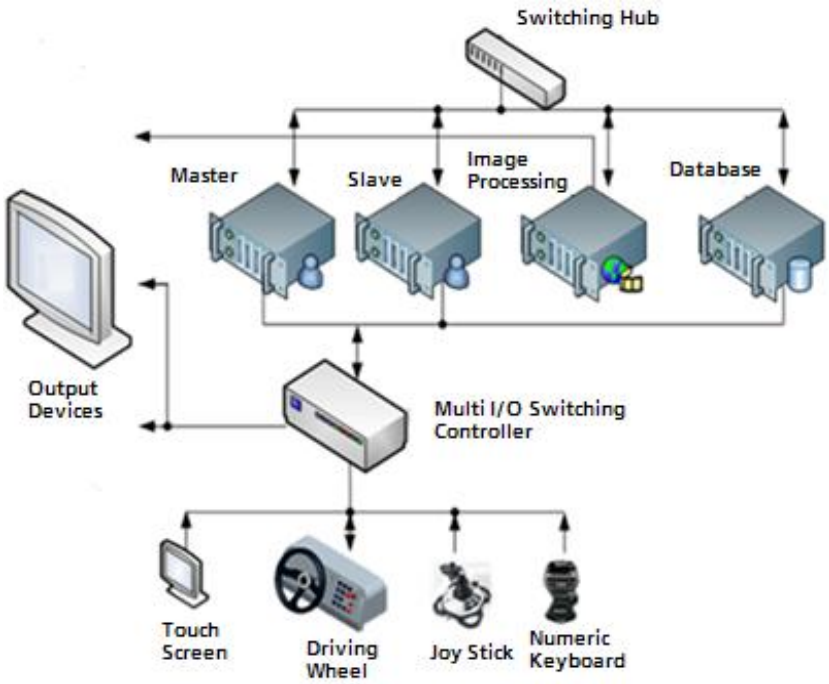



**Figure 4. Heartbeat Signal Based Standby-redundant System**

### 2.2. Unmanned Ground Vehicle

A remote-operated UGV is a vehicle that is controlled by remote control station via a communication link. The UGV must be able to send and receive telemetry and sensor data and video/audio to remote control station, as well as interacting with the environment. Also, UGV is capable of autonomous driving based upon waypoints and basic obstacle avoidance, and also capable of driving controlled by human interface from far away. For this purpose, we develop the UGV for autonomous moving using a variety of sensing techniques. The proposed UGV is consisted of many sophisticated-designed systems such as navigation, obstacle detection sensor, wheel activator for vehicle control and network device for communication between UGV and remote control station. Figure 5 depicts the core devices of UGV concretely. In our UGV, we successfully developed the video device which enables an UGV to gain the information about surrounding areas and delivery it to remote control station and conducted a great many video tests in order to verify the safety movement of UGV during day and night, as shown in Figure 6.

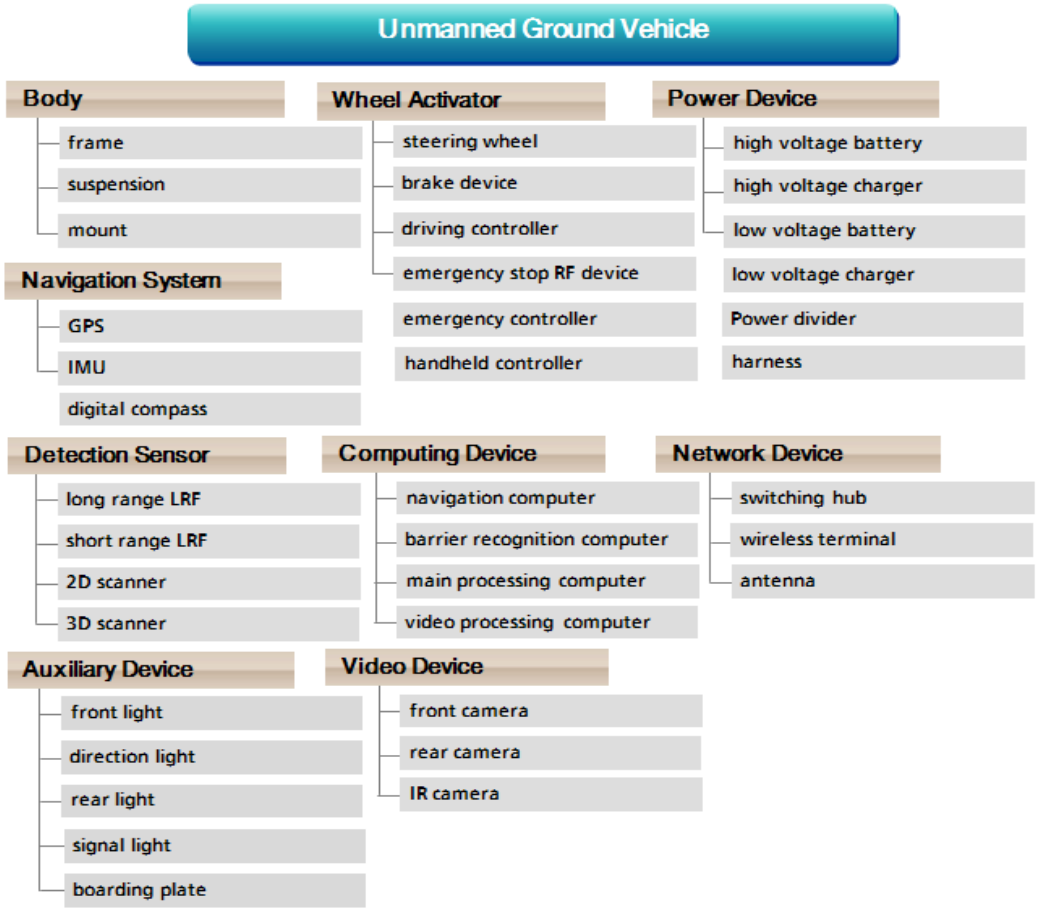
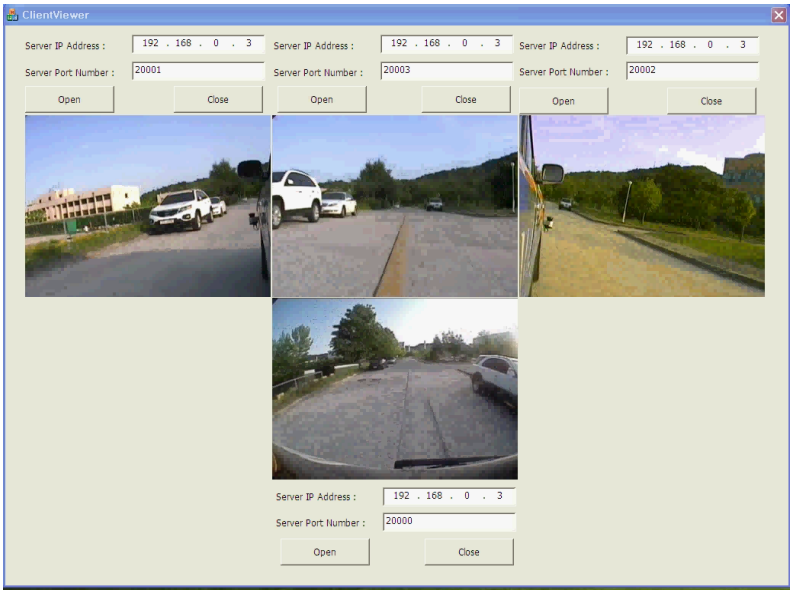
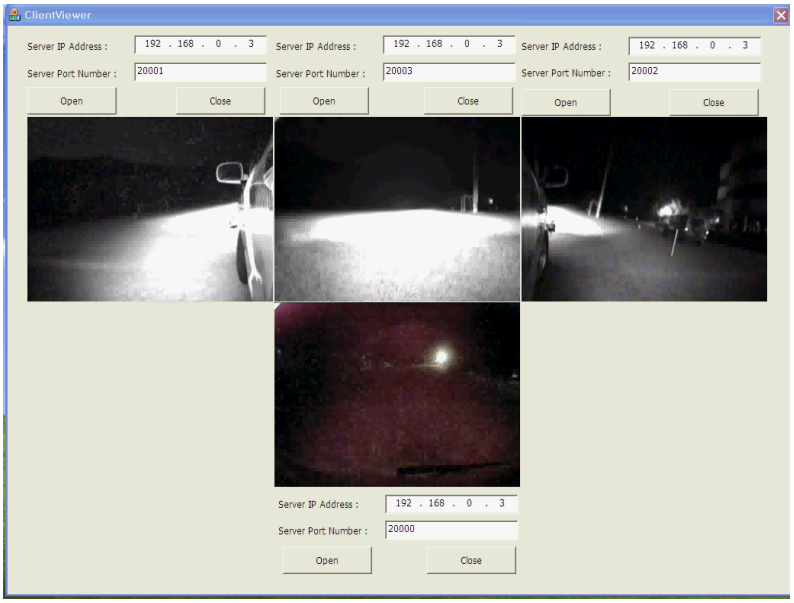



**Figure 5. Proposed Core Devices of UGV**




(a)




(b)

**Figure 6. Camera Tests for Verifying the Safety Movement of UGV; (a) Daytime Image, (b) Night Image**

In this paper, we develop the autonomous UGV in preparation for a loss of communication. An autonomous UGV is essentially a self-regulating robot that operates without the need for a human controller. The proposed autonomous UGV has the ability to gain information about the environment and to work for extended durations without human intervention. In addition, UGV can travel from one point to another without human navigation assistance using navigation and main driving computer. It also detects objects of interest such as people, vehicles and barriers instantly using barrier information computer. In

Figure 7 shows the overall system architecture of UGV for safety movement using navigation, main driving, and barrier information computer.

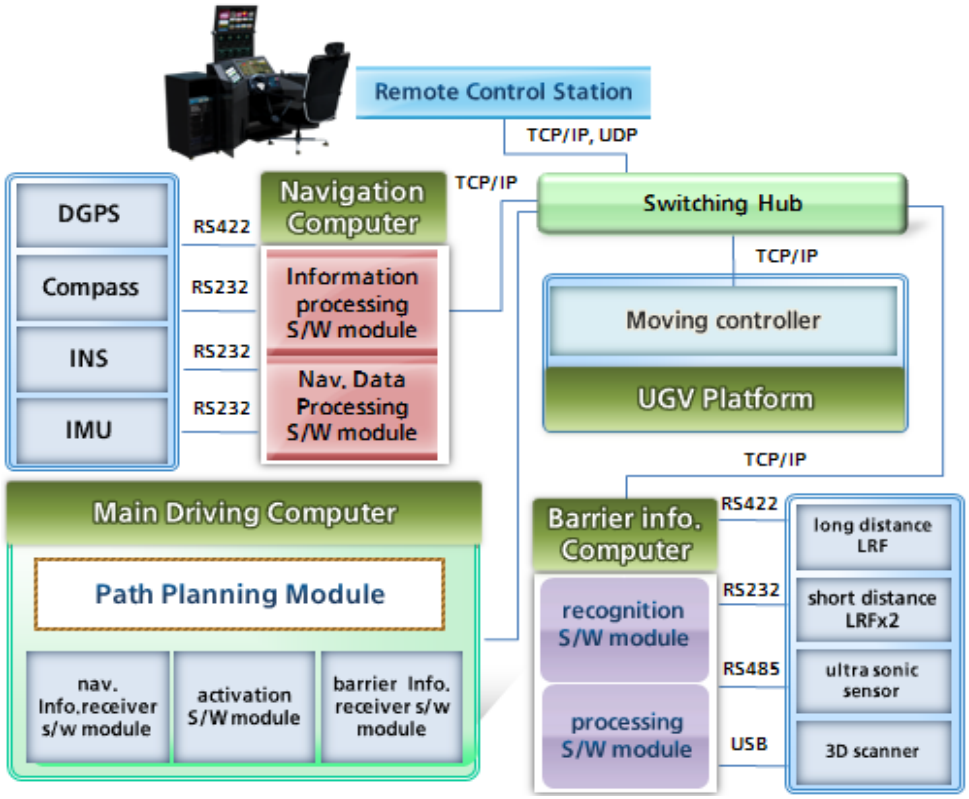



**Figure 7. System Architecture of UGV for Safety Movement**

Our UGV utilizes the GPS(Global Positioning System), IMU(Inertial Measurement Unit) and INS(Inertial Navigation System), which are widely used in the UGV or other unmanned systems to estimate position during the mission. The GPS is a space-based satellite navigation system that provides location and time information. The IMU is an electronic device that measures and reports on a UGV's velocity, orientation, and gravitational forces, using a combination of accelerometers and gyroscopes. It works by detecting the current rate of acceleration using one or more accelerometers, and detects changes in rotational attributes like pitch, roll and yaw using one or more gyroscopes. Also, an INS is a navigation aid that uses a computer, motion sensors , named accelerometers, and rotation sensors such as gyroscopes to continuously calculate via dead reckoning the position, orientation, and velocity (direction and speed of movement) of a moving UGV without the need for external references. Using a variety of navigation data obtained by these systems, our UGV can autonomously move to waypoint which is indicated by remote control station. At the same time, UGV sends navigation data to remote control station in order to notify the location of UGV exactly and instantly. In Figure 8 shows the navigation data flow in navigation computer. In order for detecting the object efficiently, a LRF(Laser Range Finder) and a ultra sonic sensor are generally used. For the same reason, the proposed UGV also utilizes a laser beam or a typical acoustic frequency to determine the distance to an object. After the object detection data using LRF and ultra sonic are generated, it can be transmitted to the remote control station directly, as shown in Figure 9.

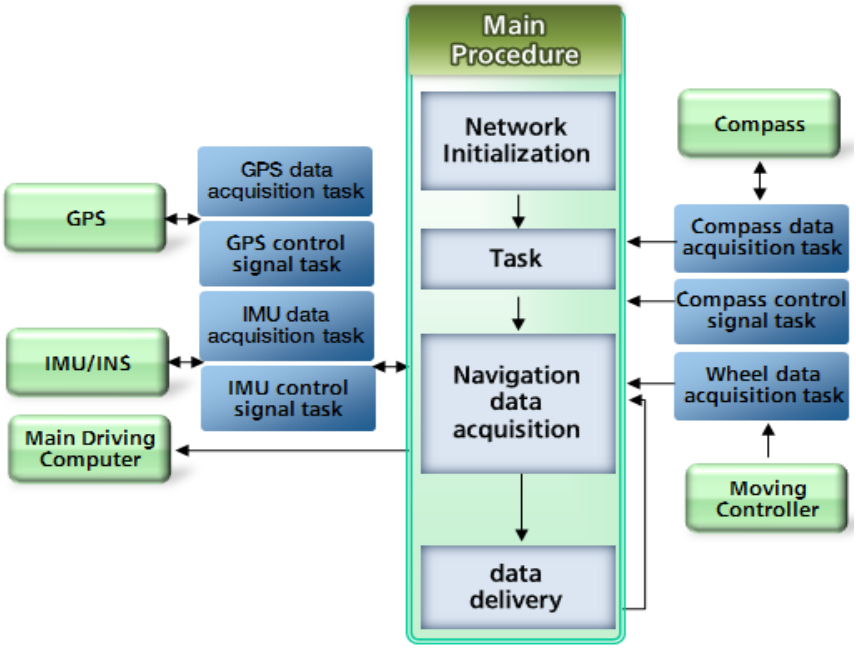



**Figure 8. Navigation Data Flow in Navigation Computer**

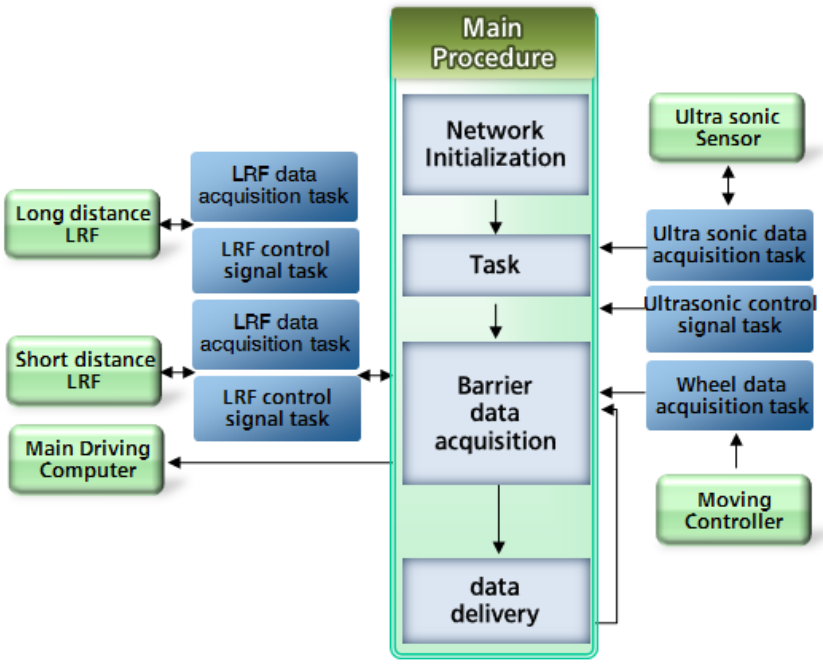



**Figure 9. Object Detection Data Flow in Barrier Information Computer**

To find the optimal way to move, autonomous UGV has to be intelligent and should decide its own action. When the autonomous robot decides its action, it is necessary to plan optimally depending on their missions. More, it is necessary to plan a collision free path minimizing a cost such as time, energy and distance. When an autonomous UGV moves from

a point to a target point in its given environment, it is necessary to plan an optimal or feasible path avoiding obstacles in its way. For this reason, optimal path planning is created using our critical navigation computer and barrier information computer. After way point information is acquired from remote control station, local path generation and path correction for barrier avoidance are automatically activated using the data which is provided by navigation computer and barrier information computer. UGV can be moved to the point according to the generated moving path. When the driving data is recursively transmitted and received by moving controller, it affects to the path correction in order to move precisely. Figure 10 depicts the path planning data flow in main driving computer.

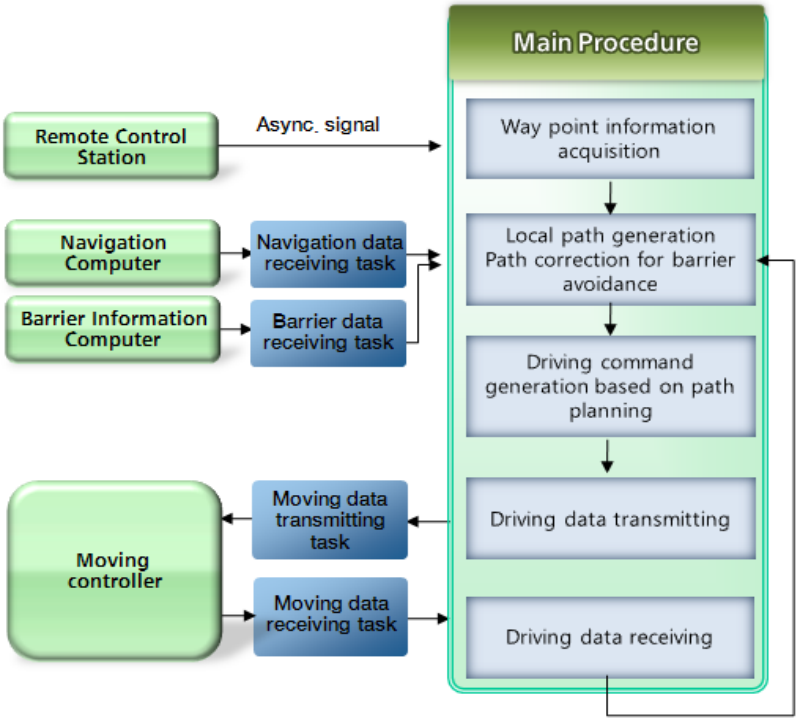



**Figure 10. Path Planning Data Flow in Main Driving Computer**

## 3. Implementation Results

To verify the effectiveness of our proposal, we develop the sophisticated remote control station and UGV respectively. In addition, we conduct a great many remote operating tests for multiple unmanned ground vehicles in the predefined combat area. Control of UGVs is accomplished remotely, through a remote control station that allows an operator to receive sensor data from the UGV and send motion commands and missions to the UGV. Figure 11 depicts the proposed remote control station. For controlling and monitoring the UGV efficiently, graphic user interfaces of remote control station are also developed as shown in Figure 12 and 13. The remote control station has digital map composed of two or three dimensional topographic maps in order to accurately display and indicate the geo-location of UGV. Figure 14 depicts the digital map based graphic user interface. Finally, Figure 15 represents the developed UGV platform for performing the military mission.

The developed systems, UGV and remote control station, is easy to operate and enable significant reduction in station operator workload by utilizing an intuitive graphic user interfaces for UGV navigation and allowing a single station operator to command multiple UGVs simultaneously. By combining advanced navigation systems such as GPS, LRF, IMU and INS, an autonomous controlled and navigated UGV is being created that is robust, user friendly, and less burdensome than many current generation systems. Thus, we convinced that this system is suitable for performing the military operation reliably and effectively.

**Figure 11. Developed Remote Control Station**

**Figure 12. Graphic User Interface for Status Surveillance**


**Figure 13. Graphic User Interface for Intuitive Controlling**

**Figure 14. Digital Map Based Graphic User Interface for Presenting the Location and Trajectory of UGVs**

**Figure 15. Developed UGV Platform for Performing the Military Mission**

## 4. Conclusions

The UGVs are used in different kind of applications like military, surveillance, security service, riot control, hostage situation, police, law enforcement, border patrol, etc. They work more effectively in environmental extremes such as heat, cold, or nuclear, chemical and biological contamination. Thus, UGV can be used to augment the soldiers' capability in the field of military operations. In this paper, we present remote control station and its software architecture to efficiently control UGV in the future combat fields. In addition, we develop the UGV for autonomous moving using a variety of sensing techniques and sophisticated-designed systems. To verify the effectiveness of our proposal, we develop the remote control system and UGV respectively. In addition, we conduct a great many remote operating tests for multiple unmanned ground vehicles in the predefined combat area. Control of UGVs is accomplished remotely, through a remote control station that allows an operator to receive sensor data from the UGV and send motion commands and missions to the UGV. The developed systems, UGV and remote control station, is easy to operate and enable significant reduction in station operator workload by utilizing an intuitive graphic user interfaces for UGV navigation and allowing a single station operator to command multiple UGVs simultaneously. In the consequence of the operation test, we expect that the remote control station and UGV play an important role in the future military operation.

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