A PROJECT OVERVIEW FOR THE DEVELOPMENT OF A LIGHT AND FLEXIBLE RAPID MAPPING SYSTEM FOR EMERGENCY RESPONSE

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ABSTRACT:

As disasters and accidents due to various natural or artificial causes being increased, the demands for rapid responses for such emergency situations also have been ever-increasing. These emergency responses are required to be not only more intelligent and systematic but also more customized to the individuals in the site for more effective management of the emergency situations. Such requirement can be better fulfilled with the decisions based on the detection of spatial changes acquired rapidly or in real-time from the sensors on the air. Such airborne sensory data can be effectively acquired by an UAV based rapid mapping system. This presentation introduces an overview of a Korean national project to develop an airborne rapid mapping system. This project is one of a series of projects supported through Korean Land Spatialization Group by Korean government. The overall budget is about 6 million US dollars and the period is about four years. The goal of this project is to develop a light and flexible system to perform rapid mapping for emergency responses. This system consists of two main parts, aerial part and ground part. The aerial part includes a UAV platform mounted with sensors (GPS/IMU/Camera/Laser Scanner/Thermal IR Camera) and sensor supporting modules for sensor integration, data transmission to the ground, data storages and sensor stabilization. The ground part includes three sub-systems with appropriate software, which are a control/receiving/archiving subsystem, a data geo-referencing subsystem, and a spatial information extraction subsystem. As being in an initial stage of this project, we will present an overview of this project, including the preliminary design, work breakdown structures, international collaboration, expected products, market status and prospect, and others.

1. INTRODUCTION

The occurrences and scales of disasters and accidents in the modern world have been rapidly increased due to the global warming, the terrorist's attacks, or many other reasons not so clearly clarified. The demands for rapid responses for such emergency situations have been thus ever-increasing. These emergency responses are required to be not only more intelligent and systematic but also more customized to the individuals in the site for more effective management of the emergency situations. Such requirement can be better fulfilled with the decisions based on the detection of spatial changes acquired rapidly or in real-time from the sensors on the air. Such airborne sensory data can be effectively acquired by an UAV based rapid mapping system.

Such a system can be also effectively utilized for military applications such as unmanned reconnaissance, observation and surveillance, their market being fast growing. For example, the European market for UAV-system is expected to be gradually expanded, as shown in Figure 1. In addition, the demand for 3D spatial information of high quality has been rising as the portal services, such as Google Earth and Microsoft Virtual Earth providing large scale spatial information of the global areas are rapidly growing. Such sophisticated spatial information required for generating real-view models of the world can be effectively acquired by a UAV based mapping system.

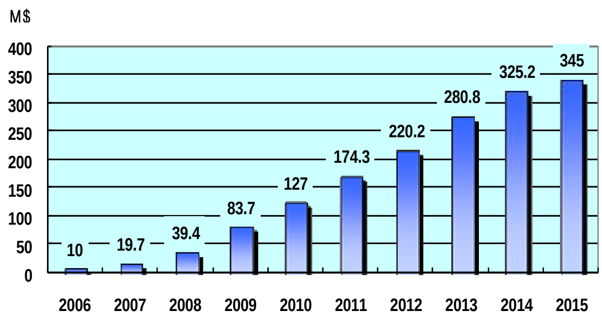

Figure 1. Trend of Europe market for UAV-system (2006, World UAV Market "Visiongain")

Since the World War II, UAV systems have been developed for mainly the purposes of reconnaissance and observation (Eck, 2001). Their applications have been gradually expanded to many other fields including photogrammetry and remote sensing.

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In 1979, an aeroplane, a UAV platform with fixed wings was firstly used for photogrammetry by Wester-Ebbinghaus (1980). But it was found that it is hard for the platform to approach a target. Hence, helicopters, UAV platforms with rotating wings, have been utilized for taking the close images of a target (Wester-Ebbinghaus, 1980).

Zischinsky, et. al. (2000) utilized a helicopter to acquire 82 ground pictures and 38 aerial pictures acquired and created 3D building modelings. Nagai (2004) generated a DSM from the data acquired by a laser Scanner and a CCD camera mounted on a Subaru helicopter whose maximum payload weight was 100kg. Jang (2004) used a mini UAV-helicopter to take the images of ancient historic scenes. Wang (2004) developed mini aeroplane to extract 3D building model from 2D GIS data and one image. Everaerts (2004) designed a UAV-system which was called pegasus. This UAV-system was equipped with solar cells to fly longer time.

Most systems developed from these previous studies did not have real-time (or rapid) mapping capability, which can produce spatial information such as DSM and orthoimages of the target area under an emergent situation. For the realization of this capability, the raw sensory data acquired by a UAV based multi-sensor system should be transmitted to a ground station and automatically processed. These functions were not fully integrated into the most of previous systems.

In the meantime, the individual technologies required for the realization of the UAV based rapid mapping system have been rapidly advanced in different fields. For examples, many robust automatic processing algorithms have been developed for the generation of spatial information from sensory data such as aerial images and airborne LIDAR data in the photogrammetry, remote sensing, and computer vision fields. In addition, based on the advances in the fields of aviation and navigation, small helicopters with a self-flying capability at a close range have emerged. In summary, many individual technologies in the fields of geo-spatial information, aerospace engineering and electronics have been enough matured to be used for the implementation of real-time rapid mapping system.

To realize the real-time rapid mapping for the practical uses in many emergent situations, we plan to develop a light, flexible and low-priced mapping system using a small unmanned helicopter. As distinct from the existing UAV-systems based expensive hardware, our system will be based on highly sophisticated software instead of using a high-priced platform and sensors. As being in an initial stage of developing this system, we will present an overview of this project, including the preliminary design, work breakdown structures, expected product and others.

2. PROJECT OVERVIEW

2.1 Goals

The goal of this project is to develop a light and flexible system to perform rapid mapping for emergency responses. This system consists of two main parts, aerial part and ground part. The aerial part is composed of a UAV platform, sensors, and sensor supporting modules. The mounted sensors are GPS, IMU, digital camera and laser scanner. The sensor supporting modules undertake to integrate the sensors, transmit the sensory data to the ground, and stabilize sensors' attitudes. The ground part is composed of three sub-systems with appropriate software, which are a control/receiving/archiving sub-system, a data geo-referencing sub-system, and a spatial information extraction sub-system. The whole system is illustrated in Figure 2.

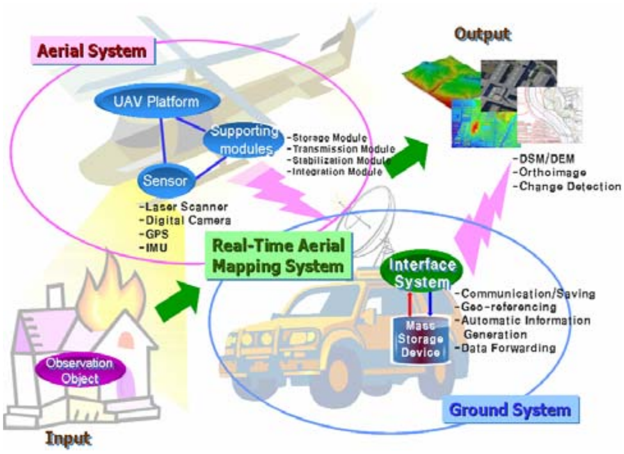

Figure 2. Introduction to real-time aerial mapping system

The sensory data acquired from the aerial system are images, returned laser information, position and attitude of the platform tagged with GPS time. These data will be transmitted to the ground system through the sensor supporting modules. Then, images and laser points autonomously will be geo-referenced by the geo-referencing sub-system of the ground system. Finally, from the geo-referenced sensory data, the spatial information extraction sub-system autonomously will generate DSM/DEMs and orthoimages of the target areas where disaster or accident occurs.

2.2 Configuration

This project is one of a series of projects supported through Korean Land Spatialization Group (KLSG) funded by Korean government. The overall budget is about 6 million US dollars and the period is about four years.

This project is divided into 5 sub-projects, as listed in Figure 3. We are concentrating on the first sub-project, design of real-time aerial monitoring system for the first period (2007.11.30 ~ 2008.8.30). Five sub-projects are grouped by research items into three sectors, aerial sector, ground sector, system verification as shown in Figure 4.

Figure 3. List of sub-projects

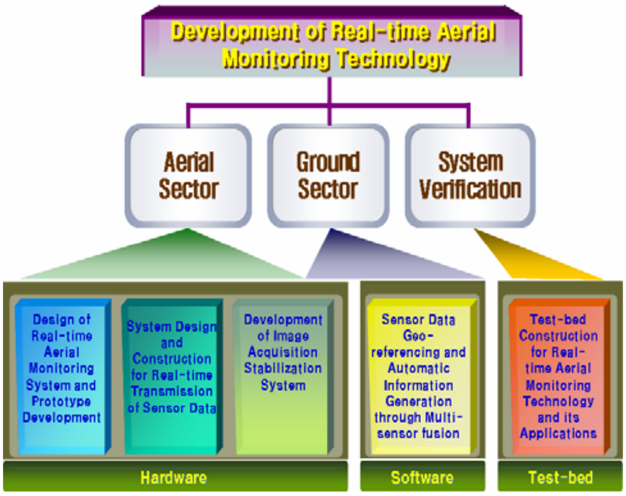

Figure 4. Classification of research items

2.3 Work Breakdown Structure

All the tasks required for this project are divided into three sectors, aerial sector, ground sector and general sector. Main tasks of each sector are presented in Figure 5. Details of the main tasks under each sector are listed in Table 1-3.

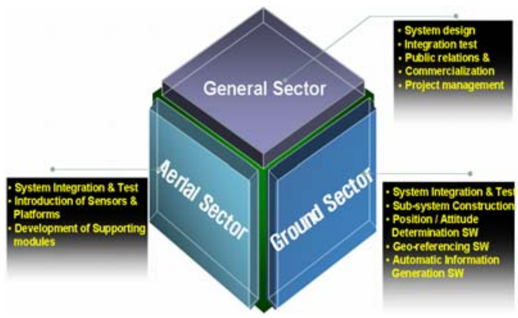

Figure 5. Work Breakdown Structure

Object	Content
Integration & Test	▪ Mechanical frame design ▪ Mounting the sensors & modules ▪ Registration & Calibration
Introduction of sensors & platform	▪ Laser Scanner ▪ Digital Camera ▪ GPS ▪ MEMS IMU ▪ UAV Platform
Development of on-board computer	▪ Time Synchronization ▪ Sensor control ▪ Data interface ▪ Data compression
Development of other modules	▪ Transmission module ▪ Storage module ▪ Stabilization module (HW) ▪ Stabilization module (SW)

Table 1. Tasks under aerial sector

Object	Content
Integrate & Test	▪ Select a vehicle & Frame design ▪ Loading the sub-systems ▪ Integration test
Sub-system Construction	▪ Data reception sub-system ▪ Order transmission sub-system ▪ Real-time storage sub-system ▪ Data forwarding sub-system ▪ Integrated interface SW
Position & Attitude Determination SW	▪ Based on GPS/IMU ▪ Based on GPS/IMU/image matching
Geo-referencing SW	▪ Automatic image matching ▪ image geo-referencing ▪ Laser scanning data geo-referencing
Automatic Generation of Information SW	▪ Automatic generation of DSM/DEM ▪ Automatic generation of ortho-images ▪ Automatic change detection

Table 2. Tasks under ground sector

Object	Content
System design	▪ Set scenarios for applications ▪ Set up requirements of sub-systems ▪ Simulation
Integration test	▪ Set the Area Of Interest ▪ Build standard data ▪ Establish the testbed ▪ Set scenario for test ▪ Test & analysis of the results
Public relations & Commercialization	▪ Domestic and abroad market survey ▪ Domestic and abroad tech. survey ▪ Public relations ▪ Commercialization
Project management	▪ Management of Products ▪ Management of Budget & Schedule ▪ Consultation & Reports ▪ Interaction with other projects

Table 3. Tasks under general sector

2.4 Applications

The applications of the real-time aerial mapping system to be developed in our project are categorized into three main fields, crisis management, reconnaissance and surveillance, and geo-spatial data acquisition. Among these fields, the crisis management has the first priority of the system usage. The best merit of the system is the rapid generation of spatial information of the areas where ones can hard to access. When disasters or accidents occur, based on the 3D geo-spatial data on the areas using our system we can rapidly dispatch a relief squad to areas and also restore the damage area. Figure 6 shows main applications under crisis management requiring emergency response. A disaster management system based on the real-time aerial mapping system is shown in Figure 7. This system is composed of a field sector, aerial sector, transmission sector, data processing sector, data analysis sector, and data supply sector. Among the six sectors, the key three sectors are supported by the real-time aerial mapping system.

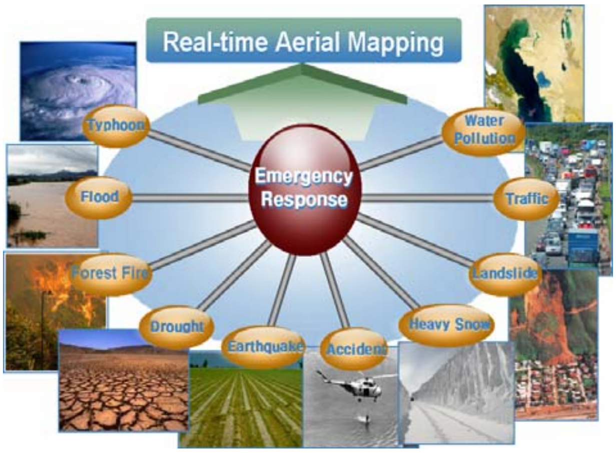

Figure 6. Various applications under crisis management requiring emergency response

Figure 7. Disaster management system based on real-time aerial mapping system

3. PRELIMINARY SYSTEM DESIGN

3.1 Requirements of Overall System

Four application scenarios based on emergency mapping are assumed. They are real-time fire monitoring, investigating damage of floods, periodic monitoring, and urban development analysis. According to these scenarios, we have derived overall system requirements of the real-time aerial mapping system to be developed in the project. This derivation process is summarized in Figure 8.

Using the process, we have determined the requirements about the platform operation and the quality of the spatial information. Table 4 shows some critical requirements for platform operation and Table 5 does the required resolution of the geospatial information.

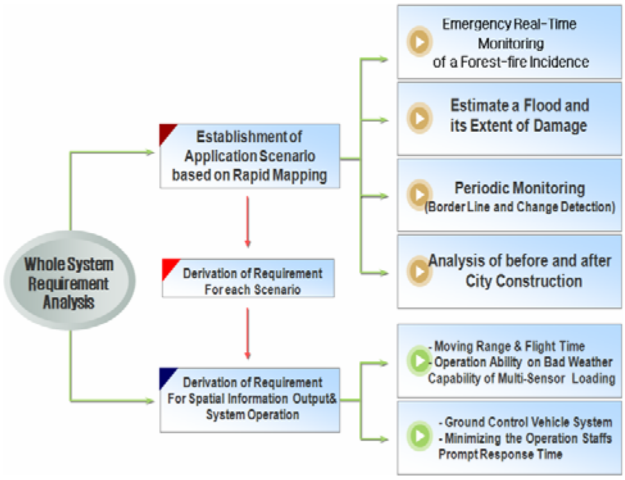

Figure 8. Analysis process of the overall system requirements

Classification	Requirements
Maximum payload	50 Kg
Altitude	300 ~ 1000 m
Endurance	5 hours
Operation range	10 Km

Table 4. Requirements of platform operation

Kind of Geo-spatial information	Expected resolution
DSM/DEM	1 m
Orthoimage	1 m
Change Detection	2 m

Table 5. Required resolution of geo-spatial information

3.2 Configuration

We propose two types of real-time aerial mapping systems. One is high grade and the other is medium grade in terms of quality and price. The high grade system is assumed to operate in not only settled but also unsettled weather. So this system mainly is targeted on disaster/accident management with unsettled weather. But the medium grade system can only operate in settled weather. Therefore this system is usually targeted on detection of unauthorized buildings or illegal discharging of waste water in fine weather.

Table 6 and Table 7 show the preliminary configurations of two systems.

Schiebel's Camcopter S-100 is adopted as the UAV platform of the high grade system. As the platform's maximum payload is 50kg, a laser scanner can be mounted on the platform which holds a top position in massive sensor list.

NEO S-300 manufactured by Swiss UAV is adopted as the UAV platform of the medium grade system. The platform's maximum payload is only 20 kg, whereas total weight of a laser scanner and GPS/IMU mounted on the platform of high grade system is about 11kg. So we don't mount a laser scanner on the medium grade system and we select a MEMS GPS/IMU integrated in one.

Component	Model	Important Specification
UAV platform	Camcopter S-100 (SCHIEBEL)	payload : 50kg, flight altitude : 1200ft, range : 80km, endurance : 6 hours
Laser Scanner	LMS-Q240i (Riegl)	weight : 7kg, FOV : 80˚ (±40˚), scanning rate : 6~80sps
Digital Camera	Lw235 (Lumenera)	weight : 0.3kg, frame rate : 12fps, effective pixels : 1616X1216, 4.4 µ m
GPS	OEMV-3 (NOVATEL)	position accuracy : 1.8m, weight : 0.075kg data rate : 20Hz
IMU	HG1700 (Honeywell)	velocity accuracy : 0.02m/s, weight : 3.4kg, data Rate : 100Hz

Table 6. Configuration of high grade system

Component	Model	Important Specification
UAV platform	NEO S-300 (SWISS UAV)	Payload : 20kg
Digital Camera	Lw235 (Lumenera)	weight : 0.3kg, frame rate : 12fps, effective pixels : 1616X1216, 4.4 µ m
GPS	MTi-G (X-sens)	Position accuracy : 2.0~2.5m, Weight : 0.068kg GPS Data rate : 4Hz, IMU Data rate : 100Hz
IMU		

Table 7. Configuration of medium grade system

3.3 Simulation

To 1) reduce the trials and errors of system design, 2) decrease economical cost, 3) set up an optimized process for designing multi-sensor system, we simulated an aerial multi-sensor system to optimize the aerial system design. The process is illustrated in Figure 9.

Aerial system simulation is comprised of three steps, including sensor data preparation, simulation software design, and implementation/application of the software. The first one is to analyze the data sheets of the digital camera and laser scanner preliminarily selected and select key parameter required for the simulation. The second one is to design the input and output parts of the simulation software. The input includes the operation conditions of the platform and the specifications of the camera and the laser scanner. Operation conditions are the path and velocity of the platform. The specifications of the camera are the pixel size, the image size, the focal length, and the frame rate. The specification of the laser scanner consists of the measurement rate, the scanning rate, the scan angle and the data rate. The outputs of this software are the properties of the output sensory data, such as the ground coverage, scale, ground resolution of each image, the ground coverage, average distance, point density of the laser data and so on.

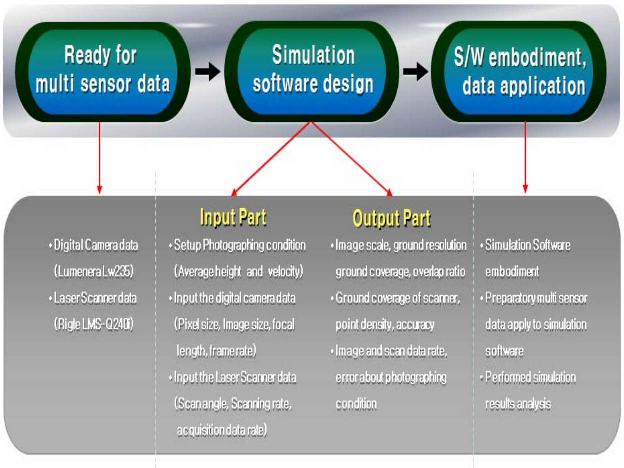

Figure 9. Simulation process

Table 8 and 9 show key parameters of the digital camera and the laser scanner used for this simulation, respectively. Table 10 and Table 11 show simulation results about the sensory data that the digital camera and laser scanner can produce. Considering the target applications, the altitude is set to 800 m and the velocity to 100 Km/hour.

Specification	Value
Image Sensor	1/1.8" " format, 7.1mm x 5.4mm array
Effective Pixels	1616x1216 square pixels, 4.40µm
Frame Rate	12 fps at 1616x1216
Dynamic Range	60dB
Dimensions (W x H x D)	2.25 x 3.85 x 1.56 inches

Table 8. Information of simulated image data

Specification	Value
Measurement rate	10000 Meas./sec
Scanning rate	80 scans/sec
Scan Angle	±40°
Data Rate	4 bytes/mea

Table 9. Information of simulated laser data

Parameters	Results
Field of View	28.4973 deg
Image Scale	0.0157
Ground Resolution	0.2514 x 0.2514 (m)
Ground Coverage	406.3086 x 305.7371
Distance btw Image	3.6361 m
Over lap	98.81 %
Max Range / 1hour	63.8228 km
Data Rate / 1 sec	94322688 bytes

Table 10. Simulation results related to image

Parameters	Results
Measures / scan	400
Angle / measure	0.125 deg
Distance btw Point (min ~ max)	1.7453 ~ 1.9258 (m)
Point Density	0.2968
Platform Velocity	157.0796 km/h
Data Rate / 1 sec	40000 bytes

Table 11. Simulation results related to laser data

4. CONCLUSION

Within this paper we provided the overview of our real-time rapid mapping system based UAV, which is equipped with a digital camera, a laser scanner, GPS/IMU and a stabilizer. We preliminarily designed aerial system and briefly verified that through the simulation. In the future we will refine the design of the aerial system and develop and test the system.

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