

A solar power generation facility state monitoring system using drone aerial photographing

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Abstract—Recently, there has been a lot of interest and issues related to solar power generation, and accordingly, various studies related to the solar power facility are being carried out. We would like to describe a solar power generation facility state monitoring system during research related to solar facility research. Proposed system will be based on drone aerial photographing technology, analyzing photographing data, and managing facilities based on the collected data. This paper describes the process of data collection, processing, and management, and proves its contents through the proposed system.

Keyword— solar power generation facility state monitoring system, drone aerial photographing

I. INTRODUCTION

In recent years, the development of photovoltaic business

is becoming more and more likely due to the implementation of the Renewable Energy Supply (RPS) system in Korea. The definition of RPS (New Renewable Energy Supply) means a system requiring operators with power generation capacity of 500 MW or more to supply a certain amount of power with renewable energy. It has implemented RPS and is doing well. Until December 2016, four years after RPS was implemented, its supply volume of FIT facilities (1 GW as of late 2011) was about 7.6 times that as much as that of current FIT facilities (solar energy 3.3 GW, non-flowing energy). The replacement rate of renewable energy in the year 2017 range is around 4 %. The government aims for 10 % in 2023 and it is forecast to rise to 28 % in 2030.

Therefore, a monitoring system for IT-related facilities will be needed. So, we would like to propose a solar power generation facility state system.

TABLE I

RPS facility confirmation by year, as of the end of 2016, Source: Korea Energy Corporation

		Y2012	Y2013	Y2014	Y2015	Y2016	Total
Solar	Number of power plants	1,670	1,898	5,501	6,944	4,056	20,069
	Facility Capacity (MW)	245	385	869	986	804	3,289
Non-Solar	Number of power plants	74	43	67	51	34	269
	Facility Capacity (MW)	1,731	509	873	441	711	4,266
Total	Number of power plants	1,744	1,941	5,568	6,995	4,090	20,338
	Facility Capacity (MW)	1,975	895	1,742	1,472	1,515	7,555

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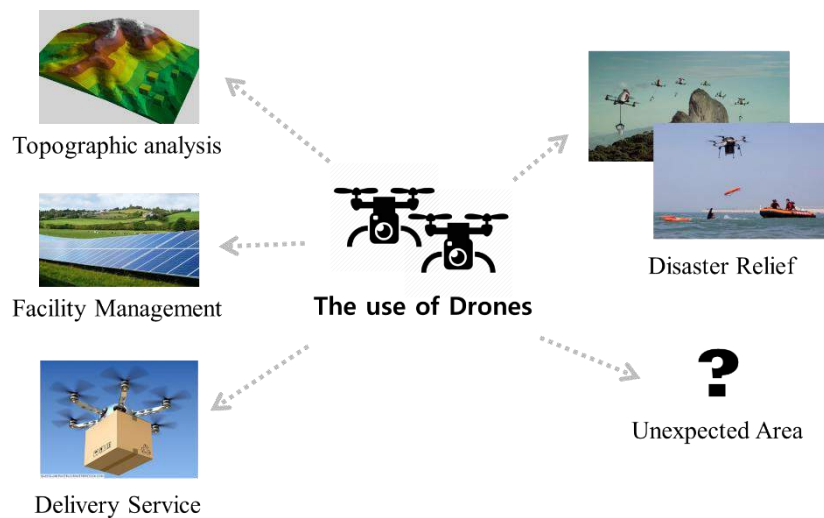


Fig. 1 Various Applications of Drones

II. RELATED WORKS

We want to use drone technology to collect basic data for facility management. Facilities mean solar power generation facilities and collect thermographic information about the solar power generation facilities. Therefore, not only solar facilities technology, but also drone technology is also relevant.

Currently, drone technology[1] is used in a wide variety of fields[6,7,8,9] like topographic analysis, facility management, delivery service, disaster relief, and it is being used in fields that were not predicted early on. As the navigation, communication, and sensor technologies related to drones have developed dramatically, the convergence market for drones such as facility inspection, disaster safety, disaster prevention, and logistics transportation is growing rapidly. The global drone market is expected to grow from \$ 6.6 billion in 2013 to \$ 11.4 billion in 2022, and is growing very rapidly[2]. The Korean Geographical Survey Institute is conducting 'a study on UAV introduction[3]' in the field of public surveying in order to establish a standard for using the drone in the field of public survey, and the research will be completed in December 2017.

In the United States, a study was made on the use of drones in the measurement of bridges, slopes and road pavement aging for the purpose of eliminating traffic congestion, improving safety, and reducing budgets.

In Europe, the efficiency of the survey was maximized by using drones in the investigation of road pavement aging mainly in Germany and Italy.

In China, research is being carried out on the use of drones for life structure, current status, and transportation of emergency goods in the event of slope failure using drone.

In the field of solar power, the drone technology can be very useful. In order to measure the overheating of the solar module, the drones can be equipped with an infrared camera to collect millions of pieces of photo information. This would save labor costs significantly compared to using individual measuring devices to inspect solar cell module information.

First Solar, the leading solar power company in the United States, is using the SkyCatch Drones service[4] at the world's

largest 290MW solar power plant.

Drones are also useful for protecting wildlife around large solar power plants[5]. In the US, large-scale solar power plants are obliged to maintain and manage wildlife habitats. When drilling in the construction planning stage, wild animals and plants in the construction area can be identified and appropriate action taken. Based on this drone technology, we are going to overlook thermal camera technology, communication technology, and monitoring technology.

This study is also related to remote management[9,10,11,12,13] of facilities. Compared with various remote facility management methods, this study is distinguished in terms of using solar facility management, drone and thermal camera technique.

III. A SOLAR POWER GENERATION FACILITY STATE MONITORING SYSTEM USING DRONE AERIAL PHOTOGRAPHING

We propose a solar power generation facility state monitoring system using drone aerial photographing. Figure 2 shows the overall of the proposed system.

The facilities can be monitored by the drones taking aerial photographs, real-time or batch data transmission and processing. Of course, data collection and processing are based on the IT infrastructure which consists of maps and database servers, and application servers.

The system we propose consists of two main functions. One is the thermal imaging camera image analysis function and the other is the solar power facility state monitoring function.

A. Thermal imaging camera image analysis function

We use a variety of information to recognize specific phenomena. In particular, we perceive phenomena based on visual information. And we want to know about the state of facilities based on visual information. Drones generally provide visual information for facility management. At this time, the thermal imaging camera is mounted on the drone, and thermal imaged photograph information is analyzed.

1) Location analysis of images

Drones thermal cameras are based on aviation cameras. EXIF (EXchangeable Image File Format) information is input into the image data taken for the air. In particular, the

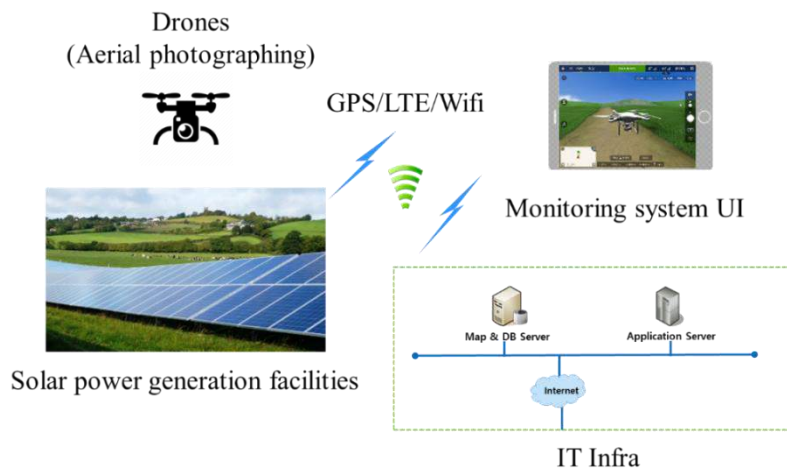


Fig. 2 Overall of the proposed system which is solar power generation facility state monitoring system using drone aerial photographing

equipment equipped with GPS will store latitude, longitude and altitude data when shooting. In order to find out the characteristics of a specific area, a color image analysis is carried out after taking an image with an infrared camera, and a specific temperature point can be found based on the color analysis. After finding a specific temperature point, map the relevant image data and corresponding point of the solar facility site and display it on the screen. Map the position data (latitude, longitude) to the scene image as a preliminary task.

Image formats that contain location (latitude, longitude) data include GeoTiff information. For images without general location (latitude, longitude) data, you can enter the latitude and longitude data using the map mapping system.

2) Metadata for data exchange: EXIF

EXIF (Exchangeable Image File Format), which is metadata recorded in an image file or the like, is recorded in an image file of JPEG or TIFF format as an exchange image file format.

Attributes of a JPG file

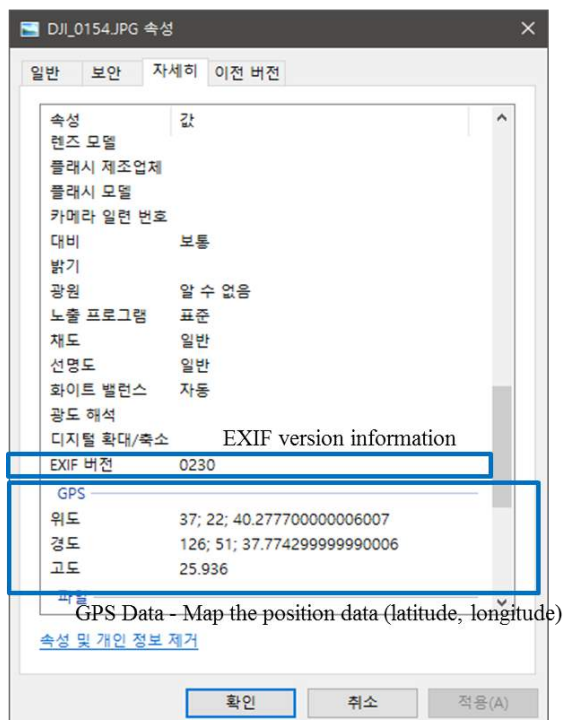


Fig. 3 EXIF information in JPG file

The EXIF data includes the following information.

- Camera information
- Camera settings
- Copyright Information
- Location information

TABLE II
GPS information

Tag ID	Variable name	Description
0	GPSTimeStamp	GPS version
1	GPSPeakRef	N (north), S (south)
2	GPSPeak	Latitude
3	GPSPeakRef	E (east), W (west)
4	GPSPeak	Hardness
5	GPSPeakRef	Relationship between altitude and sea level
6	GPSPeak	Altitude
7	GPSTimeStamp	The time (hours, minutes, seconds)
8	GPSSatellites	Satellite used for measurement
9	GPSStatus	The status of the GPS receiver used in the shooting
10	GPSPeakMode	GPS measurement mode
11	GPSPeak	Accuracy of GPS data
12	GPSSpeedRef	Code for GPS receiver speed
13	GPSSpeed	Speed of GPS receiver
14	GPSTrackRef	Code for GPS receiver direction
15	GPSTrack	Direction of GPS receiver
16	GPSPeakDirectionRef	Symbol for the direction of the subject
17	GPSPeakDirection	The direction of the subject
18	GPSPeakDatum	Information on geopolitical location
19	GPSPeakLatitudeRef	N (north), S (south)
20	GPSPeakLatitude	Latitude of target point

We want to use GPS information. There are various types of GPS information as shown in the table 2. Of the EXIF GSP

information provided in Table 2, we use the latitude, longitude, and altitude information 'GPSPLatitudeRef', 'GPSPLatitude', 'GPSPLongitudeRef', 'GPSPLongitude', 'GPSPAltitudeRef', and 'GPSPAltitude'. We extract latitude, longitude, and altitude information from images as shown above.

3) Thermal imaging camera image analysis

And analyzes the captured images based on the positional information and the thermal image information described above in a complex manner.

The data captured by the thermal imaging camera has its own color depending on the temperature of each pixel of the entire image, so that the entire image has color. There are various modes as follows.

Figure 3 below shows the change information according to the mode of the thermal imaging camera.

Among the various modes, White Hot is suitable for specific temperature detection and Rainbow is suitable for temperature distribution detection.

In case of 'White Hot' mode, it is suitable for specific temperature detection. For 'Rainbow' mode, it is suitable for temperature distribution. In other words, 'Rainbow' mode is suitable for 'measuring temperature distribution' and 'White Hot' mode is suitable for 'measuring specific temperature precision'.

The characteristics of the 'measuring temperature distribution' are as follows:

- The overall temperature distribution of the shooting area can be distinguished by color
- Quickly identify temperature changes around each shot
- Maximum temperature, minimum temperature and average temperature can be checked
- It is possible to check temperature distribution of temperature change by radiant heat over time
- It is possible to check temperature distribution according to seasonal temperature change.

And, the characteristics of the 'measuring specific temperature precision' are as follows:

- prediction of specific temperature spots in large areas
- Possible location determination at specific temperature
- Data base can be analyzed by data base

4) Image analysis for specific temperature detection

The steps of image photographing and analysis are as follows:

- ① Copying the original data shot by the thermal camera to the system
- ② Copy the temperature distribution data and specific temperature data separately
- ③ Display temperature distribution image on screen
- ④ Displays a specific temperature image on the screen, detects a specific temperature, and displays the corresponding point

Figure 4 shows the steps of image photographing and analysis.

5) Thermal imaging camera image analysis

The steps of thermal imaging camera image are as follows:

- ① The selected images stored on the SD card are copied to a specific folder for analysis as shown Figure 5. If we already have the same date data when we copy images, we can create a new date folder and copy it several times a day.
- ② The original image can be called a temperature data image and the spontaneous data image, respectively, and the copied image is stored as an image by date as shown Figure 6.
- ③ Select a temperature distribution image and check the temperature distribution of the entire low-firing range on the main screen. Map the latitude and longitude coordinates stored in the respective images to the latitude and longitude coordinates stored in the main map image and outputs them to the corresponding screen positions.
- ④ Select a specific temperature image as shown in Figure 7 to start temperature analysis for each image, and the image with a specific temperature color is displayed in the same position as the temperature distribution image.

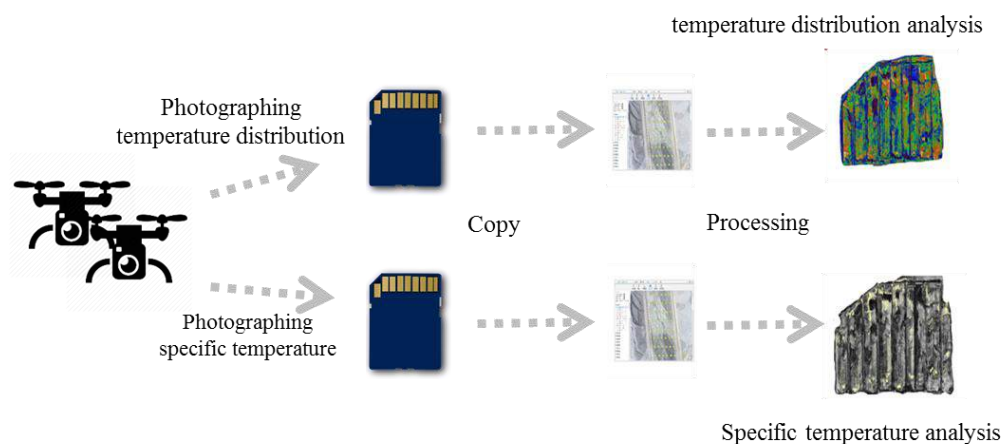


Fig. 4 Steps of image photographing and analysis

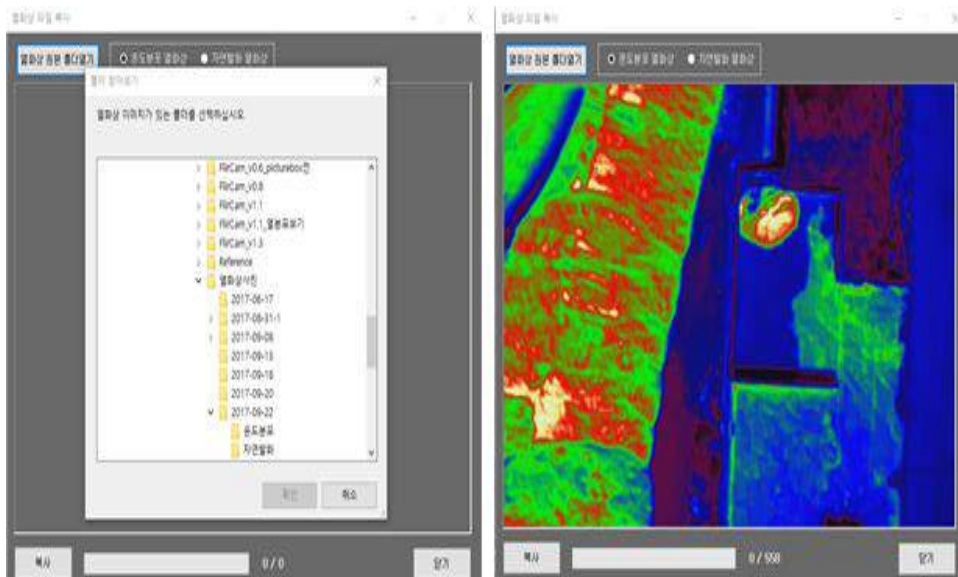


Fig. 5 Photographing images copy

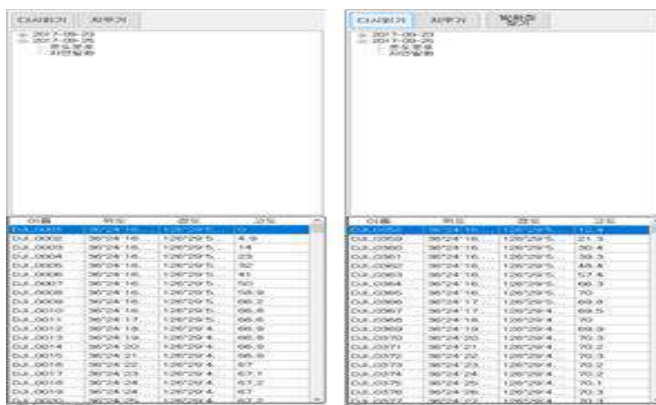


Fig. 6 Save by image

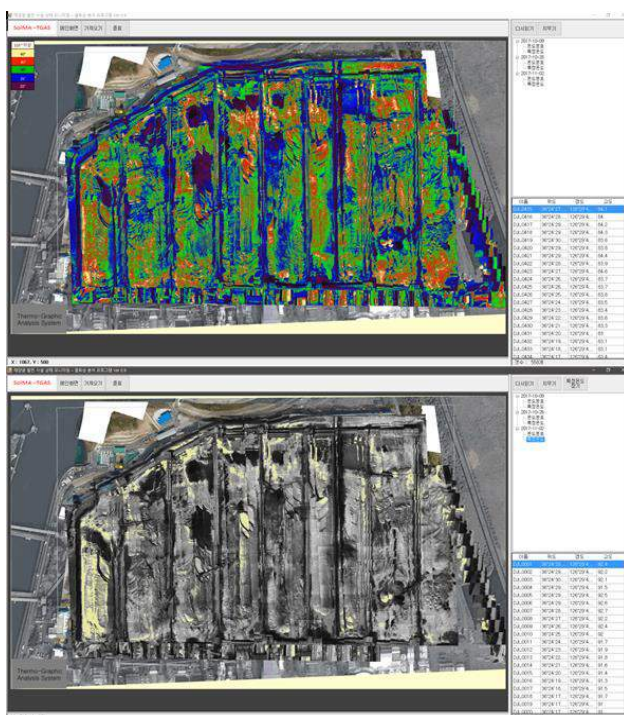


Fig. 7 Temperature distribution and specific temperature detection

B. Solar power facility state monitoring function

We can define and operate a monitoring process based on thermal imaging camera image analysis function.

Figure 8 is the operating process of the solar power facility state monitoring system. It is a process that is configured to analyze the thermal image information collected through the drone, and to check and review the status of facilities.

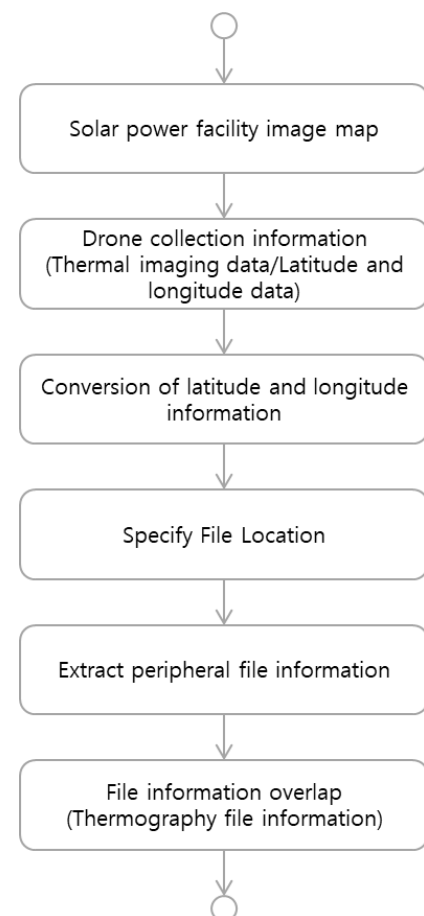


Fig. 8 Operating process definition of the solar power facility state monitoring

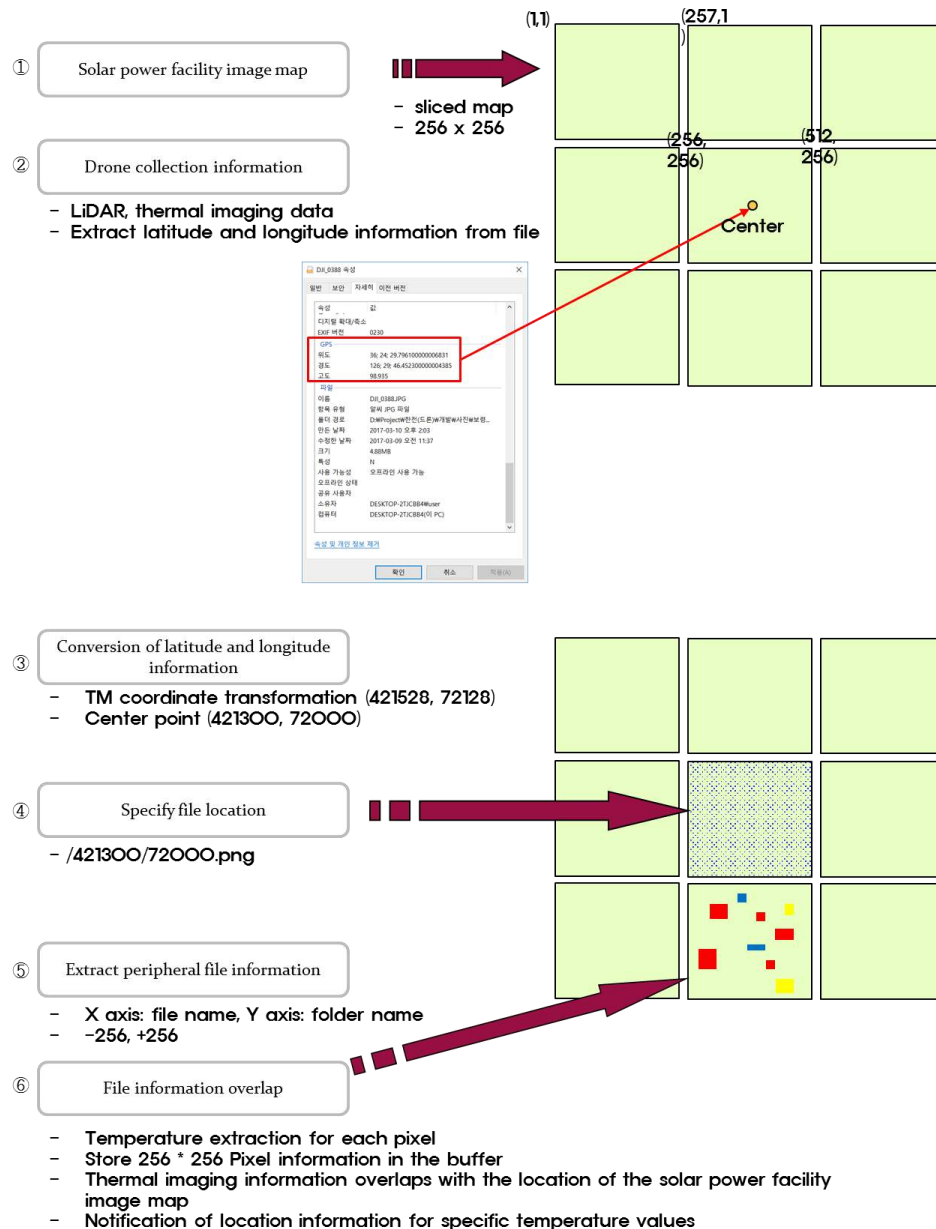


Fig. 8 Operating process of the solar power facility state monitoring system specific temperature detection)

Figure 8 shows operation which is the solar power facility state monitoring system specific temperature detection of the process defined in Figure 7. According to this operating method, we can monitor the state of the solar power facility.

First step is to import the solar power facility image map. The image map is composed of a slice map of (256*256) sizes. Second step is to gather information from the drones. At this time, the thermal image data and the latitude and longitude information in the file are extracted together. Third step is to convert latitude and longitude information as appropriate. Fourth step, the location file name is extracted at the center. In fifth step, the file name and the folder name are extracted. The sixth step is the last step, extracting the temperature of each pixel, repeatedly storing the pixel information in a buffer and overlapping the thermal image information.

It also provides information on the location of a specific temperature with anomalous signs. In this way, the monitoring system can be operated and the management of solar power facility state can be systematically automated.

IV. CONCLUSIONS

In this paper, we propose a solar power generation facility state monitoring system using drone aerial photographing.

We describe the thermal camera technology and the related analysis technology that we are dealing with in the proposed system, and describe the operation method to monitor the facility management using the technology. The technology includes techniques for processing photographic data as well as technologies for the thermal imaging camera itself, including methods for managing images and for analyzing and monitoring managed images.

We believe that this proposed system is a study on facility management and that it will play an important role in the future of new technology energy management.

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REFERENCES

- [1] DANIEL, Kai, et al. *AirShield: A system-of-systems MUAV remote sensing architecture for disaster response*. In: *Systems conference*, 2009 3rd Annual IEEE. IEEE, 2009. p. 196-200.
- [2] US Teal Group, *US Teal Group Report*
- [3] Korean Geographical Survey Institute, *a study on UAV introduction*
- [4] Skycatch, Inc., *Skycatch: Drone Image Processing Platform*, <https://www.skycatch.com/>
- [5] Quater, Paolo Bellezza, et al. "Light Unmanned Aerial Vehicles (UAVs) for cooperative inspection of PV plants." *IEEE Journal of Photovoltaics* 4.4 (2014): 1107-1113.
- [6] RESTAS, Agoston. *Drone applications for supporting disaster management*. World Journal of Engineering and Technology, 2015, 3.03: 316.
- [7] KIMA, C.; MOON, H.; LEEA, W. *Data Management Framework of Drone-Based 3d Model Reconstruction of Disaster Site*. ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2016, 31-33.
- [8] Ok Hyun and Kim Seong-Jin, "Application Method of Remote Site Monitoring in Public Road Construction Projects," *Journal of the Korea Academia-Industrial cooperation Society*, Vol. 14, No. 12 pp. 6550-6557, 2013
- [9] Kyoong-Tai Kim, "Development of a Mountainous Area Monitoring System based on IoT Technology," *Journal of the Korea Academia-Industrial cooperation Society*, Vol. 18, No. 3 pp. 437-446, 2017
- [10] Barker, William E., et al. "Method for computer internet remote management of a telecommunication network element." U.S. Patent No. 6,363,421. 26 Mar. 2002.
- [11] Hunter, Robert R., David A. Vogt, and Leslie Cheong. "Multi-capability facilities monitoring and control intranet for facilities management system." U.S. Patent No. 6,363,422. 26 Mar. 2002.
- [12] Wang, Shengwei, and Junlong Xie. "Integrating Building Management System and facilities management on the Internet." *Automation in construction* 11.6 (2002): 707-715.
- [13] Yun, Chang Ho, et al. "Intelligent management of remote facilities through a ubiquitous cloud middleware." 2009 IEEE International Conference on Cloud Computing. IEEE, 2009.
- [14] Suiter, F. J., and T. M. Cortes. "Considerations for a reliable telecommunication power system at remote facilities utilizing valve regulated lead-acid battery management system technologies." *Telecommunications Energy Conference*, 1994. INTELEC'94., 16th International. IEEE, 1994.



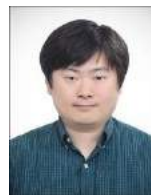
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