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Application of Remote Monitoring to Overcome the Temporal and Spatial Limitations of Beach Litter Survey

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Abstract. This study used a remote sensing technique as an environmental monitoring tool to assess beach litter. To determine both the time at which beach litter was deposited and the area affected, we undertook real-time monitoring with a network camera. When the cameras confirmed generation of a large amount of litter, an unmanned aerial vehicle was used to monitor the contamination status of the beach. If the monitoring technique used in this study is adopted as part of a beach litter management policy by central or local government, practical assistance could be provided to future beach litter collection and maintenance programs.

Keywords: Beach litter, Remote Monitoring, Network Camera, Unmanned Aerial Vehicle.

1 Introduction

To solve the marine debris problem and efficiently collect beach litter, an accurate assessment of the current situation is a prerequisite. The most commonly used method is monitoring through beach surveys [1]. Both in Korea and abroad, many studies have been undertaken to determine levels of beach litter, its spatial distribution, composition, and morphology using monitoring methods [2-4]. In Korea, to quantify and classify beach litter, the Korean National Marine Debris Monitoring Program ran from 2008 to 2012. A total of 20 beaches were targeted, with a 100-m section selected to monitor beach litter every 2 months [5]. The monitoring method was based on beach litter collection and analysis, and enabled identification of the source, type of material, and area affected [6]. Through the results of the survey and statistics based on long-term monitoring, the actual status of beach litter was determined. The results were also used to improve the effectiveness of management policies [7]. However,

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studies to date have been limited to research on general features of beach litter, such as the type of material, source, and the period of generation. Beach surveys require large amounts of time, labor, and funding. A study with a non-continuous survey cycle time of more than 1 month cannot determine specific changes in beach litter over time [8]. The aim of this study was to utilize remote-sensing techniques for beach litter monitoring and to enhance the effectiveness of beach surveys.

2 Materials and Methods

2.1 Monitoring Site

Remote monitoring of beach litter was undertaken at a site on Geoje Island, in the south of Korea (Fig. 1). Heungnam Beach is located in the northeast of Geoje Island, and has a length of 350 m and a width of 30 m. Its slope is gentle and it has a monotonous sandy surface. Every year, this island is affected by fishery-based litter caused by Styrofoam buoys and trash deposited illegally by tourists. In addition, it is adjacent to the mouth of the Nakdong River, which is the largest river inflowing to the southern sea, with an estimated 2,000 tons of litter flowing to the coast each year [9].

Fig. 1. The location and shape of Heungnam Beach on the southern coast of Korea (red circles indicate the locations and areas photographed by the network camera system).

2.2 Configuration and Operation of the Monitoring Equipment

Heungnam Beach is located on the southeast coastline, and the left side of the beach is wider than the right side. In this study, to monitor a wide area, we established network cameras on top of the left side of a building (Fig. 1). We also erected a 4-m pole and set up two cameras facing left and right to maximize the photography area and angle (Fig. 2a). We also established a control box including a server, which was capable of real-time monitoring and controlling a high-definition video surveillance network, terabyte (TB) storage, a power supply, and Internet router (Fig. 2b). This server not only acted as a digital video recorder but could also assess storage, the Internet environment, and the operational state of the cameras. Beach litter monitoring took place from 1 January to 31 December 2013 using the network cameras. The cameras observed through the Internet connection a remote PC (in the laboratory) could monitor the beach status in real time. Each network camera was allocated a private IP address, which facilitated access to the monitoring videos using a web browser (Fig. 2c).

Fig. 2. The structure of the network camera system: (a) a network camera setting on a 4-m-high pole (SNO-7080R), (b) the structure of the control box, and (c) the web browser for real-time monitoring.

The area covered by the network cameras was limited by constraints such as camera angle, height, and location of installation. Therefore, it was difficult to monitor the whole beach. To compensate for this, we combined the use of an unmanned aerial vehicle with camera monitoring. The unmanned aerial vehicle used in this study was a mini quadcopter (GAUI 500X: TSH GAUI, Fig. 3), which can be equipped with a camera. For beach photography, a GPS, on-screen display module, and autopilot system were combined, so that the current location above the ground could be recorded while maintaining flight parameters such as positioning and auto balance (Fig. 3b). On the ground, the video and flight information (*e.g.*, height, distance, and location) could be viewed through a color monitor installed in the receiver, and the position of the flight could be adjusted (Fig. 3c). We installed a gimbal mount at the bottom of the engine, so that the vertical angle of the receiver could be adjusted and a digital camera for aerial photography could be attached (Fig. 3d). Unmanned aerial vehicle monitoring enabled the identification of locations on the beach with high pollution levels. Photographs were taken from the left to right side of the beach; i.e. from the narrow to broad sections of beach. Through the color monitor installed in the receiver, we could confirm the range of photography and the size of beach litter. During the monitoring, the photography height was controlled to be ~15 m.

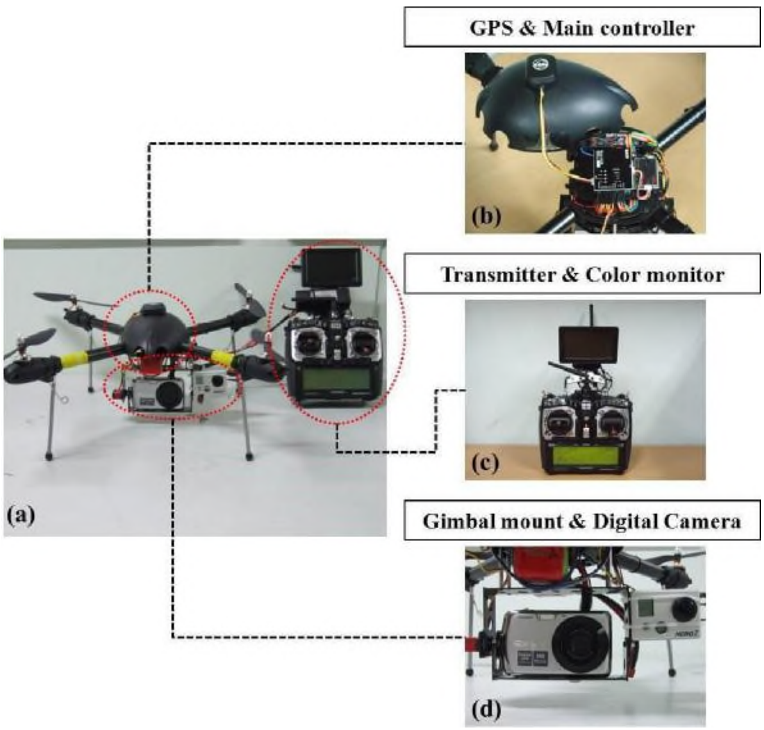

Fig. 3. Micro-UAV equipped with a digital camera on a gimbal mount: (a) the quadcopter, (b) GPS and main controller, (c) transmitter and color monitor and (d) gimbal mount and camera.

2.3 Beach Litter Detection Software

For beach litter monitoring, we used software developed by [10], which can detect beach litter from unmanned aerial vehicle portraits. After the portrait underwent image pre-processing, morphology conversion, and image recognition, the Beach Litter Detection (BLD) software was used to identify items of beach litter (Fig. 4).

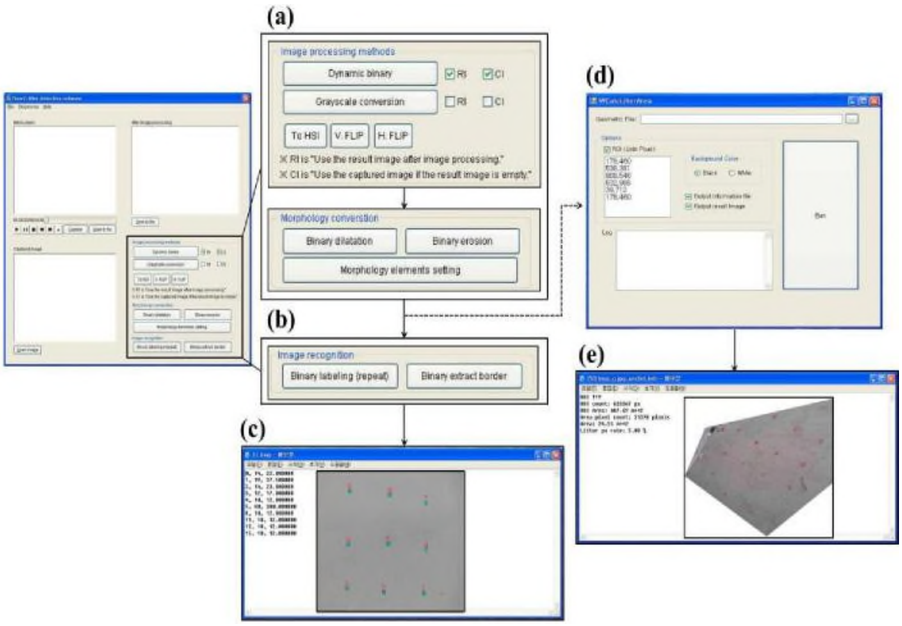

Fig. 4. The structure of the beach litter detection (BLD) software: (a) Image pre-processing and the morphology function for noise and background elimination from the remotely monitored image, (b) and (c) image recognition function for the calculation of beach litter and a background-eliminated unmanned aerial vehicle image, and (d) and (e) result of using the BLD software to calculate the area of beach litter from background-eliminated networked camera images.and main controller, (c) transmitter and color monitor and (d) gimbal mount and camera.

The background and noise in the portraits produced by distortion corrected network cameras and the unmanned aerial vehicle were eliminated using BLD software operations, such as red, green, and blue (RGB) to hue, saturation, and intensity (HIS) conversion, dynamic binary translation, and binary dilatation and erosion (Fig. 4a). After background and noise elimination, beach litter was identified in the unmanned aerial vehicle portrait by means of an image recognition procedure, which consisted of labelling and extracting borders (Fig. 4b). The result included the quantity of litter along with pixel information, which was provided as a portrait (Fig. 4c). To estimate the area of beach litter, software using the Visual C# development language was used (Fig. 4d). After geometric correction, this software identified the area of beach litter in a defined region of interest (ROI) by user defined pixel coordinates. Following removal of background and noise by geometric correction, the network camera portraits were used to identify the area of pollution. The portraits could be used to show the area of beach litter pollution, the time at which pollution occurred, and pixel information (Fig. 4e).

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