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# Application of Remote Environmental Monitoring Technique to Efficient Management of Beach Litter

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***Abstract***

*This study aims to present a environmental monitoring tool which is using remote sensing technique to improve the understanding ability of beach litter condition. In order to grasp occurrence time of beach litter and its pollution area, we did the real-time monitoring with network camera. When confirm that there is a lot of litter occurred within the scope of camera, we use unmanned aerial vehicle to monitoring contaminated status of total beach. The area monitored was Heungnam Beach on Geoje Island, which is located in the south of Korea. During the monitoring period, the maximum beach litter was produced on 28th May 2013 (29.9 $m^2$/580 pieces). In the future, the proposed monitoring method can be used in association with remote detection methods to determine the appropriate time for collecting litter and improve the effectiveness of beach litter management policies.*

**Keywords:** *Remote Environmental Monitoring, Network Camera, Unmanned Aerial Vehicle, Beach litter, Detection*

## 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 [2-10]. The National Marine Debris Monitoring Program (NMDMP) is an example of such a monitoring program that was conducted at the national level in the United States. From 1996 to 2007, to determine beach litter status, research was conducted as part of the NMDMP in nine coastal regions of the USA. In each region, 20 beaches were selected and a 500-m-long survey section was monitored for 28 days [11]. 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 [12]. The monitoring method was based on beach litter collection and analysis, and enabled identification of the source, type of material, and area affected [13]. Through the results of the survey and statistics based on long-term monitoring the actual status of beach litter

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was determined. The results were also used to improve the effectiveness of management policies [14]. However, 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, labour, 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 [15]. Such studies can compare and analyse litter only on a monthly or seasonal basis, but not at a specific time. Hence, there is a need for new monitoring schemes that can overcome the temporal and spatial limitations of existing methods, and enable the practical collection and management of litter. The aim of this study was to utilise 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 (Figure 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 [16].

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 [17]. Approximately 40 tons of floating litter were deposited on Heungnam Beach in July 2012 [18].

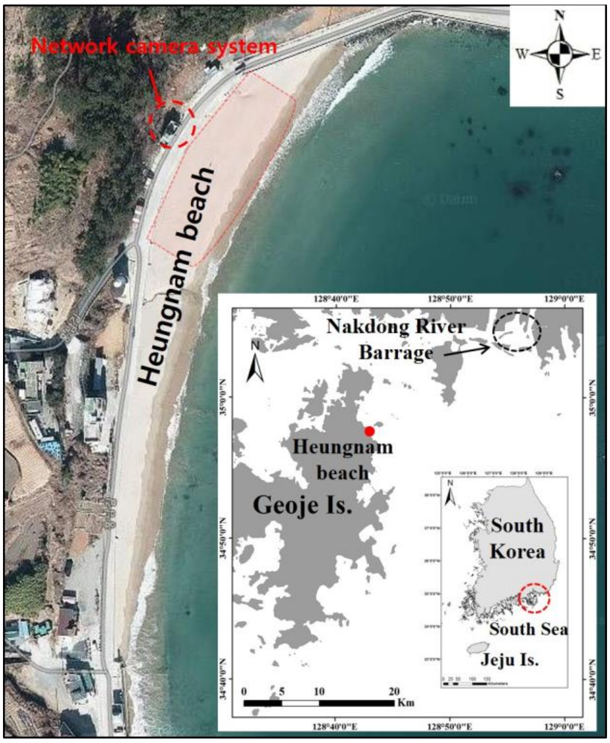


**Figure 1. The Location and Shape of Heungnam Beach on the Southern Coast of Korea (Red Circles Indicate the Locations and Areas Photographed by the Network Camera System)**

 

### 2.2. Configuration and Operation of the Monitoring Equipment

**Network cameras.** 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 (Figure 1).

We also erected a 4-m pole and setup two cameras facing left and right to maximise the photography area and angle (Figure 2a). The specifications of the network cameras (SNO-7080R: Samsung Techwin, South Korea) are given in Table 1; the camera coverage had ~30% overlap. 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 (Figure 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 1st January to 31st December 2013 using the network cameras. The cameras observed the beach from sunrise to sunset, and 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 (Figure 2c). The video was automatically backed up and stored on the server on a daily basis.


**Figure 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**

**Table 1. Detailed Specifications of the Network Cameras (SNO-7080R)**

| | |
|---|---|
| **Valid pixel** | 2,096(H) × 1,561(V) |
| **Focal length** | 3~8.5 mm(2.8X)Motorized Vari-focal |
| **Angle of view** | H: 94°(Wide)~32.9°(Tele),<br>V: 69.86°(Wide)~24.92°(Tele) |
| **Video compression method** | H264.MREG |
| **Protocol** | TCP/IP, UDP/IP, RTP(UDP), RTP(TCP), RTSP, NTP, HTTP, DNS, DDNS, QoS, FTP |
| **Power supply** | 12V DC/785Ma, 24V AC/880Ma |

**Unmanned Aerial Vehicle.** 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 (UAV) with camera monitoring. UAVs have advantage as a major method for spatial information obtain [19]. The unmanned aerial vehicle used in this study was a mini quadcopter (GAUI 500X: TSH GAUI, New Taipei City, Taiwan), which can be equipped with a camera. For the exact specifications, please refer to Table 2.

**Table 2. GUAI 500X Operational Data [20]**

| | |
|---|---|
| **Dimension** | Main controller : 53.5 × 38.5 × 12 mm |
| **Operating temperature** | -20 ~ 80℃ |
| **Operating modes** | Rate (manual) mode, Auto-balance mode,<br>GPS positioning mode |
| **GPS positioning mode** | Hovering accuracy: Horizontal: ± 2 m Vertical: ± 0.5 m<br>Max horizontal speed: 10 m/s<br>Max vertical speed: 8 m/s |
| **Maximum flying weight** | 2,200 g |
| **Suitable wind condition** | < 10 m/s |

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 (Figure 3b). On the ground, the video and flight information (*e.g.*, height, distance, and location) could be viewed through a colour monitor installed in the receiver, and the position of the flight could be adjusted (Figure 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 (Figure 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 colour 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.

 

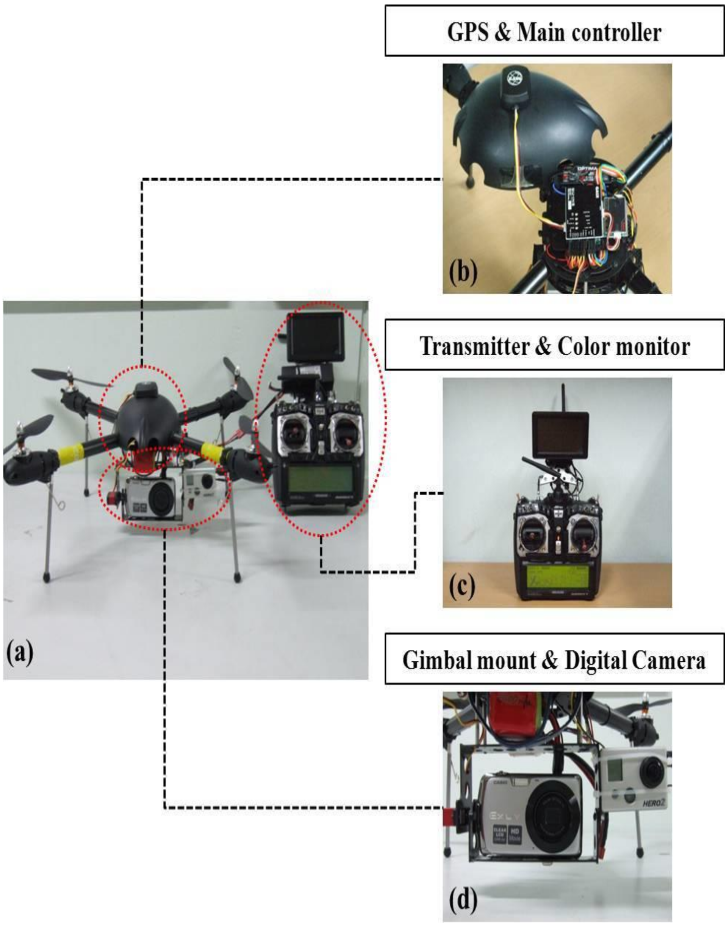


**Figure 3. The Structure of the Network Camera System: (a) a Network Camera Setting on a 4-m-High Pole (SNO-7080R), (b) the Structure of the Control Box, and (c) the Web Browser for Real-Time Monitoring**

### 2.3. Beach Litter Detection

**Lens distortion calibration and geometric correction.** Because of their non-metric design, lens distortion was greater in the network cameras than for a typical surveying camera. To obtain accurate levels of beach litter pollution and its time of production, it was necessary to eliminate the geometric distortion and determine the mapping relationship between the pixel coordinates and geographical coordinates. We referred to the geometric distortion correction for camera calibration and GPS investigations in [21] as a basis for this. To correct the distortion, before installing the network cameras at the beach, we used a calibration target and Close-range Digital Workstation (CDW) to calculate the lens characteristics and interior orientation parameters. Furthermore, to correct the geometric distortion of a portrait, after installing the network cameras on the beach we established 54 Ground Control Points (GCPs) spaced 6 m apart, and then used the VRS-GPS (Virtual Reference Station-Global Positioning System) for measurement. Figure 4 shows the results of the geometric distortion correction using calibration data and GCPs date.

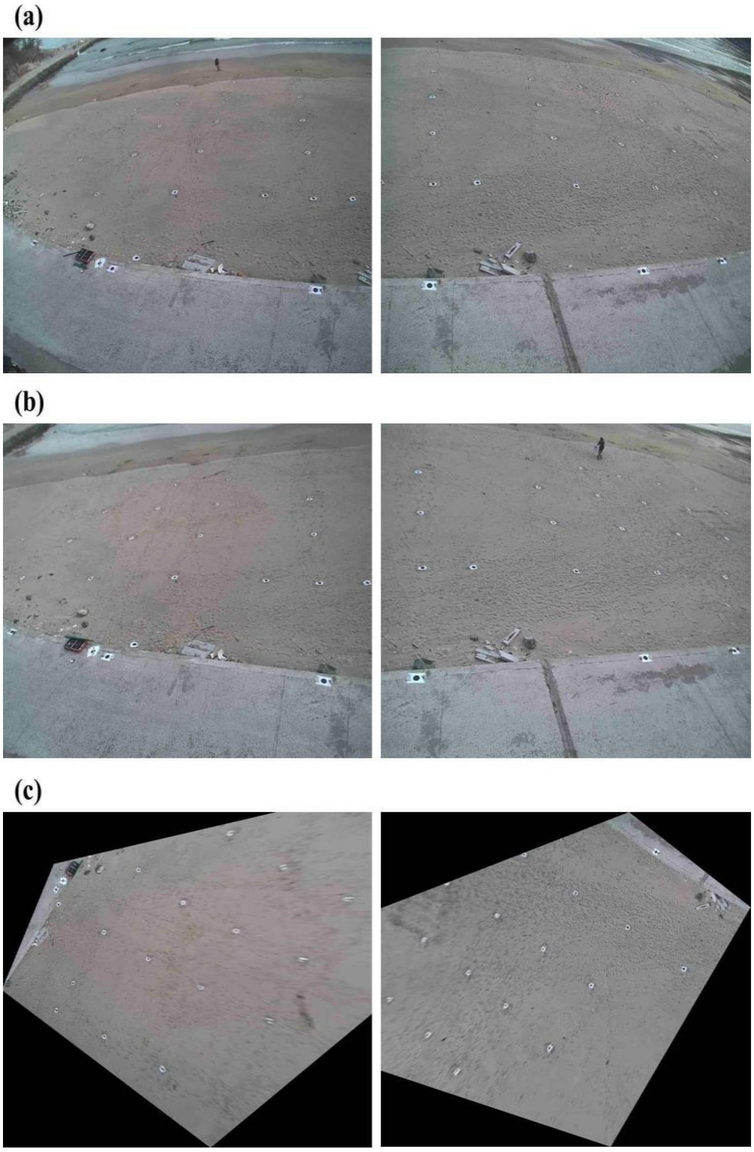


**Figure 4. The Geometric Distortion Correction for a Network Camera: (a) Original Photographic Image from the GCPs for Camera 1 and Camera 2 Installed on the Beach, (b) Image Corrected for the Distortion of the Camera Lens, and (c) Geometric Correction Results for Distortion-Corrected Images**

**Beach Litter Detection Software.** For beach-litter monitoring, we used software developed by [22], 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. 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 (Figure 5a). 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 (Figure 5b). The result included the quantity of litter along with pixel information, which was provided as a portrait (Figure 5c). To estimate the area of beach litter, software using the Visual C# development language was used (Figure 5d). 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 networked 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 (Figure 5e).

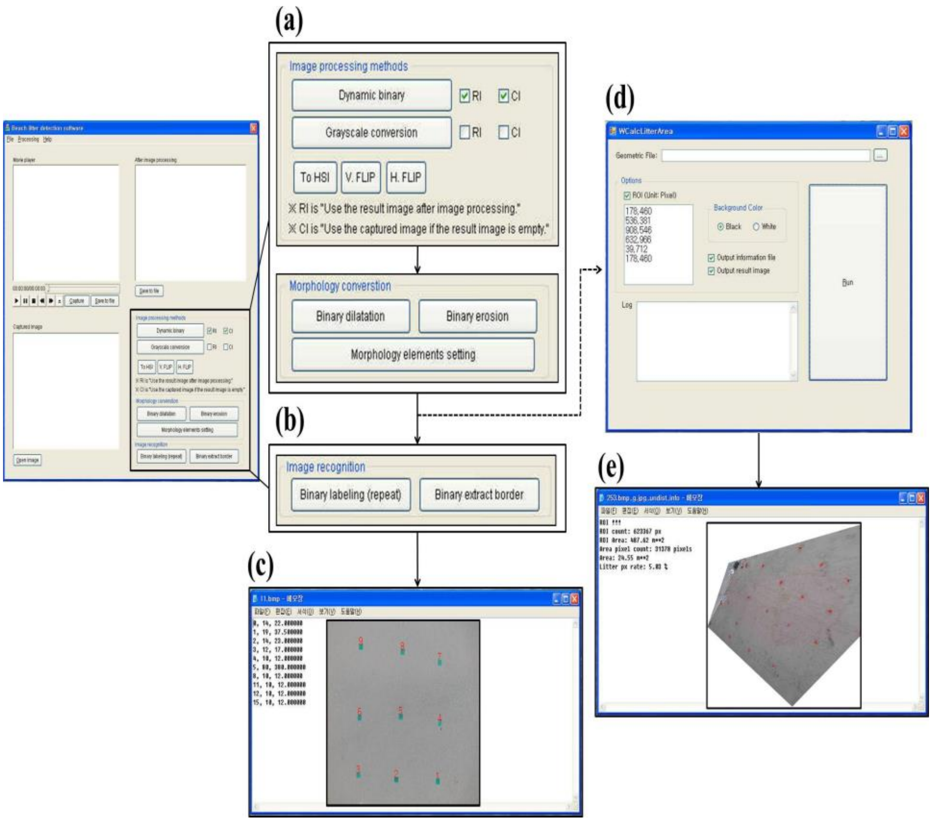


**Figure 5. The Structure of the Beach Litter Detection (BLD) Software: (a) Image Pre-Processing and the Morphology Function for Noise and Background Elimination from the Remotely Monitored Image, (b) and (c) Image Recognition Function for the Calculation of Beach Litter and a Background-Eliminated Unmanned 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**

## 3. Results

The networked camera real-time monitoring identified a large amount of beach litter that was deposited on 28th May 2013 (Figure 6c). Camera 1 covered a beach area of 487.6 $m^2$, of which 24.6 $m^2$ was polluted (Figure 6f). The area of beach litter pollution had increased substantially from the 0.07 $m^2$ recorded on 1st May (Figures 6b and 6e). The main litter items were discarded buoys and pellets, as shown in the right bottom of Figure 6c.

 

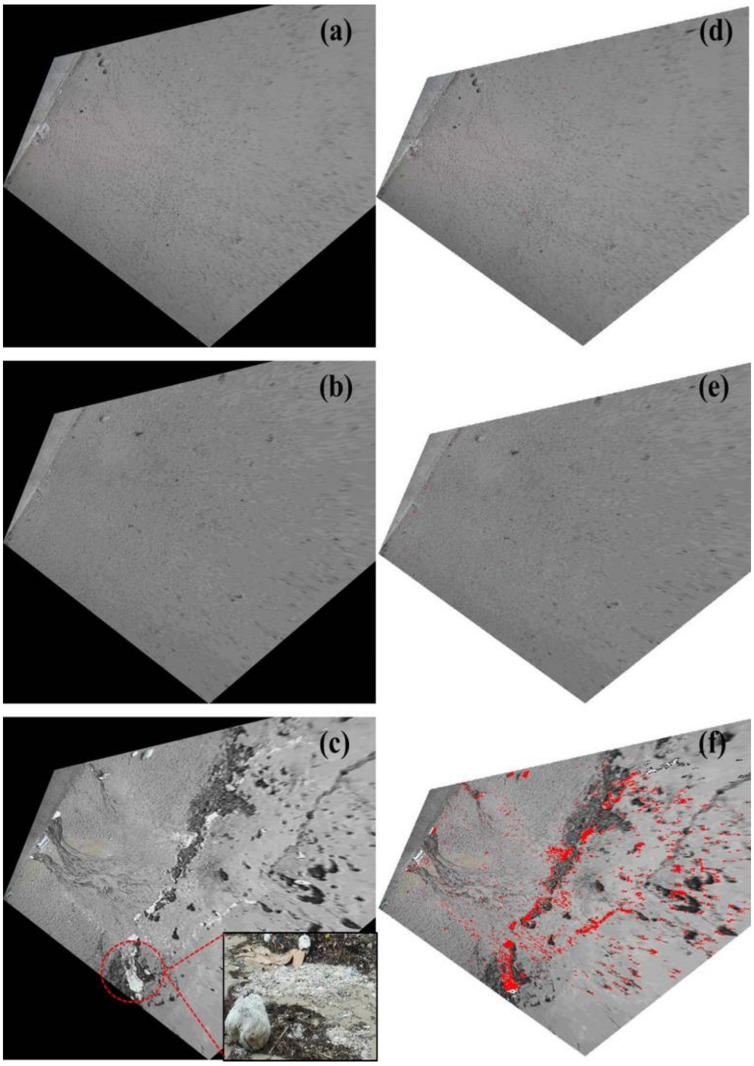


**Figure 6. The Area of Beach Litter Pollution Calculated from Camera 1 Images: (a) - (c) the Geographic Correction Images for the Detection of the Polluted Area (1st, 15th, and 28th May 2013), (d) - (f) the Results of (a) - (c) using Software [(d) 0.07 $m^2$, (e) 0.1 $m^2$, (f) 24.6 $m^2$]**

Camera 2 covered a beach area of 471.5 $m^2$, of which 5.32 $m^2$ was polluted (Figure 7f). As with camera 1, the area polluted showed substantial growth from the 0.2 $m^2$ recorded on 1st May (Figures 7a and 7b) and the 0.07 $m^2$ recorded on 15th May (Figures 7b and 7e). However, the polluted area was smaller than that identified by camera 1 because fewer pellets were present (Figures 7c).

 

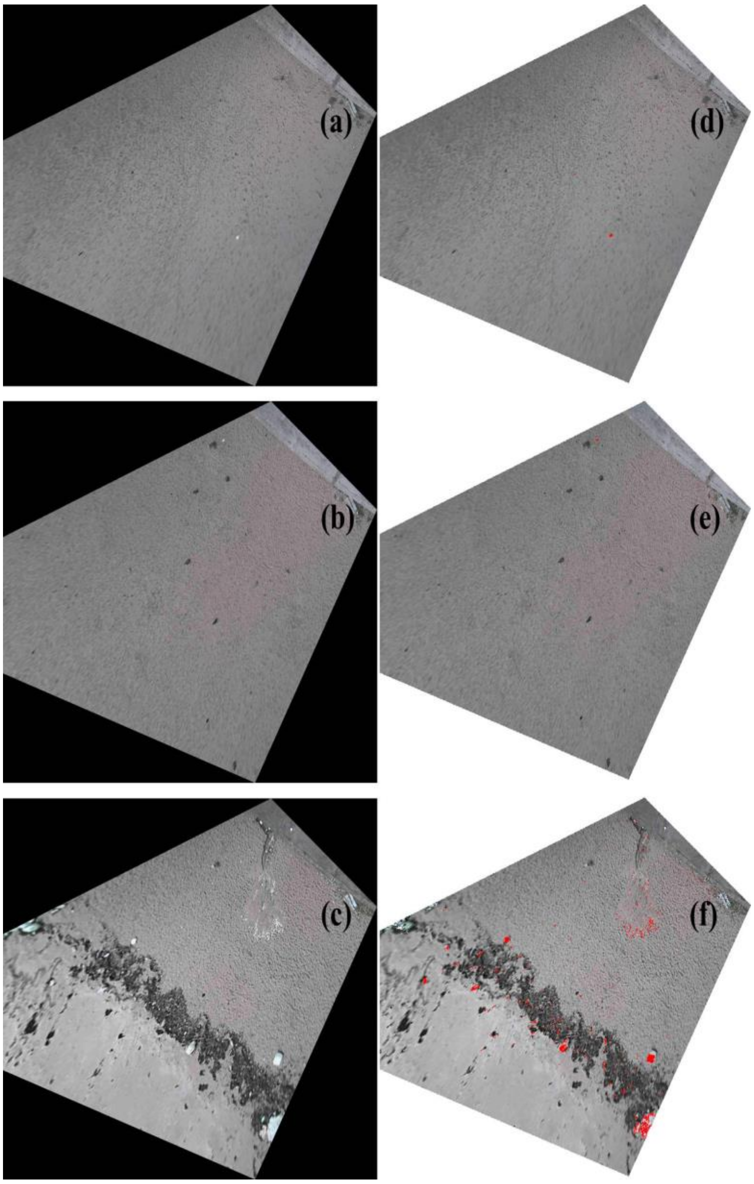


**Figure 7. Area of Beach Litter Pollution Calculated from Camera 2 Images: (a) - (c) Geographic Correction Images for Detection of the Polluted Area (1st, 15th, and 28th May 2013), (d) - (f) Results of (a) - (c) using Software [(d) 0.2 m$^2$, (e) 0.07 m$^2$, (f) 5.32 m$^2$]**

Upon discovery of deposition of a large amount of beach litter on 28th May, we used the unmanned aerial vehicle on 29th May to monitor the entire beach. By moving from the narrow left side to the right side of the beach, we obtained a portrait using the BLD software. To determine the quantity of beach litter items deposited, we eliminated small particles (*e.g.*, pellets) during image processing. As a result, 580 pieces of beach litter were detected from nine still images (Figure 8). This is six fold more than the 95 items that were detected on 5th March, when the areas of beach litter pollution were 0.43 m$^2$ (camera 1) and 0.25 m$^2$ (camera 2).

 

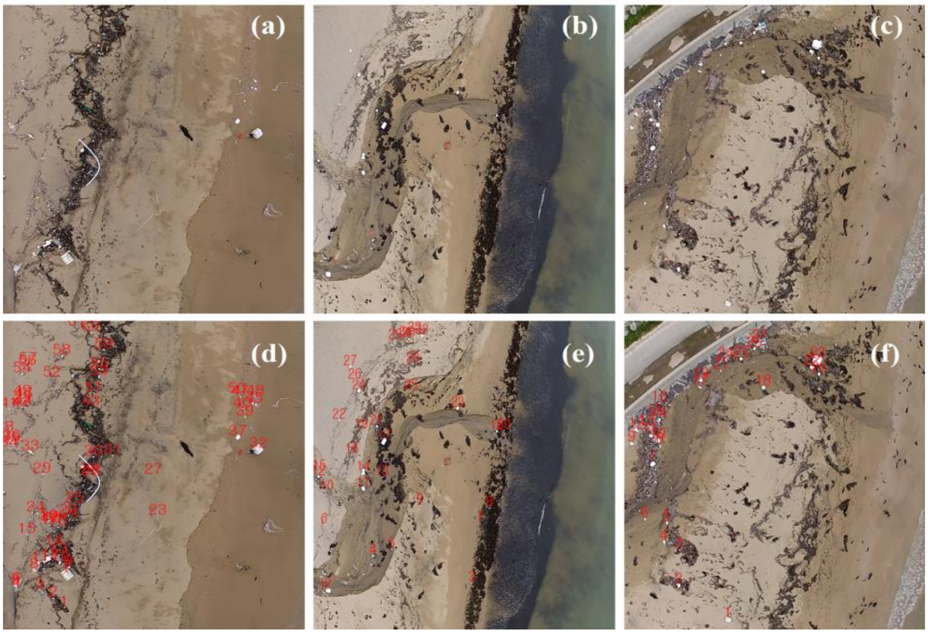


**Figure 8. Beach Litter Detected using Images from Unmanned Aerial Vehicles on 29th May 2013: (a) and (d) Original Images and Results for the Right Side of the Beach, (b) and (e) Centre of the Beach, and (c) and (f) the Left Side of the Beach**

There were large quantities of discarded buoys and fishery-based litter on the beach (Figure 9a). Seaweeds, including mustard, were also found along the coastline in the form of dark red stripes (Figure 9b).


**Figure 9. Beach Litter Detected using Images from Unmanned Aerial Vehicles on 29th May 2013: (a) and (d) Original Images and Results for the Right Side of the Beach, (b) and (e) Centre of the Beach, and (c) and (f) the Left Side of the Beach**

## 4. Discussion

The field investigation cycle in this study was more than 1 month and discontinuous; therefore, it was not possible to identify the exact time at which beach litter was deposited and the changes caused by litter pollution. The amount of litter generated in a particular spatial area could be estimated and then compared and analysed by month or season. In this research, to overcome the limitations of field investigation, we used a remote-monitoring method. The monitoring method using networked cameras facilitated continuous monitoring of beach litter; therefore, sequential changes in the quantity of beach litter could be identified, enabling appropriate investigation and collection times to be established. The amount of beach litter generated could be estimated, which is useful for allocating manpower and monitoring instruments. However, monitoring the whole beach using networked cameras is problematic for two main reasons:

(1) The limitations of camera installation and management because of the lack of buildings with an electrical power supply and network environment.
(2) The prohibitive cost of installing the large number of cameras required.

However, beach monitoring using an unmanned aerial vehicle enables determination of the spatial distribution of beach litter in a short time with little manpower. Its use can also meet a wider range of monitoring objectives, improving the effectiveness of beach litter management. However, this method cannot be performed constantly and has temporal limitations. In this study, we used an unmanned aerial vehicle in association with networked cameras and limited manpower to monitor the beach at times of generation of large amounts of litter. By using this method we overcame the temporal and spatial limitations. The remote-monitoring data were used by Geoje Municipal Government, who removed 2.5 tons of beach litter in the 10 days following the large beach-litter event on 28th May (polluted area = 29.9 $m^2$, amount of litter = 580 pieces). The amount collected was an improvement compared with the event on 5th March when only 11.3 kg of beach litter were collected (polluted area = 0.68 $m^2$, amount of litter = 95 pieces). The results of the remote-monitoring method for beach litter are dependent on the photographic and image-processing methods used. Therefore, the results will indicate less beach litter than is actually present in the field. Despite this, remote monitoring enabled rapid identification of the time at which beach litter is generated and the approximate amount deposited, and could therefore assist central or local government in collecting and managing beach litter.

## 5. Conclusion

We have proposed a monitoring method using remote detection that improves the identification of beach litter by overcoming the limitations of current field investigation methods. We continuously monitored beach litter using networked cameras at Heungnam Beach, Geoje Island on the southern coast of Korea. To overcome the spatial limitations of networked cameras and determine beach litter levels on the beach, we used an unmanned aerial vehicle. On 28th May 2013 we identified a large area (29.9 $m^2$) of litter on the beach (camera 1 = 24.6 $m^2$, camera 2 = 5.32 $m^2$) from the networked camera images. We identified 580 pieces of litter on the beach, most of which was fishery-based; e.g. Styrofoam buoys and pellets. The proposed monitoring method can be used in association with remote-detection methods to determine the appropriate time for collecting litter and improve the effectiveness of beach-litter management policies.

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