Promotion of countermeasures against
marine plastic litter in Southeast Asia and India (CounterMEASURE)

Aerial Image Analysis Survey in Mekong River

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AGENDA

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- About Us
- Background
- Objectives
- Method and Technology
- Results
- Consideration
- Recommendations for Next Steps

About Us

PIRIKA

Pirika Inc. is a tech start-up company based in Tokyo, JAPAN.

It was established to resolve all of environmental issues through the power of science and technology in 2011.

We are a team of approx. 50 staffs.
Most of our staff are engineers and scientists.

Currently we focus on the global litter problems.

*Pirika means "beautiful" in ‘Ainu’, the language spoken among the Ainu people in northern side of Japan.

Background

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One of purposes of CounterMEASURE Project will establish a model of Identification and monitoring of plastic litter sources and routes in the Mekong River basin.

As a part of the project, in collaboration with the Asian Institute of Technology (AIT) Geoinformatics Center (GIC), Pirika has developed and improved a system to figure out the actual distribution and discharge situation of litters by using image analysis technology of aerial images taken with the drone.

Objectives

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Purpose of this Study

To detect mechanically what seems to be litter and waste from the aerial image of the riverbed taken from above by using the drone.

Objectives

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Previous Method

In order to understand the distribution situation of drifting litters on rivers and coasts, a field survey by human eyes and a collection survey for picking up the drifted litters have been conducted.

Problems

- Inconsistent of survey results depend on the individual investigator
- Difficulty to unify the survey times and conditions

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Alternative Method

Some researches tried to understand the distribution of litters uniformly over a wider area by analyzing images taken from Artificial Satellites.

Problems

- Maximum resolution of current commercial satellites is about 31 cm (ex. WoldView-3 or 4)
- Difficulty in distinguishing items correctly such as single can or plastic bottle

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WorldView-4 is a multispectral, high-resolution commercial satellite launched on 11 November, 2016 in California, US.

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Introduction of Drone

We tried to detect litters from aerial images using a Unmanned Aerial Vehicle (Drone) in order to establish a survey method

Advanteges

- Adjustment of the shooting altitude
- Low cost
- Not affected by the skill of the investigator

Method and Technology

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Aerial Photography by Drone

The Asian Institute of Technology Geoinformatics Center (GIC) attempted aerial photography with a commercial drone DIJ Phantom 4 Pro along the Mekong River

Sites

- Ubon Ratchathani, Thailand
- Vientiane, LaoP.D.R.
  - Altitude: 30m
  - Resolution of Camera: 4K(3840×2160pix)
  - 564 images

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Phantom 4 Pro

Method and Technology

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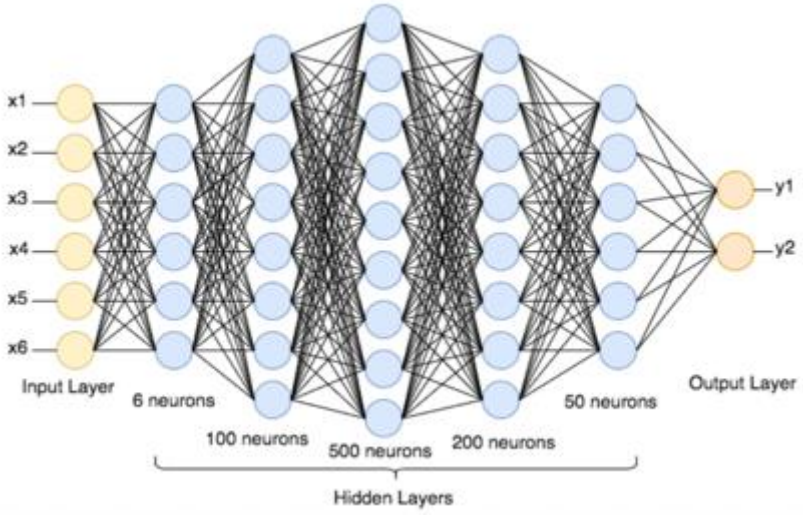
Image Analysis by Machine Learning

Based on the optical image data of the aerial image shared by the Drone of GIC, Pirika analyzed them with 2 models for predicting the presence or absence of litter by machine learning.

Models

- Model developed in the survey of river litters in Japan
- Model specialized for aerial image of Lao PDR.



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Neural Network Architecture

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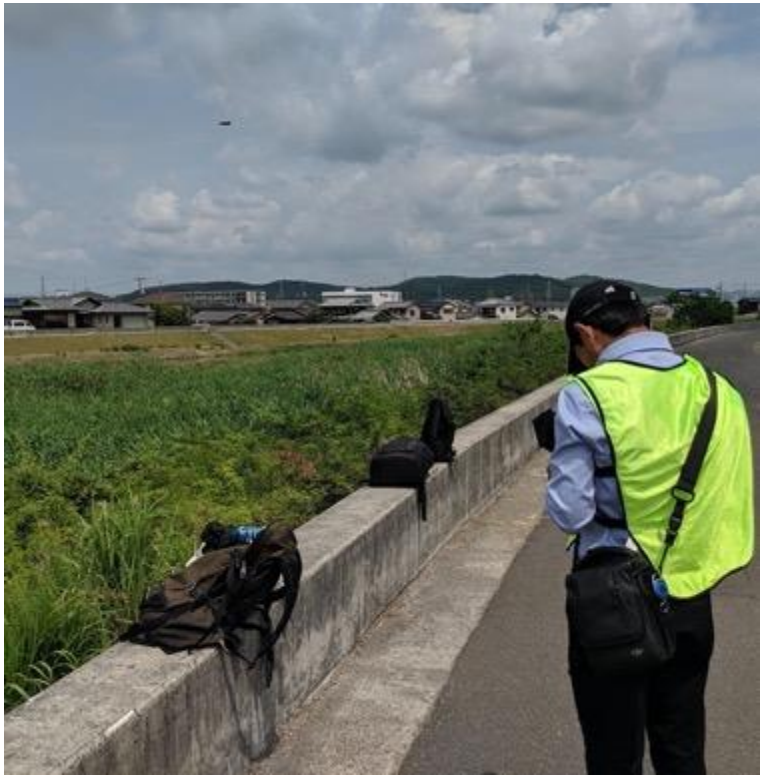
Lesson Learnt of the Litter Presence Prediction Model in Japan

With the litter presence prediction model established in Japan, the aspect ratio of images acquired by a drone is evenly divided, and the prediction of presence or absence of litters is conducted using deep learning for each area using the **Slide Window Method**.



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Sliding Window Method

This is the simplest object detection method. As shown in the figure below, the entire image is analyzed by sliding a fixed-width rectangle. There are only a total of three parameters to handle: the width of the rectangle (vertical / horizontal) and the slide width, making it intuitively easy to handle.

To handle a 4K size (3840 x 2160 pixels) image, it is necessary to analyze 220 times.

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Output of the Litter Presence Prediction Model in Japan

In the demonstration experiment using these models, it was possible to predict with a precision of 95.37% for images taken by drones in the rivers of Toyama and Okayama in Japan.

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Visualization of the Litter Hot Spots

The distribution of litters to be analyzed was displayed on the map as a heat map. We identified hot spots where litter was particularly high and dense.

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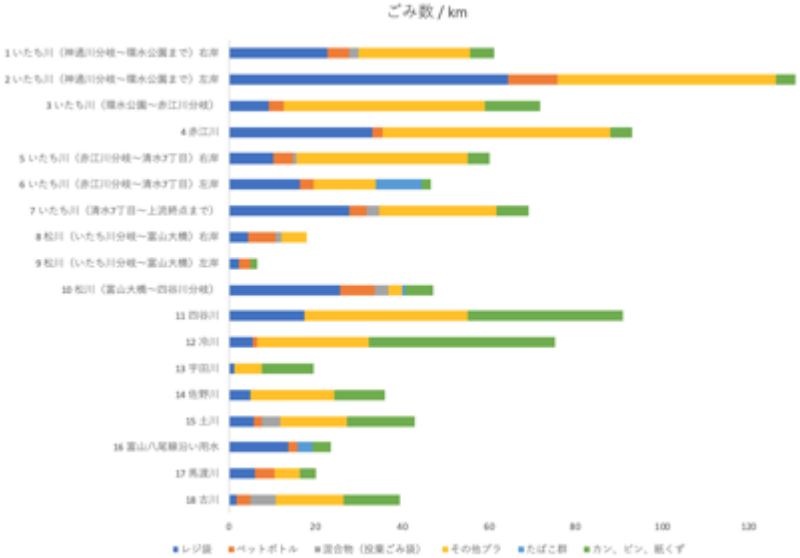
Detailed Investigation and Composition Analysis of Litters in Hot Spots

In several hotspots, we collected litters. Then, the litters was classified by material and product, and their compositions were analyzed. The results show that there are considerable differences in the materials and products of the litters were depending on the topography and conditions of the river.



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Creating a Model Using Images of Lao PDR

1. **Classification Model (litter/non-litter)**

The model was created using only images of rivers in Laos.

Dataset

-3,423 images with litters

-7,000 images without litters

2. **Object detection model**

This model was created using Google's Vision API so that a total of 1,098 litters areas can be predicted.

Results

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Litter in the Mekong River around Vientiane, Lao PDR by Laos Version Model

Total of 4,841 litters were detected.

The total shooting area is 761,400㎡ (however, overlapping areas of images are not taken into consideration), so an average of about 10.89 litter is distributed per 1㎢.

-Shooting area per image: 45m x 30m = 1,350㎡

-Total shooting area: 1,350㎡ × 564 sheets = 761,400㎡ * -

Duplicates are not considered

-Number of detected litters 8,284 pieces / 761㎢ = -

Distribution of litters about 10.89 pieces / ㎢

* No riverside / bankside classification

Results

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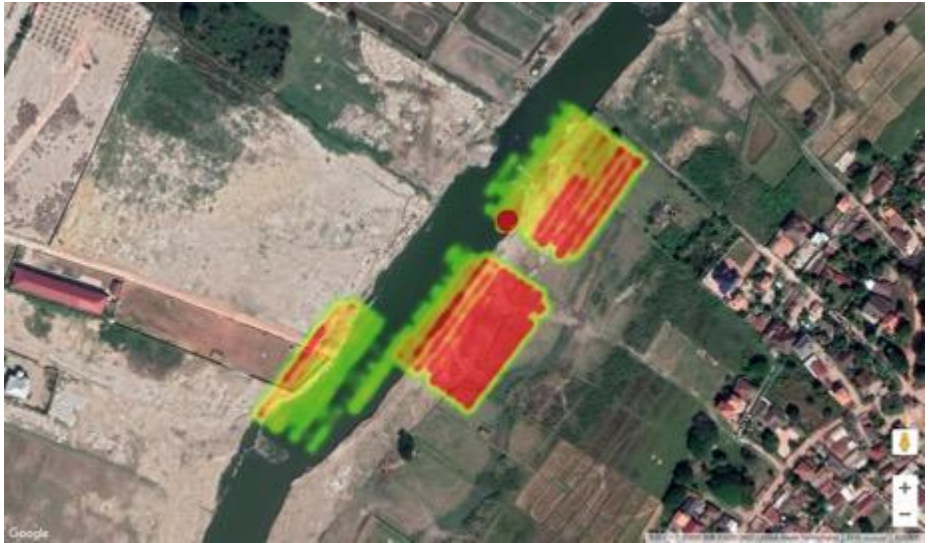
Analysis Accuracy

Japan Version of the Prediction Model

The prediction accuracy was **70.6%** when the litter prediction model created based on the river image in Japan was applied to the image taken by the drone in Laos PDR.

Laos Version of the Prediction Model

The accuracy of image analysis by the litter presence prediction model specialized for optical images in Laos was improved to **83.9%**, compared with the accuracy of 70.6% by the Japanese version model.



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Hypothesis

The reasons for the difference between the accuracy of image analysis in Japan and that by the Laos version litter presence prediction model are ;

1. **Effects of Shooting Method and Conditions for Aerial Images**

2. **Alignment with Transfer Learning**

Consideration

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1. Effects of Shooting Method and Conditions for Aerial Images

Aerial images taken by drones on rivers in Japan are mainly in the low altitude of 10 to 20 m, and the resolution is 4K (3840 x 2160 pixels). On the other hand, in Laos PDR, the resolution of camera was the same, but the altitude was 30m. Due to characteristics of the region and seasons, most of Laos' litters were covered with sand, and there was difficult to distinguish sand-covered litter image from the background.

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2. Alignment with Transfer Learning

The accuracy of the Japanese version of the model for predicting litter was significantly improvement by using the trained model for the ‘ImageNet’* dataset.

It is possible that the reason that transfer learning did not work well was that the types of litters contained in the images were mostly unrelated to the types of substances contained in ‘ImageNet’.

*It’s the dataset of more than 14 million images and semantic tags that was developed after a team at Princeton University published it in 2009.

http://www.image-net.org/

Red frame was correctly detected as litter, blue frame was not litter.

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Solution to Improvment

In order to improve the accuracy of image analysis, the following two policies can be considered as future tasks.

1. **Case Classification and Model Creation**

2. **Search for the Improvement of Aerial Photography**

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1. Case Classification and Model Creation

One of the reasons why Laos did not work this time was difference between the rivers in Japan and those in Laos PDR.

When targeting rivers of which conditions change significantly, this can be done by (1) creating a more general-purpose model or (2) creating individual models that are customized for each case.

It is effective to classify river conditions and types of litters from qualitative and quantitative analysis in advance, and then create a model for each case.

2 Types of Case Classifications

Classification by country / region / river status
It is possible to create a model that does not require performance tuning by creating a model that suits their characteristics through classifying countries and regions that are similar to some extent by river conditions.

Classification by size of litters
The current model is created so as to predict all litters, but by creating a model for each size, it is possible to create a model that does not depend on river conditions.

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2. Search for the Improvement of Aerial Photography

In Laos PDR, aerial photography was carried out using the photography method that seems to be the best among the available equipment and within survey period. However, it was also considered that it was not completely consistent with the photography method in Japan.

Pirika is conducting experiments on aerial shooting methods, and is verifying how to shoot with drones that can be utilized in many countries and cameras that can be installed.

Ideal Condition of Aerial Photograhy

- Altitude: 15m or less
- Resolution of Camera: Over full high-definition (Full HD, 1920×1080pix)
- Over 200 images or more
  Alternatively, 50 to 100 images with a large amount of litters and a total amount of litters exceeding 1,500.

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Development of a More Accurate General-purpose Type Prediction Model

While accumulating new river data, it is possible to develop a more general-purpose model for predicting the presence or absence of litter by using the following two methods while minimizing tuning depending on the shooting area and river conditions.

1. **Multiple Classification**

By modifying the model (identify whether litter exist or not) to multiple classification problem (identify the items), the characteristics of each litter can be captured.

2. **Multitasking Architecture**

The architecture of the model will be changed to the one that can use the information around the identification rectangle including litters and the multitasking architecture that predicts the location of the identification rectangle at the same time.

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Presuming the Type of Litter

In the future, it is necessary to presume the type of detected litter in order to study more accurate measurement and countermeasures for plastic litter that flows into the ocean through rivers.

By modifying the model (identify whether litter exist or not) to multiple classification problem (identify the items), the characteristics of each litter can be identified. This will simultaneously help the litter detection accuracy to be improved.

Example of a litter presence prediction system interface with a litter type estimation function

Recommendations for Next Steps

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Estimation of Litter Volume and Weight

It is necessary to calculate the volume and weight of litters when considering methods and plans for countermeasures and collection of plastic litters that flow into the ocean through rivers. For that purpose, the following two policies can be considered.

A. **Combination of Detection of Litter/Type Estimation by 2D Aerial Photography and Library**

A. **Combination of 3D Aerial Photography・SfM and Library**

Recommendations for Next Steps

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A. Combination of Detection of Litter / Type Estimation by 2D Aerial Photography and Library

(1) It is necessary to calculate what kind of / how many litter is distributed at what location by detecting the type of litter detected by the litter presence / absence prediction model from the planar optical image taken by the drone.

(2) By creating a library that lists the volume and weight of each type and state of litter, if the detected type of litter is compared with the library, the volume and weight of the litter distributed at each point and range can be estimated.

This method makes it difficult to identify and calculate the location where various kinds of litter are mixed up in one place or where it is three-dimensionally compiled like a dumping site.

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A. Combination of Detection of Litter/Type Estimation by 2D Aerial Photography and Library

It is suitable for generally understanding the distribution status of litters in wide-area and the status of runoff routes. Therefore, there is a possibility that the distribution status of litter can be quickly grasped at low cost by combining this visual analysis with the operation of a GIC's drone that can fly long-distance of 10 km or more and conduct aerial photography.

Fixed-wing drone owned by AIT GIC
Flying height: Up to 1,000 m
Flying time: 50-60 mins.
Coverage: 10-40 km per flight

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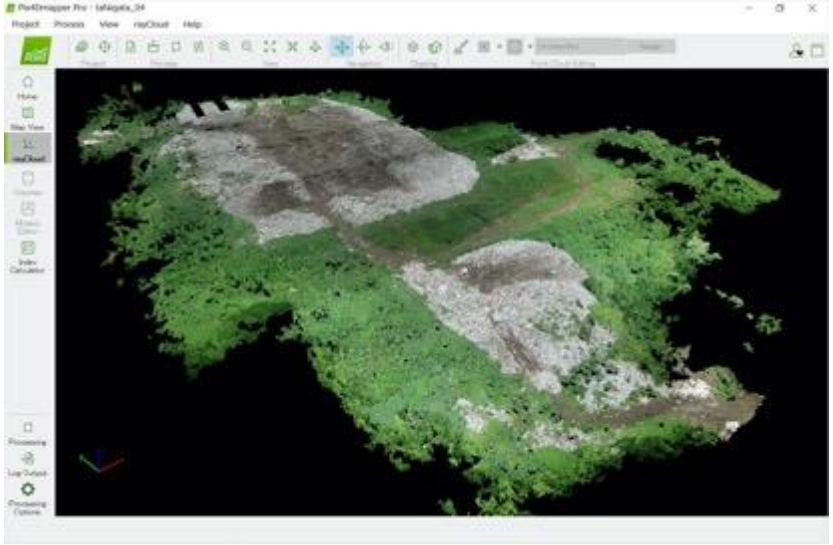
B. Combination of 3D Aerial Photography・SfM and Library

(1) A three-dimensional (3D) map is created from optical images taken by a drone using SfM (Structure from Motion) software for aerial survey.

(2) By using a model for predicting the presence or absence of litter, the location information of the litter is identified, and at the point where the litter is concentrated and compiled, the volume of the compiled litter can be predicted by collating with the 3D map.

(3) In addition, the weight can be estimated by comparing the detected litter type with the library.



This method is also used to estimate the amount of deposits at final disposal landfill sites and open dumping sites

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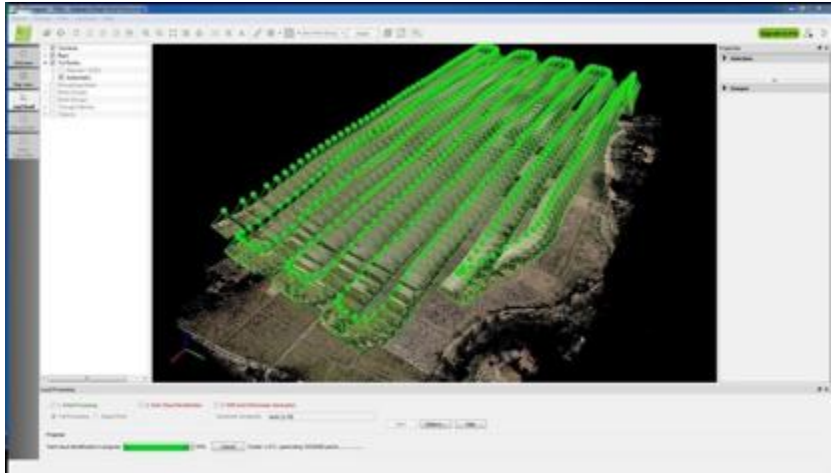
B. Combination of 3D Aerial Photography・SfM and Library

When acquiring position information using GPS (Global Positioning System), an error of about 2 m may occur. Thus, it is necessary to acquire detailed position information from network-type RTK (Real Time Kinematic)-the positioning satellite (GNSS: Global Navigation Satellite System).

Therefore, in areas where electronic base stations are not installed nearby, it is difficult to create accurate 3D maps and estimate the volume unless an independent electronic base station is installed.

It is difficult to conduct a wide-range survey.



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In order to create a 3D map, it is necessary to set a route and shoot a large amount of aerial images within the target area

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Estimation of Litter Volume and Weight

A. **Combination of Detection of Litter/Type Estimation by 2D Aerial Photography and Library**

B. **Combination of 3D Aerial Photography・SfM and Library**

As a result of the above comparison, B. The combination of 3D aerial photography・SfM and the litter type classified library has difficult conditions for drone aerial photography, its operation, and requires a long aerial time and a lot of images in a long river with wide catchment area such as the Mekong River.

Thus, after establishing a method using the combination of A with a Long-distance drone, many places where a lot of litter was 3D accumulated were found, and when it was necessary to estimate more accurately, It is considered efficient to examine applying and operating the method of B to the specific accumulated area.

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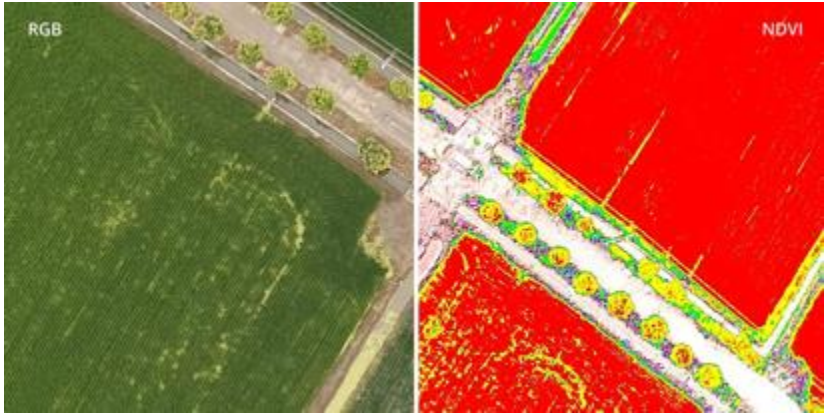
Possibility of Improving Litter Detection and Type Estimation by Improving Cameras and Shooting Methods

At present, the analysis of optical images by a camera (three-band spectrum camera) that captures the wavelength bands (bands) of three types of RGB (Red, Green, Blue) light is currently underway.
However, combining the image data of other bands enables to detect some materials of litter more accurately even on those that were not possible to be discriminated whether it is litter or the pattern of the ground by using only RGB.



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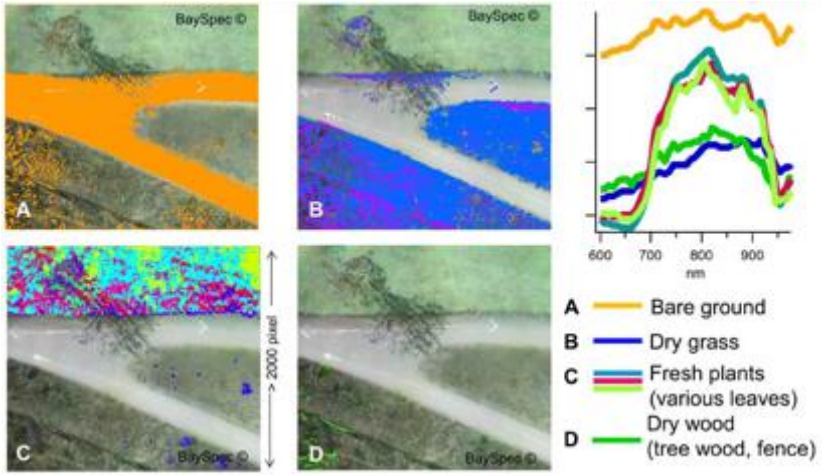
Possibility of Improving Litter Detection and Type Estimation by Improving Cameras and Shooting Methods

A camera capable of acquiring data in various wavelength bands other than RGB is called “multispectral camera” or “hyperspectral camera”.

The data acquired by these cameras is an overlay of the image data of each band, and when the information of the pixels at the same coordinates on all the band images is connected, it becomes the spectral spectrum data at that point.

Thus, it enable to detect and identify litter that was difficult to do so by human eyes and RGB cameras.



Utilization example of visualization of vegetation and land use condition by hyperspectral camera from a drone

Source：OCI-UAV-1000 Flight Data Example (processed with pseudo-RGB color and material color based on spectral characteristics) ©Bayspec

https://www.bayspec.com/spectroscopy/oci-uav-hyperspectral-camera/

Recommendations for Next Steps

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Possibility of Improving Litter Detection and Type Estimation by Improving Cameras and Shooting Methods

There is a product called a bandpass filter that can change the wavelength band to be captured and acquire data of different bands by filtering the lens of a normal RGB camera.

Since the bandpass filter is relatively inexpensive and lightweight, it can be attached to the camera mounted on a commercial drone.

The bandpass filter can change the band only to a specific wavelength band, but if the band, in which litter can be detected more easily, can be specified, the detection rate may be further improved.

©Kokins

Bandpass Filter Kit For Machine Vision

Thank you!

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