# Experiment of Multispectral Sensing Sensor for Urban Road Materials in Outdoor Environment

**Matthew Rio Darmawan, Heru Purnomo Ipung, & Maulahikmah Galinium**

*Faculty of Engineering and Information Technology, Swiss German University, Indonesia*

matthew.darmawan@student.sgu.ac.id, heru.ipung@sgu.ac.id, maulahikmah.galinium@sgu.ac.id

**Abstract:** This research is the first attempt to conduct several experiments of multispectral sensing sensor for urban road materials in outdoor environment. This research aims to classify five urban road materials that are aggregates, asphalts, concrete, clay, natural fibre including vegetation and water. There were 9 cameras in the multispectral sensing sensor. Seven camera attached with narrow band optical filter with the centre spectrum at 710nm, 730nm, 750nm, 800nm, 870nm, 905nm and 950nm. One camera attached with 720 nm normalization band uses high pass optical filter. Another camera attached with UV/IR cut optical filter works as a RGB camera. The images results, that have been taken, are processed in MATLAB to get the imaging index results from the multispectral system. Naïve Bayes classifier is used in Weka to classify the urban road materials with vegetation and water. The first classification and testing that classifies five urban road materials with vegetation and water have accuracy results ranged from 0 % to 32% while the accuracy results without vegetation and water have better accuracy results ranged from 0 % to 55 %.

**Keywords:** Multispectral, Urban road materials, Imaging index, Image processing

## 1. Introduction

Remote sensing is useful for urban structure extraction, urbanization monitoring, agriculture, meteorology, and mapping. Common remote sensing that are used is wideband multispectral imaging indexes using satellite. The other method in remote sensing is narrowband multispectral imaging index using multispectral camera.

The problems with current multispectral remote sensing is the multispectral cameras and the aerial surveillances on the market are expensive. The price of the multispectral cameras made by Spectrocam ranged from USD $21,263 (Rp. 288,560,173.00) until USD $43,120 (Rp. 585,181,520.00) according to Spectrocam's website. And the price of the multispectral camera that already combined with air surveillance for remote sensing product named Parrot Sequoia made by Parrot that not for sale but instead only offer to rent the product with the price USD $158 (Rp. 2,145,956.00) / day based on Parrot's website. The multispectral sensor of Parrot Sequoia that can be bought separately costed USD $3,500 (Rp. 47,537,000.00).

The solution for this problem is using commercial digital cameras that has been converted into multispectral cameras and combine it with sensor to create a multispectral system that is more economical and cheaper than those already on the market. The early prototype of the multispectral remote sensing system has been developed in the Swiss German University and the prototype has already tested on laboratory or indoor scale, the next step is adjusting and testing the multispectral remote sensing system on the real world or outdoor scale.

## 2. Related Works

**Table 1.** Table of comparison of previous works

| **Differences** | **NDVI derived from near-infrared-enabled digital cameras: Applicability ACR different plant functional types** | **Urban Road Materials Identification using Narrow Near Infrared Vision System** | **This research** |
|---|---|---|---|
| **Experiment Environment** | Outdoor | Indoor | Outdoor |
| **Light source** | Sun | Halogen Lamp | Sun |
| **Camera** | NetCam SC IR security camera | Yi Home Camera China version | Yi Home Camera International version |
| **Camera Quantities** | 17 | 9 | 9 |
| **Materials to classify** | Forest and Agriculture (vegetation) | Aggregates, Asphalt, Clay, Concrete, Life Fibre | Aggregates, Asphalt, Clay, Concrete, Life Fibre, Vegetation, and Water |

The experiment "NDVI derived from near-infrared-enabled digital cameras: Applicability across different plant functional types" by Filippa *et al.* (2018) can differentiate type of vegetation especially vegetation area in the forest. The data that taken is in 4 seasons (spring, summer, autumn, winter).

This experiment is an early research on multispectral vision system where the related work of this based on research and study by Ipung and Tjandrasa (2017) titled "Urban Road Materials Identification using Narrow Near Infrared Vision System" where it is use multispectral vision system to classify the 5 urban road materials that are aggregates (rock and sand), asphalt, clay, concretes, and natural fibres that consists of dry leaves and woods.

The differences of this experiment with Ipung and Tjandrasa (2017)'s work are this experiment is tested on outdoor environment therefore the results may different from the other work because this experiment is tested in the outdoor situation, the light source and the humidity is changing unlike in the indoor where the light source is only Halogen lamp with fixed light intensity that experimented by Ipung and Tjandrasa (2017). For the urban road materials that need to be classify, there are 5 urban road materials from previous work (clay, aggregates, concretes, dry natural fibres, asphalt) including vegetation and water added that need to be classified.

## 3. Methodology

### *3.1. Preparation*

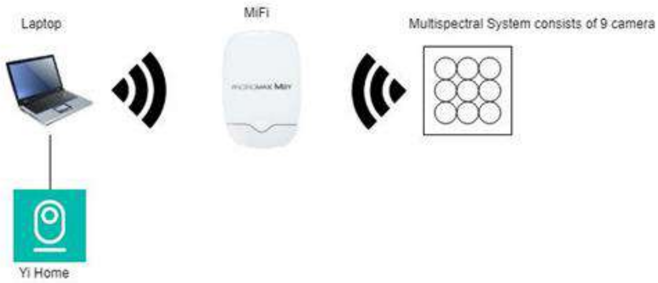



**Figure 1.** Architecture Diagram

As shown in the architecture diagram of the device in Figure 1, the multispectral system that need to be prepared is the camera that attached with the optical filters. The selected optical filters specification was important aspect in this research. There were two aspects that needs to considers on the selection of the optical filters: spectral centre and Full Width at Half Maximum (FWHM). The selected optical filters cover the sample ranges of 700nm to 1000nm that are based on previous studies by (Ipung and Tjandrasa, 2017) is listed on Table 2.

**Table 2.** List of Optical Filters Attached to the Camera

| Camera No. | Optical Filter Type | Optical Filter centre (nm) | FWHM | Information |
|---|---|---|---|---|
| 1 | UV/IR Cut | - | - | RGB camera and to ensure that no UV or IR interfere the image result |
| 2 | High pass | 720 | 10 | Used as the normalized spectrum band |
| 3 | Narrow-band | 710 | 10 | - |
| 4 | Narrow-band | 730 | 10 | - |
| 5 | Narrow-band | 750 | 10 | - |
| 6 | Narrow-band | 800 | 10 | - |
| 7 | Narrow-band | 870 | 10 | - |
| 8 | Narrow-band | 905 | 10 | - |
| 9 | High pass | 950 | - | cut off the camera at 1000nm |

## *3.2. Image Acquisition*

This is a process where the image acquired by capture the images of the 9 cameras that are already equipped with optical filters at the same time because the outdoor environment's condition can be changing in humidity and temperature aspects. The images that need to be acquired are five dry urban road materials (clay, aggregates, natural fibres, concretes and asphalts), vegetation, and water.

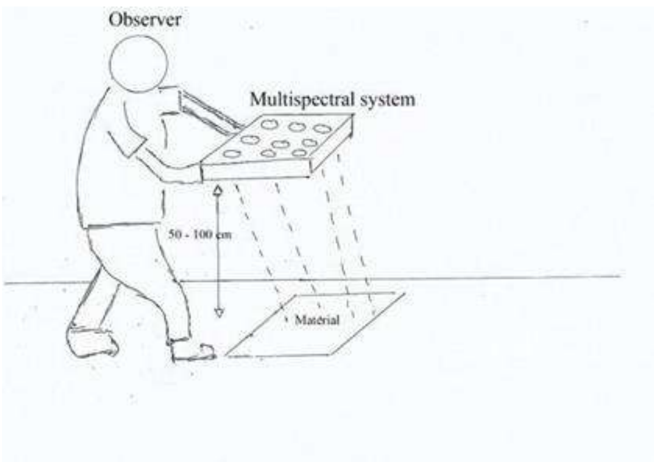



**Figure 2.** Experiment Diagram of Image Acquisition

To do image acquisition, as shown in the Figure 2, the multispectral vision system needs to be above where the area of the materials that need to be taken. During this process, the humidity and the temperature of the area need to be recorded by using Thermo-Hygrometer Analog, but keep in mind that for now, the humidity and temperature data serve only as a reference because this experiment's research is still in the early phase.

After that, the image acquisitions data that stored on each of the camera's micro SD memory card need to be transferred to laptop or computer to process the data. The image acquisitions data can be transferred via FTP (File Transfer Protocol) server that has been installed on each of the camera in the multispectral vision system by connecting from the laptop by using Filezilla software to connect to the IP address of the camera and the image acquisitions data can be downloaded.

### *3.3. Pre-processing Images*

In the pre-processing, the images are sorted based on the 5 dry urban materials (clay, aggregates, natural fibres, concretes and asphalts), vegetation, water and the images of the 9 cameras that has been taken at same time. There are 10 samples of each urban materials including vegetation, and water. Each sample has image from each 9 cameras with optical filter.

First the images that has been acquired from the 8 IR (Infrared) cameras beside the RGB camera cropped into in the centre of the image. The images converted into grayscale by using MATLAB rgb2gray function. The rgb2gray function converts RGB images to grayscale intensity image by eliminating the hue and saturation information while retaining the luminance. After the images from the 8 IR (Infrared) cameras and the RGB camera that has been turned into grayscale, the image of the grayscale RGB camera cropped into 600 x 400 pixels and the grayscale images from the other 8 IR (Infrared) cameras cropped into 150 x 150 pixels. The next step is the cropped grayscale images will be aligned to the grayscale image that taken from the RGB camera. The grayscale RGB image from camera 1 works as a reference of the image alignment. The image alignment will be more on the feature based image alignment rather than intensity based. The image alignment is important to make sure that the image captured are synchronized.

### *3.4. Feature Extraction*

First, we need to find out the imaging index on each grayscale images taken on each camera by using MATLAB with image processing module. The result of imaging index will be stored in Microsoft Excel. The data of 150 x 150 pixels of each grayscale cropped images will be averaged 15 x 15 so the imaging index data will be into 10 x 10 pixels that has been averaged. The averaging is needed to minimize the error from the image alignment.

The next step is the imaging index need to be normalized with the imaging index from camera that equipped with 720nm high pass optical filter because it is used as the normalized spectrum band using the NDVI (Normalized Vegetation Index) formula. Near infra-red imaging indexes with normalization (N) value from 720nm high pass optical filter for the rest of NIR optical filters (V) value using the following index calculation, similar to the NDVI formula in the equation 1.

$$I = \frac{(N-V)}{(N+V)} \tag{1}$$

The result of the equation 1 will be only in the range of -1 to 1 and the results for each processed image index will be stored in Microsoft Excel file.

### *3.5. Classification*

In the classification, the result of the image index that has been normalized as training data. Then the result is sorted based on the categorized materials in a table for testing. The seven imaging index will be trained as the classifier. The training data use Weka as the tool for the classification and Naïve Bayes for the classifier. The reason why Naïve Bayes is chosen as the classifier because Naïve Bayes can be able to make probabilistic predictions and Naïve Bayes is easier to implements comparing to other classifier.

### *3.6. Visualization and Testing*

In Visualization and Testing phase, a new image that contain more than one material in one image is tested to make it classified. First, the processes from the preparation until feature extraction are repeated again.

After that, Naïve Bayes with Weka as the tool is used to find the classification result. The result of the classification as training set and the result of the images that contain combined materials will be used as testing set. From this Naïve Bayes result, the percentage of each material that are classified in the testing images can be acquired. The result also visualized illustrated as 10x10 box with each colour represent the material including visualization of the actual result to get the comparison of the prediction result and the actual result. There is also an accuracy result based on the correctly classified material that checked by comparing the actual and prediction result.

## 4. Results and Discussion

### *4.1. Preparation*

First, search a software / application that can capture images on multiple camera at the same time is needed, because that's one of the requirement to do the experiment on outdoor environment. 2 Action Camera were provided for early testing on capture images on multiple camera at the same time, when on research and testing, both cameras couldn't connect to the laptop or computer because it is limited by the factory of the camera and the camera can't be accessed by third party software because it is locked from the manufacture of the camera.

Later, the multispectral system that consists of 9 Xiaomi Yi Home Wireless Camera with optical filters attached has been provided. On the early testing, the multispectral system can't connect to the phone for authenticating and connecting the camera to the MiFi modem using Yi Home app from Xiaomi, it is said that it can only be used in China because that Yi Home Wireless Camera is for China Region only or China version. Also there still an issue that the research need to find out how to capture images of the 9 cameras at the same time. During the research, there is a possible solution that has been found to access the camera so it can be seen in laptop or computer by using Yi Home PC software that is official from Yi. It is unfortunately that the application only works on international version of the Yi Home Camera and not available for China version. The only solution is the multispectral system need to be disassembled and all of the 9 Yi Home Camera China version need to be replaced with new Yi Home Camera International version to make the multispectral system can be able to work properly and reassembled the multispectral system. For each of the Yi Home Camera international version is installed with the 32 GB Micro SD Card to store the video and images that has been captured by the camera and to be able to install Yi Hack so each camera can be renamed with camera number to make the camera easier to differentiate by the number of camera and the optical filters that are attached to the camera. Yi Hack also installed FTP server in the camera so the camera files can be accessed easier by connecting via FTP to access the data of the camera. There is finally a solution for the 9 cameras that be captured at the same time, the frame in the video of each camera and use the frame that are in the same time so the image on each camera can be implied to be taken at the same time by the information on the time of the video.

Before image acquisition process, the reassembled multispectral system that consists of 9 cameras with optical filters need to be prepared. The MiFi modem has turned on and prepared the cable roll extension. After the MiFi connected to internet, the cameras starting from camera 1 until camera 9 has been turned on one by one to the cable roll extension because if all of the camera (camera 1 until camera 9) are turned on at the same time, it will slow down the MiFi connection to the camera and some of cameras might run into problems during image acquisition. The problem that can be happened is the camera did not capture any data.

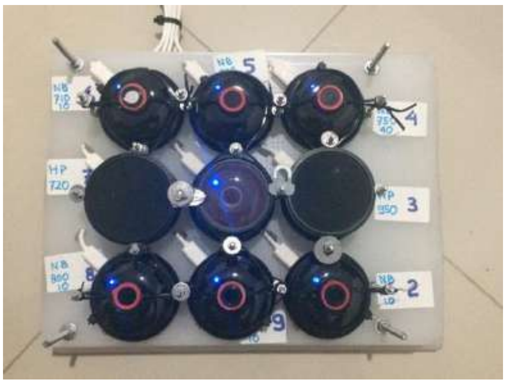


**Figure 3.** Multispectral Vision System

As can be seen in Figure 3, all the camera in the multispectral system already labelled except for camera 1, camera 1 (located in the centre) is with UV/IR cut optical filter attached. Camera 2 with Narrow Band 905 nm and FWHM (Full Width at Half Maximum) 10 nm. Camera 3 with High Pass 950 nm. Camera 4 with Narrow Band 750 nm and 40 FWHM. Camera 5 with Narrow Band 730 nm and 10 FHWM. Camera 6 with Narrow Band 710 nm and 10 FHWM. Camera 7 with High Pass 720 nm. Camera 8 with Narrow Band 800 and 10 FHWM. Camera 9 with Narrow Band 870 and 10 FHWM. The reason why the camera must be positioned in 3x3 in the multispectral system is because the camera 2 until camera 9 is near with the camera 1 (RGB camera) where camera 1 work as the image basis and reference for the image alignment. If the position of the camera is not in square or 3 x 3, the results that are taken might be different and it may cannot be aligned because the camera position is too far.

After that, all of the camera number 1 until number 9 that are connected to the network need to be checked by observe the user list by connecting to 192.168.1.1 in computer or laptop that connected to the MiFi by using internet browser because 192.168.1.1 is the IP address of the MiFi. When the User List are clicked, the list of all the camera in multispectral vision system can be seen connected successfully.

### *4.2. Image Acquisition*

During the image acquisition, there are some problems that sometimes during the process of image acquisition, one or two of the camera in the multispectral system are disconnected from the MiFi connection, this problem occurred because of heavy traffic of the connection from 9 cameras and laptop that are connected to the MiFi. There is also another problem that happened when the outdoor temperature become hot during the experiment, the MiFi and the camera get overheat and it will not work properly. There are some occasions that some of the image results become pitch black color or white because of the direct light from the sun if the sun shines directly to the multispectral system.

### *4.3. Pre-processing Images*

In Pre-processing, after the samples images from each camera has been transformed into grayscale, the image cropped into 150 x 150 pixels, except the image from camera 1 which is RGB camera, the camera 1 cropped into 600 x 400 pixels in the center. The image from RGB camera works as the reference for the image alignment from 150 x 150 pixels from images of all other camera (camera 2-9). There are some minor difficulties during image alignment. Because the images result from the not flat surfaces such as rock (aggregate), dry leaves (natural fibres), and clay (using roof for clay data), the curves surface of the material makes the images harder to be aligned.

### *4.4. Feature Extraction*

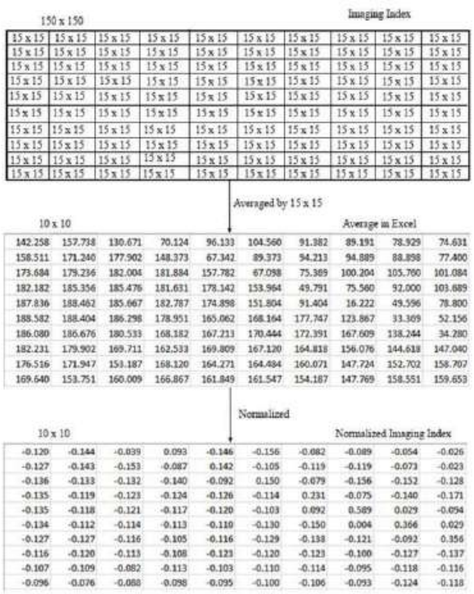



**Figure 4.** Feature Extraction process

In feature extraction as shown in Figure 4, the aligned images processed in MATLAB creating grayscale imaging index value from the image and stored in Microsoft Excel. As shown in Figure 5, the 150 x 150 imaging index from 7 proposed imaging index and the normalized indexes are averaged by 15 x 15 in the excel. After the imaging index become averaged and the data become 10 x 10. Using NDVI formula to normalize the value of 10 x 10 of 7 proposed imaging index with the 720 nm normalization value.

### *4.5. Classification*

Each pixel of the sample images data is sorted with the value of proposed imaging index as a classifier (710, 730, 750, 800, 870, 905, 950) and the material information (aggregates, asphalt, clay, concrete, natural fibre, vegetation, and water). After the training data formatted in the arff file, the training data processed in Weka using Naïve Bayes Classifier.

#### *4.5.1. Classification of 5 urban road materials (aggregate, asphalt, clay, concrete, and life fibre) with vegetation and water*

=== Confusion Matrix ===

| a | b | c | d | e | f | g | <-- classified as |
|---|---|---|---|---|---|---|---|
| 433 | 0 | 3 | 8 | 0 | 53 | 3 | a = Asphalt |
| 0 | 445 | 0 | 50 | 0 | 5 | 0 | b = Clay |
| 0 | 33 | 399 | 7 | 0 | 46 | 15 | c = Concrete |
| 0 | 17 | 0 | 455 | 3 | 25 | 0 | d = Vegetation |
| 0 | 0 | 0 | 16 | 480 | 4 | 0 | e = Water |
| 28 | 14 | 16 | 81 | 14 | 307 | 40 | f = Aggregate |
| 6 | 28 | 107 | 22 | 2 | 83 | 252 | g = Life Fibre |

**Figure 5.** Confusion Matrix of Training Data Result

For the confusion matrix result on Figure 5, it can be seen that the aggregate and life fibre classification are not good enough because aggregate and life fibre has 2 type of data that are taken. Aggregate is rock and sand, life fibre is dry leaves and wood.

#### *4.5.2. Classification of 5 urban road materials (aggregate, asphalt, clay, concrete, and life fibre) without vegetation and water*

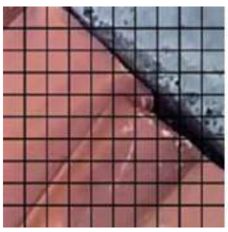
=== Confusion Matrix ===

| a | b | c | d | e | <-- classified as |
|---|---|---|---|---|---|
| 433 | 0 | 3 | 61 | 3 | a = Asphalt |
| 0 | 470 | 0 | 30 | 0 | b = Clay |
| 0 | 34 | 399 | 52 | 15 | c = Concrete |
| 28 | 17 | 16 | 399 | 40 | d = Aggregate |
| 6 | 31 | 107 | 102 | 254 | e = Life Fibre |

**Figure 6.** Confusion Matrix Result of Training Data without vegetation and water

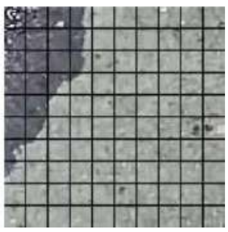
Based on the research by Ipung and Tjandrasa (2017), to classify the vegetation and water is using decision tree first before classifying the urban road materials, therefore this might be a problem that some of the materials are misclassified as vegetation or water, so another classification is running with only using 5 urban road materials (aggregate, asphalt, clay, concrete, and life fibre). For the confusion matrix result in the Figure 6, it can be seen that the clay, aggregate, and life fibre result are better than previous training result.

### *4.6. Visualization and Testing*



(1)

(2)

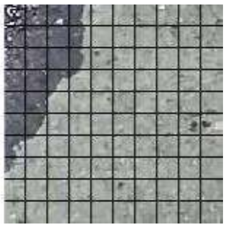


(3)

*ISSN: 2477-1538*


(4)


(5)


(6)

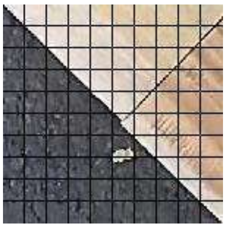

(7)

**Figure 7.** RGB Picture (1) Testing Set 1 (2) Testing Set 2 (3) Testing Set 3 (4) Testing Set 4 (5) Testing Set 5 (6) Testing Set 6 (7) Testing Set 7

**Table 3.** Table of Imaging Index Results and Accuracy of Figure 7

| | Material | Testing Set | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5 Urban Road Materials with water and vegetation | | | | | | | 5 Urban Road Materials without water and vegetation | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 5 | 7 |
| Real Imaging Index Result | Aggregate | - | 64% | 23% | - | 28% | - | - | - | 64% | 23% | 28% | - |
| | Asphalt | - | - | - | - | - | 80% | 45% | - | - | - | - | 45% |
| | Clay | 73% | - | - | 6% | - | - | - | 73% | - | - | - | - |
| | Concrete | 27% | - | - | - | 72% | - | - | 27% | - | - | 72% | - |
| | Life Fibre | - | 36% | 77% | - | - | - | 55% | - | 36% | 77% | | 55% |
| | Water | - | - | - | - | - | 20% | - | - | - | - | - | - |
| | Vegetation | - | - | - | 94% | - | - | - | - | - | - | - | - |
| Prediction Result | Aggregate | 20% | 37% | 34% | - | 28% | 31% | 10% | 69% | 85% | 74% | 7% | 46% |
| | Asphalt | - | - | 3% | - | - | 15% | - | - | - | 6% | - | - |
| | Clay | 13% | 6% | - | 87% | - | 7% | - | 21% | 14% | - | 93% | - |
| | Concrete | - | - | 4% | - | 72% | 3% | 2% | - | - | 6% | - | 2% |
| | Life Fibre | 10% | 1% | 19% | 4% | - | 4% | 51% | 10% | 1% | 14% | - | 52% |
| | Water | - | 3% | 21% | - | - | - | 22% | - | - | - | - | - |
| | Vegetation | 57% | 53% | 19% | 9% | - | 40% | 15% | - | - | - | - | - |
| Accuracy | | 13% | 32% | 18% | 12% | 0% | 0% | 7% | 21% | 55% | 35% | 0% | 7% |

Based on the accuracy results that shown on the Table 3, the accuracy results of the 5 urban road materials without vegetation and water are better than the accuracy results of 5 urban road materials with vegetation and water. Many of the urban road materials are misclassified as vegetation. The aggregate classified better without vegetation and water.

## 5. Conclusion

This research focuses on the outdoor experiment of multispectral sensing for urban road materials and the result of imaging index. It is important that the outdoor situation affecting the multispectral system because of the changing environment. There need to be caution of high outdoor temperature that makes the multispectral system could not work as intended.

After that the multispectral system need to be able to classify the urban road materials by using the proposed 7 imaging index that are 710nm, 730nm, 750nm, 800nm, 870nm, 905nm, and 950nm. However, with the testing data result, there are many materials that are misclassified, in the first training and testing result that tested on 5 urban road materials with vegetation and water, most of the misclassified material, classified as vegetation and water. The reason why vegetation and water is not The second training and testing result that tested on 5 urban road materials without vegetation and water, most of the aggregates can be classified correctly, the results are better than the first training and testing result. Both of the training and testing results cannot classify asphalt and concrete correctly.

## References

Filippa, G. *et al.* (2018) 'NDVI derived from near-infrared-enabled digital cameras: Applicability across different plant functional types', *Agricultural and Forest Meteorology*. Elsevier, 249(November), pp. 275–285.

Ipung, H. P. and Tjandrasa, H. (2017) 'Urban Road Materials Identification using Narrow Near Infrared Vision System', *International Journal of Electrical and Computer Engineering (IJECE)*, 7(3), p. 1171.