Illegal Logging Vehicle Detection and Classification in Forward Scatter Radar

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ABSTRACT

Illegal logging is a continuous environment issue not just in Malaysia but all over the world. It threatens the environmental sustainability, shrinks state government's income and undermines the right of local community. Furthermore, it can cause deforestation, greenhouse effect and imbalance of the eco-system. Various efforts have been placed to reduce this activity such as drones, satellite and remotes sensing, however, it can be only detected if there are changes in the image received from those technologies which mean deforestation is already happened. Hence, forest surveillance and monitoring, as well as automatic early detection of the intruders, plays important roles in preventing and ending illegal logger activities. Therefore, this paper presents vehicle detection and classification system based on Support Vector Machine (SVM) in Forward Scatter Radar to detect illegal vehicle entering the forest. Measured signals from four different vehicles are used as the input of the system. To achieve high accuracy in classifying the vehicle, certain features are extracted from the spectra of the vehicles and fed as the input of SVM. The result shows that different classes of vehicles can be separated and classified using the proposed classification algorithm. Although, the are some overlapping of data for similar size of vehicles, the separation of data can be further improved by applying hyperplanes. The

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proposed FSR system has a potential to be used in detecting and identifying vehicle entering the restricted area such as reserved forest henceforth illegal logging activities can be curbed.

Keywords: *High Frequency; Illegal Logging; FSR; Detection and Classification; SVM*

Introduction

According to the United Nations Food and Agriculture Organisation (UN FAO), 62.3% of Malaysia is forested, of which 1.8 million ha is planted forest. With recent development and modernization in the country, these forest areas continuing to be threatened by the diversities, frequencies, and intensities of forest degradation.

Illegal logging has been an issue in many countries to deal with and can be minimized by monitoring the logger activities of forest-covered areas. Illegal logging is defined as the illegal harvesting, processing, transportation, purchase or selling timber to the black market. These activities not only violate the laws, but also have devastating environmental consequences, such as deforestation, biodiversity loss, and greenhouse gas emissions. In Malaysia, the most common cause of illegal logging is agricultural conversion; for example, in Cameron Highland where most of the highland areas are deforested, and causes the water runoff and massive flash floods that killed three people in 2013[1]. Furthermore, illegal logging undermines Malaysia's effort to implement sustainable forest management.

Various technologies such as detection of acoustic signals of chainsaw, effective surveillance using satellite image, drones, CCTV, and remote sensing [2,3] are adopted to overcome the forestation problem. The advantages of drones and remote sensing is it can monitor forests in real-time, however, logging activities can only be detected if there are changes in the images for remote sensing and as for the drones, monitoring is based on the flight time. Furthermore, other challenges and limitations are weather conditions and data resolutions. Meanwhile, detection using acoustic signals of chainsaws is more practical as compared to above mentioned approaches whereby the sound of the chainsaw is quite loud and can be easily detected by the system [4,5]. Nonetheless, the detection is based on checking fundamental frequency and sound intensity in a very large area which can be masked by other acoustic noise in surrounding such as boat engine in a nearby river, wind acoustic, and others. Thus, a low-cost, real-time, and auto-alert system should be developed to inform the authorities so that immediate action can be taken when illegal logging and deforestation activities are in place.

In this research, the feasibility study on detection and classification of the illegal logger vehicles have been conducted for forest monitoring and surveillance by using Wireless Sensor Network (WSN) based on Forward Scatter Radar (FSR) system. The Forward Scatter Radar is a special configuration of bistatic radar. It is characterized by the bistatic angle that approaches or close to 180° with the target crossing the baseline between the transmitter and receiver [6]. The main advantage of FSR is its capability to detect stealth or low radar cross-section object. This is due to the fact that FSR produces a radar signal via the transmitting emission shadowed by the target body [6,7].

Recently, the FSR application has been extended for target classification. With the current technology, automatic vehicle recognition and classification can be realized. [8,9] have been discussed on the classification in FSR by combining Principal Component Analysis (PCA) and K-nearest neighbour (KNN) where PCA is used as data extractor and dimension reduction and KNN as a classifier. This combination gives a good classification performance which give more than 90% accuracy.

Meanwhile, Neural Network (NN) gives a similar performance in classifying different types of vehicles. This technique used a multilayer perceptron network (MLP) as a neural network structure which produced promising results [10,11] and the input for the classification process has been extracted manually. The result shows that only 10% of the data are misclassified in vehicle recognition and 2% in vehicle categorization. Other approach has been conducted by combining z-score with NN [11]. In this case, Z-score is used as a data extractor of the target signal and the NN is used for classifying the target [12] where significant data chosen by z-score are used as input for classifier and is extracted based on the features of signals. The research concluded that the more the features extracted, the higher classification accuracy will be.

Another technique that has been used for classifying data in radar application is the Support Vector Machine (SVM) [14-17]. By applying SVM, the system uses the lesser time to train the data and fewer complexity to calibrate when there is a problem with high generalization capabilities [16]. The main feature of SVM is able to create a hyperplane in a space between two different classes of data in order to separate them. The hyperplane is a decision boundary that helps classify any class of data points. Meanwhile, support vectors are data point represent each class that influences and use to determine the position and location of the hyperplane itself. These support vectors also would determine a maximize margin of separation between two classes. If the support vector is changed or deleted, then the hyperplane would also be changed in order to keep enough margin of separation.

In classification, data imbalanced may also be occurring and can be a problem for performance analysis. This is when the data samples of one class are more than the data samples of other classes in datasets [17,18]. The advantage of the SVM classifier is, it is trained with an imbalanced dataset, and has been identified that the separating hyperplane found can be biased towards the minority class. Hence, a huge number of false-negative predictions can be given as results by the classifier [19]. In [20], the SVM classifier provides the best performance in target detection using Gabor features based on micro-Doppler signatures as compared to KNN and Bayes linear classifier. All three classifiers are able for target identification with the recognition rates fallen between 44% to 92% for SVM classifier, 42% to 84% for KNN and 38% to 78% for the Bayes linear classifier.

Therefore, the main objective of this research is to analyse the detection and classification performance of illegal logger transportation by using the SVM technique. Very high frequency (VHF) continuous wave (CW) signal is used in order to minimize the effect of clutter.

This paper is organized as follows: the next section introduces the methodology to analyse vehicles signatures and follows by measured data analysis and illustration of the main results and findings. Finally, the last section concludes the work proposed.

Methodology

In practice, the logs are transported using oversize vehicles such as long logger trucks or mule trains trucks. Due to our limitations in accessing this kind of vehicle, small vehicles are used in this analysis, in particular the vehicle models like SUV, sedan, and a hatchback. Theoretically, larger vehicles are easy to detect and classify compared to smaller vehicles due to their radar cross-section, thus this the analysis is valid for larger size of vehicles use in future.

The dimensions of the vehicles are tabulated in Table 1. As presented, we can observe clearly that Land Rover and Ford Focus have a totally different shape (SUV and hatchback) and sizes which can be easily discriminated from others. Meanwhile as for BMW and Nissan, both vehicles are similar with sedan shape and the length and height only differ by 0.1 m.

The signals received from the vehicles are measured at 151 MHz with a separation of 50 m baseline between the transmitter and receiver. Each vehicle was crossing perpendicularly in the middle of the baseline with a consistent speed of around 10 km/h as shown in Figure 1. The signal was recorded for 20 seconds and the measurement of each car was repeated 40 times just to ensure the consistency of the signals.

Table 1: Dimension of vehicles

Type of vehicles	Size of vehicles	
	Length (m)	Height (m)
Land Rover	4.8	2.1
Nissan	4.4	1.5
BMW	4.5	1.4
Ford Focus	4.0	1.4

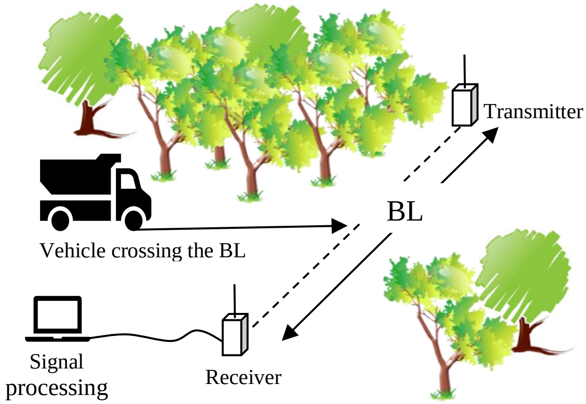


Figure 1: Vehicle crossing the baseline.

Figure 2 shows the flowchart of the overall classification system. First, the signals from all four types of vehicles are measured and stored as a dataset. The time-domain signal of the vehicles is transformed into a frequency domain signal using Fast-Fourier Transform (FFT) in order to extract hidden information regarding the target. Subsequently, the frequency domain signals need to go through a pre-processing stage whereby the signals are normalized based on their speed and power. This is because the power and velocity of the signal vary with the movement of the target and received power. The normalization of the spectrum can be done by widening or narrowing the width of the spectrum, which is highly dependent on the velocity of the vehicle.

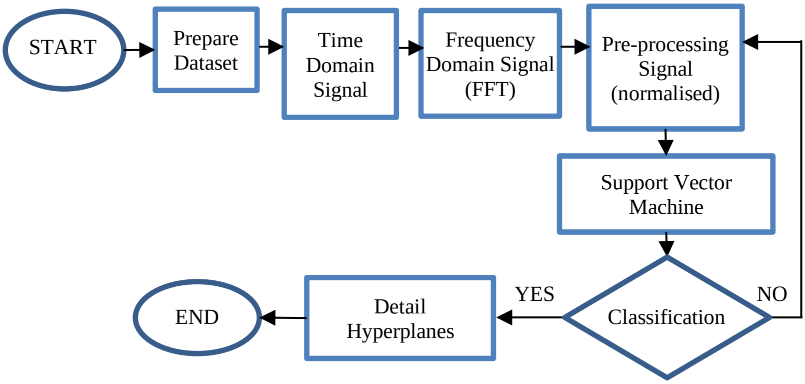
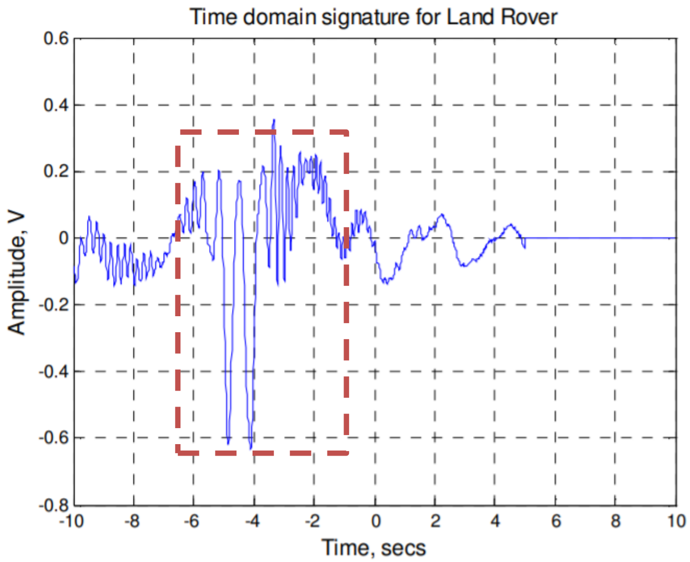


Figure 2: Flow chart of classification system.

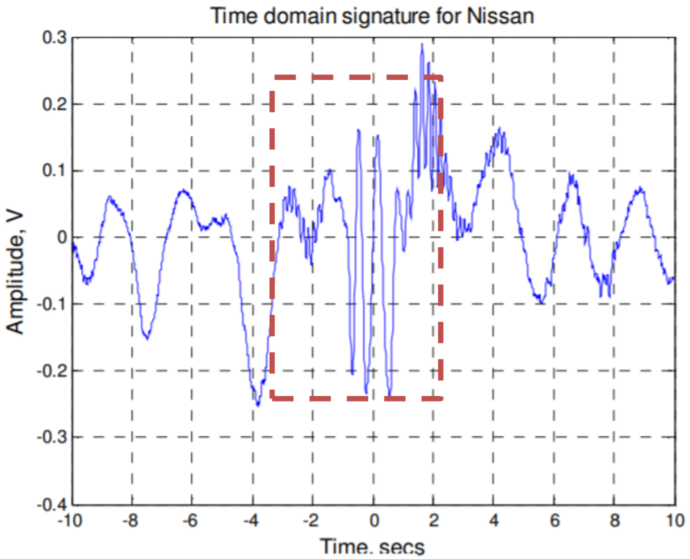
Then, the extracted features are trained using SVM functions. At this point, it should be able to group or separate the data signals according to their classes. If the classification accuracy is very low, the signal will be returned to the pre-processing step. The reason behind this is that the accuracy of the data might be affected by the discrepancy of the normalization process when it reformed to a set of values to decrease its dimensionality. Otherwise, the overlapping data will be passed to the hyperplanes to separate and differentiate all data points of one class of vehicle from the other classes.

Results and Discussion

In this experiment, four different sizes of vehicles are being tested. Despite their moderate size in comparison to larger vehicles (illegal logging lorries), the sensor can detect any type of vehicles or even human trespassing in the area. Figure 3 shows example of time-domain signals of the Land Rover and Nissan crossing the baseline. As can be observed, we can see clearly the signatures of the vehicles especially for Nissan as it crossing the baseline, however the signals are slightly corrupted since the recorded signal comprised the refection from all object surrounding the radar including slow moving and swaying objects which can be treated as clutter or noise. This might affect the classification process. Henceforth, the signal has to go through a pre-processing stage to remove the unwanted signal and extract any hidden information that characterizes the signal before being sent to the SVM for classification.



(a)



(b)

Figure 3: Time domain signal of; (a) Land Rover, and (b) Nissan.

In pre-processing stage, all time domain signal is converted to frequency domain signal. The power spectrum is normalised in order to avoid different levels of signal power. Then the signal spectrum is resampled to match the reference speed. This is due to the fact that the target's speed influences the signal (and its spectrum). The output from this stage, which contains the characteristics of the vehicles, is then fed into the SVM as an input.

Figure 4 shows the output of the pre-processing stage. As we can see, the distinct differences between the spectra of main lobe and side lobes become visible for all vehicles. The shape of the spectrum describes the vehicle's properties.

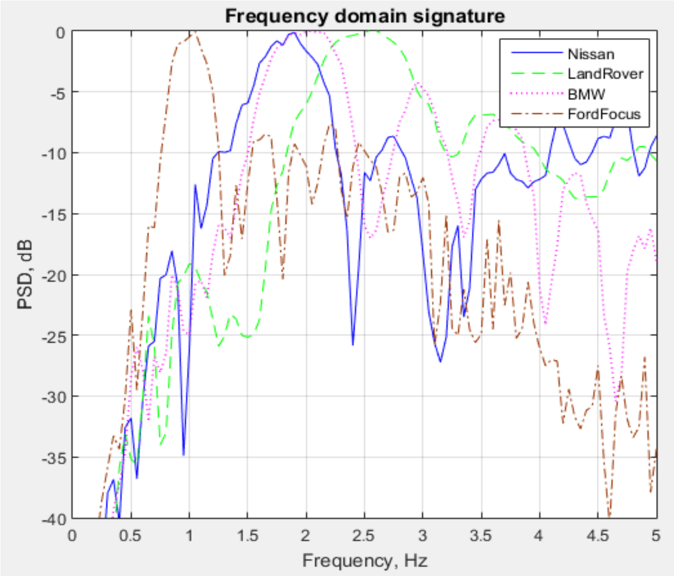


Figure 4: Pre-processing signal for all vehicles.

Next, the signals are extracted and trained by using SVM. The results from the classification process using SVM are shown in terms of data plots. Figure 5 demonstrates the class of each vehicle in data points. It can be seen that data points for Land Rover and Ford Focus are well separated from cluster. This finding is significant since Land Rover has a two-box shape and big dimension compared to other vehicles which represent different properties as we have shown in Figure 4. While, the hatchback shape of the Ford Focus resulting the separation of the data despite of its small dimension.

As for the other two classes of vehicle which are Nissan and BMW, we can observe that there are few overlapping and discrepancies in the data points.

Theoretically, in forward scatter, when the target partly blocks the signal wave front from the transmitter the shadow field occurs and the pattern of the shadow depends on the target silhouette and not on the target surface shape [7]. Consequently, in the case of Nissan and BMW, when the vehicles were crossing perpendicularly to the baseline, the incident wave blocks by the target forms a shadow contour. Hence, the intensity and phase of the incident and reradiated fields produced by both vehicles are supposed to be almost the same due to their similar dimensions. Other possible reasons are the error occurs during the normalization process of the spectrum due to the estimated speed and also the contribution of reflected signal and clutter from surrounding during measurements [21] which can be seen in the time domain signature as shown in Figure 3.

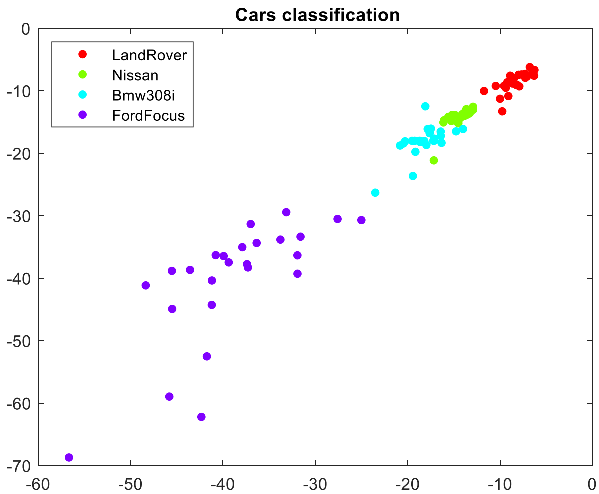


Figure 5: SVM in data point of each class.

To overcome and improve this discrepancy, hyperplanes are used to separate these two classes. Figure 6 displays the two vehicles data points and also the support vector points. The support vector points produce a hyperplane by selecting points from both sides and make a threshold. The threshold is located at a centre distance between the two different points. The hyperplanes will keep the two close classes of vehicles separated. Therefore, if any of the new signal came into testing, the hyperplanes will determine the class of the new signal based on its location. If the new observation rest on the side of Nissan, it will be considered as in Nissan and the same goes for the BMW. To confirm that the hyperplane is located in a good spot, there is a need to have more than one support vector point [22]. The reason is it can pinpoint the most suitable and accurate location of the hyperplane. Hence, both classes will be having the same distance or space to the border that separates them.

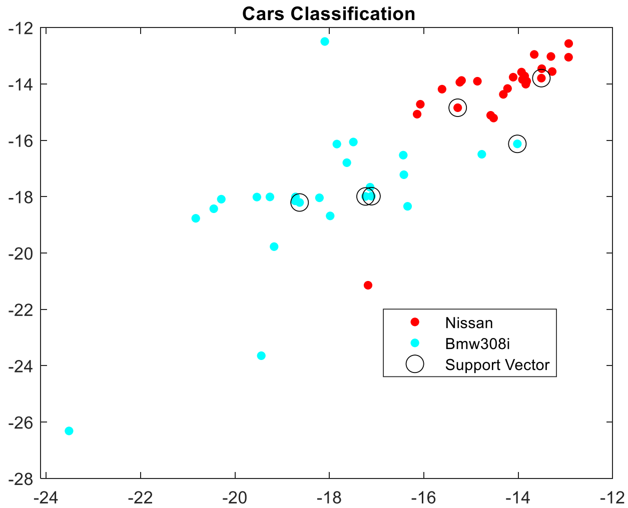


Figure 6: Support vector point (hyperplanes).

Conclusion

This paper presents the vehicle detection and classification process of illegal logger vehicles in FSR. The results demonstrated the effectiveness of vehicle detection and the classification process using SVM especially for Land Rover and Ford Focus. Any overlapping and discrepancy between the vehicle's classes can be separated using hyperplanes. From the results, it can be concluded that any illegal logger's vehicle trespassing certain protected area which has been covered by this radar system, authorities can be informed and alerted by just sending information gathered by the sensor and immediate action can be made. For future study, instead of extracting the data manually, the classification process can be improved by combining SVM with automatic data extractor such as Principal Component Analysis.

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