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Tyre Detection System using Machine Vision

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Abstract: The tyre is one of the most critical parts of a vehicle that keeps the driver safe. A prototype of tyre detection using OpenMV4 H7 plus that will notify the operators using different LED indicators for different conditions has been designed and the prototype is able to identify the tyre condition whether it is full or low pressure. The range between the tyre and the prototype is 70 cm parallelly in front of the tyre and operates when the car fully stops and no motion. Red, green and yellow LED as an indicator to notify the operators and tyre aspect ratio of 65 and diameter of the rim is 14. OpenMV4 H7 plus is used to run the trained model, the model is trained using MobileNet V2. The MobileNet V2 has been trained using more than 300 pictures from each class of full tyre, low tyre and tyre not detected. The suitable range of the OpenMV Cam from the tyre parallelly with the camera is 70 cm so that the tyre is in the centre frame to achieve accuracy above 0.9842. The prototype is able to differentiate the tyres' pressure with an accuracy of 0.9921, 0.9960 and 0.9960 for low pressure, full pressure and tyre not detected, respectively. The prototype has an average of 91% success rate for 20 set testing in detecting the tyre pressure. The red LED will turn on when low-pressure tyres, the green LED will on when full tyre pressure and the yellow LED will on when no tyre is detected. In this project, it can be observed that the pressure of a tyre will affect the sidewall of the tyre. As the pressure tyre decreases the sidewall decrease. A tyre pressure detection system can be used at the petrol pump. User can simply check their tyre condition from inside of their car.

Keywords: Tyres Pressure, Openmv4 H7 Plus, Machine Vision

1. Introduction

Everything regarding the internal design and functionality of cars is about to change as autonomous and electric vehicles for improving their performance. However, vehicles constantly come into contact with the pavement hence, tyres are crucial in terms of car security. The state of tyres is not only important and dependent not only on current tyre pressures but also on abrasion well. Additionally, tyre pressure affects abrasion in addition to the use of fuel or power [1].

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There are two types of Tyre Pressure Monitoring System (TPMS) which are Direct Tyre Pressure Monitoring System (dTPMS) and Indirect Tyre Pressure Monitoring System (iTPMS). The TPMS is provided either at the factory level for cars or it can be made available as an aftermarket solution. The use of a TPMS can reduce the likelihood of road accidents caused by tyres, and they can increase fuel efficiency and reduce tyre wear due to Over or Under-inflation [2]. For iTPSM it does not need to be attached to the tyre but the accuracy of the system will be lower than TPSM [3]. However, the application of iTPSM will be more practical in the tyre industry during the quality check process. Therefore, this project will implement a vision system to detect tyre pressure and will notify the operators if they have a low-pressure tyre.

Recently, the current technologies to detect air pressure in tyres can be characterized into two main methods which are based on pressure sensors [4]- [6] and machine vision [7]-[9]. The disadvantage of using a pressure sensor is that the sensor must be connected with the tyre so it will take more time to know the tyre pressure compared to using machine vision. However, by using machine learning the system can recognize the tyre pressure which has the same tyre rim and aspect ratio as many cars. Therefore, this project will implement a vision system to detect tyre pressure and will notify the operators if the tyre is low pressure using MobileNetV2 transfer learning which is a convolutional neural network (CNN).

2. Research Methodology

The software used in this project is OpenMv IDE for coding suitable programming which acts as a controller in this project. SolidWorks will be used for designing the casing of the prototype. Edge Impulse Studio is for testing, training and exporting trained models. The hardware for this project is an OpenMV4 H7 Plus which will be used to identify and determine a client's tyre car condition.

2.1 Project Implementation Structure

Figure 1 shows the training of the data, first of all pictures of the tyres must be taken of the same width and height. For this project, the default size is 96 x 96 which is suitable for the training model which is the MobileNetV2 96x96 0.35 model. The pictures are taken in grayscale and each of the categories which are full pressure, and low pressure has 300 pictures initially. Next, the pictures are uploaded to Edge Impulse Studio to be trained. The pictures are being split by 80% for training and 20% for model testing. The data is being trained using MobileNetV2 96x96 0.35 model. The transfer learning uses 80% of the pictures taken from each category. Then, the trained model is tested with the 20% test picture. After the pictures are in their specific categories, transfer learning is executed. The validation set is acceptable when having an accuracy of above 93.89% based on a previous paper [10] which use the same transfer learning model. For this project, the initial system achieves an accuracy of 98.6% during the transfer learning process (validation set). Next, the model is tested by the test data pictures. If the model testing results achieve above 90.72% then this model can be exported, for this project, the initial accuracy of the testing set of 95.56% is achieved. After adding more images to the dataset, the model accuracy achieves 100% accuracy during the transfer learning process and model testing results. If the accuracy is above 85.34% can be uploaded to the OpenMV4 H7 Plus. If not, then more images will be added to the training session to increase the accuracy.

After the model have been exported to the camera when a live image appears it will compare each of the tyre classifications whether the tyre is low, full or tyre not detected. The LED will turn on according to the highest accuracy reading of the live image. Troubleshoot will be done if no LED is on or the wrong colour is on. If the LED is on accordingly the system end.

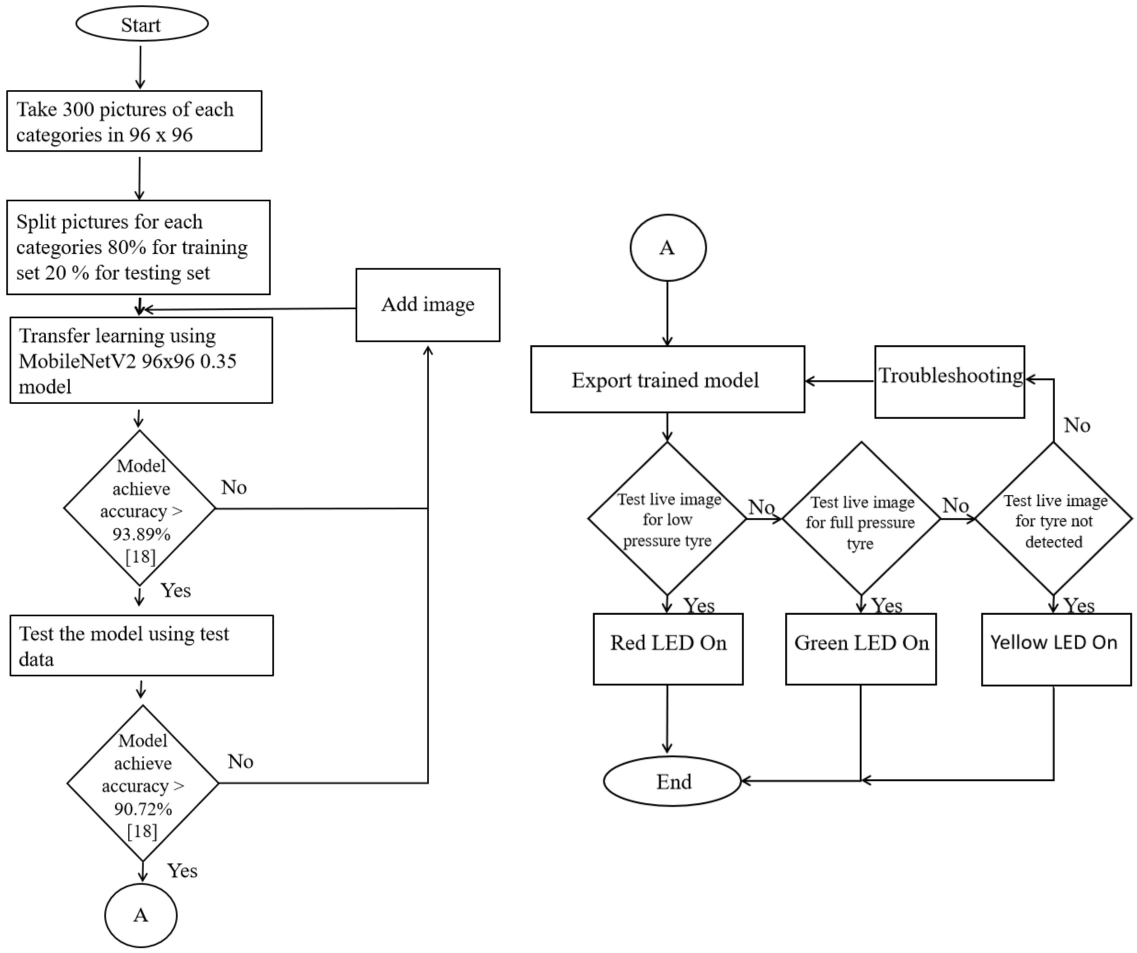


Figure 1: Flowchart of a tyre detection system using machine vision

3. Results and Discussion

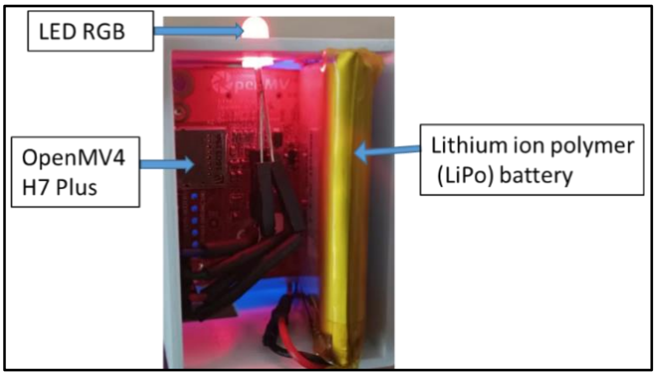
This section will discuss the results and analysis obtained from all processes that involved in developing the prototype of tyre detection using machine vision.

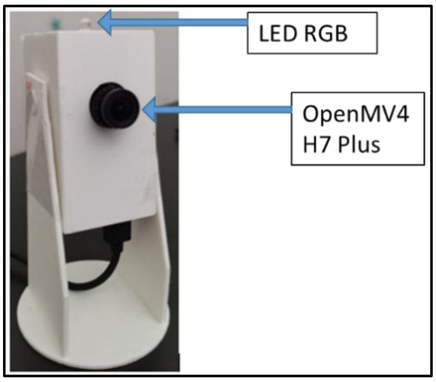
3.1 Simulation of Edge Impulse Studio

The confusion matrix for the validation set for the tyre not detected achieves a 100% result, meanwhile for the full pressure achieves 100%, and for low pressure 100%. The dataset used here is from the 80% from each class of full low and tyre not detected. The result in this project exceeds the project that uses the same MobileNet V2 transfer learning which is 93.89%. After that, the next step can be done which is testing the validation set with the test set. The confusion matrix for the test set for the no tyre achieves a 100% result, meanwhile for the full pressure achieves 100%, and for low pressure 100%. The dataset used here is from the 20% from each class of full, low and tyre not detected. The result in this project exceeds the project that uses the same MobileNet V2 transfer learning which is 90.72%. After that, the next step can be done which is uploading the trained model into OpenMV4 H7 Plus.

3.2 Result of Tyre Detection System Using Machine Vision

The main component of this system detection is the OpenMV H7 plus. The system works by detecting the tyre pressure of a car. The system will notify the operators by LED indicator which will indicate red, yellow and green colour. The red colour will indicate that the tyre is low pressure, the yellow will indicate the tyre is not detected and the green colour will indicate that the tyre is full pressure. Figure 2(a) and 2(b) show the inner and outer view of the prototype, respectively.





(a) (b)

Figure 2: The (a) inner and (b) outer view of the prototype.

3.2.1 Analysis of the effectiveness of the OpenMV Cam H7 Plus

This project starts with the analysis of the effectiveness of the OpenMV Cam H7 Plus to detect the tyre in the frame. The effectiveness is measured in terms of the whole tyre is in the frame. Figure 3 shows the setup for the experiment which mainly uses the tyre of Perodua Axia 165/65 R14. The OpenMV Cam casing was made using 3D printing so that the reading can be more stable and consistent. The findings show that the suitable range of the OpenMV Cam from the tyre parallelly with the camera is 70 cm so the tyre is in the center frame because it produces the highest accuracy which is above 0.9842. The optimum range of detection is marked with a blue dashed frame and the red frame area cannot be detected by the camera because the tyre is not entirely in frame. This shows the limitation of the OpenMV Cam which needs to have some distance from an object so that the object can be fully in the frame. Table 1 shows the relationship of the distance of the camera to the tyre parallelly to the accuracy. The tyre used for the testing was a 30 PSI, full-pressure tyre.

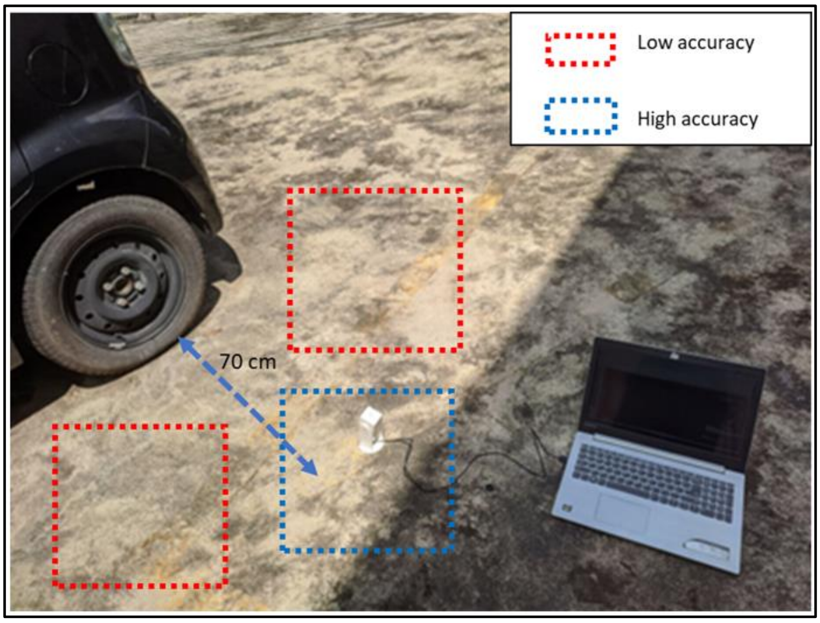


Figure 3: Testing of the optimal range for the OpenMV Cam

Table 1: The relationship of the distance of the camera to the tyre parallelly to the accuracy

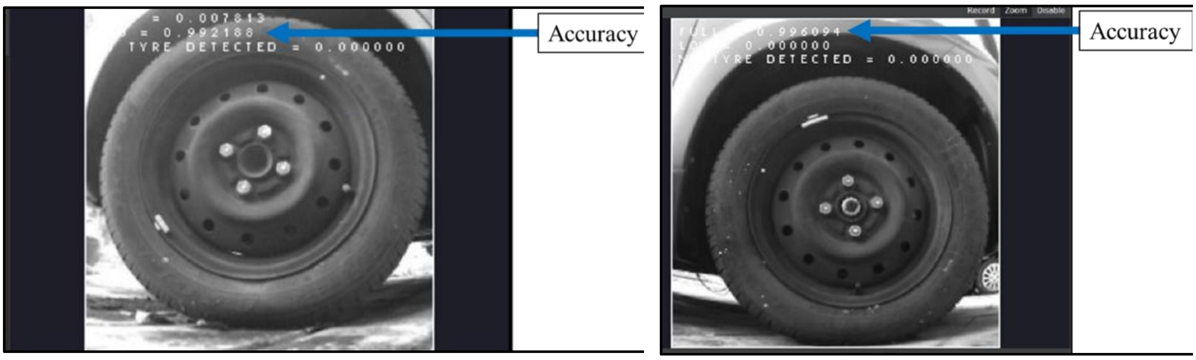
Distance of Camera to The Tyre Parallelly (cm)	Accuracy of system	Tyre detection
30	0.8945	Tyre not detected
40	0.7832	Tyre not detected
50	0.6652	Tyre not detected
60	0.7743	Tyre not detected
70	0.9931	full
80	0.9842	full
90	0.9765	full
100	0.6445	Tyre not detected
110	0.7344	Tyre not detected
120	0.8901	Tyre not detected

3.3 Testing the Prototype

This section discusses the result of tyre pressure detection for full and low tyre pressure. Then, this section also will discuss the notification of LED for different conditions such as low, full and tyre not detected.

3.3.1 Tyre Pressure Detection

First of all, to test the prototype the range of the tyre must be specific for each class. In this experiment for low pressure, the tyre pressure is in the range of 10 to 20 PSI and for full pressure, the tyre pressure is in the range of 27 to 30 kPa. The prototype is able to differentiate the low and full tyres pressure with high accuracy of 0.9921 and 0.9960 as shown in Figures 4(a) and 4(b), respectively. The sidewall of the tyres is responsive to the tyre pressure that is inserted into them. The sidewall of the tyres is recorded with different pressure as shown in Table 2 and a bar chart from the data is made in Figure 5. From Table 2 it can be concluded that as the pressure increase the sidewall of the tyre increase. The tyre pressure that is safe for driving is between 25 PSI to 30 PSI [11] but the minimum tyre pressure that can be used is 22.5 PSI.



(a) (b)

Figure 4: The (a) tyre pressure of 20 PSI (low pressure) and (b) tyre pressure of 30 PSI (full pressure)

Table 2: The relationship between the tyre pressure and the tyre sidewall

Tyre Pressure (PSI)	Sidewall (mm)
10	73
15	81
20	92
25	103
30	107

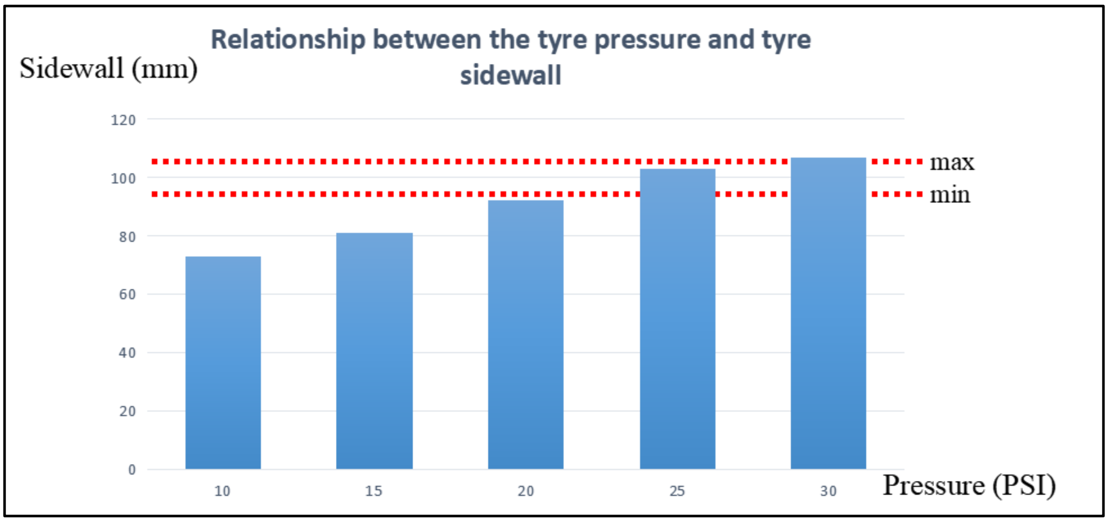


Figure 5: The red dashed line indicates the range of tyre pressure that is safe to use for driving

3.3.2 Notification by LED Indicator

After the tyre pressure for the low pressure and full pressure has been decided. Then the system will be able to produce clear and consistent outcomes as shown in Figures 6(a), 6(b) and 6(c). To test the success rate of tyre detection, each tyre pressure is tested 20 times to determine the percentage of success from each tyre pressure. Table 3 shows that the system is able to recognize the tyre and has an average of 91% success rate in detecting the tyre pressure. The lowest success rate is the tyre pressure with 25 PSI and the highest is the tyre pressure with 30 PSI. To justify this, this percentage is assumed to be determined by the quality of the picture dataset. Noise, light, and background all have an impact on the accuracy of machine learning and encoding.

(a) (b) (c)

Figure 6: The (a) red LED turns on as low-pressure tyre detected, (b) green LED turns on as full tyre pressure detected and (c) yellow LED turns on as tyre not detected

Table 3: Success rate of tyre detection in 20 tests

Tyre pressure (PSI)	Tyre detection test	Success rate (%)
10	20/20	100
15	19/20	95
20	17/20	85
25	15/20	75
30	20/20	100

4. Conclusion

This project has been completed to establish a tyre detection system using machine vision to detect low-pressure tyres and produce output in the form of LED notifications. This prototype was implemented using OpenMV Cam H7 Plus to detect the different tyre pressure. For the validation set and training set for the three categories accuracy of 100% has been achieved. Besides that, the range of the OpenMV Cam is that it must be horizontally aligned from the tyre outside the car so that the camera can see the tyre fully in its camera frame. The distance recommended to set up the camera from the tyre is 70 cm. When the camera is set up more or less than 70 cm the accuracy of the tyre detection will decrease to less than 0.9931. The prototype is able to differentiate the different types of tyre pressure with an accuracy above 0.99 for all classes. The prototype has an average of 91% success rate for 20 sets of tests in detecting tyre pressure. The OpenMV Cam H7 Plus has a trained model in it so it will be able to differentiate the condition of tyres whether it is low or full pressure and the LED will correspond to the result if the tyre is low then the red LED will light on but if the tyre is full the green LED will turn on. The yellow LED will turn on if there is no tyre is detected. A tyre detection system can be used at the petrol pump. In the Covid-19 epidemic, user can simply check their tyre condition from inside their car so that they will be safer from any surrounding virus. The device can also work on any type of tyre when the camera has been trained.

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