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Husk Detection Using Thermal Imaging Technology

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Abstract

Harvested paddy normally contains impurities including husk. This study focuses on the use of thermal imaging to detect husk. Heating and cooling treatment was applied to 20%, 40%, 60%, 100% husk and 100% seed to differentiate between husk and seeds due to heat transfer. From result, mean pixel of seed thermal image is higher compared to husks. It value at 25 s gave a suitable indicator to separate between seed and husk. The technique can be used to detect husk with 100% success rate for 20% and 40%, 98.33% for 60% and 97.67% for 100% husk, while 94.33% for 100% seeds.

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Keywords: Paddy husk; thermal image; seed

1. Introduction

Paddy is one of the most crucial agricultural crops in Malaysia. After harvesting, normally it contains contaminations and impurities. Thus, cleaning and grading plays important roles in improving the quality of paddy in order to have good yield of paddy crop. Traditionally, cleaning is based on the principle where lighter materials like straw and husk are blown away by air. To fulfil this purpose, machines for cleaning, separating and grading were introduced. Fundamentally, the machines perform the task based on paddy thickness, aerodynamic behaviour, length and other characteristics. One of the by-products is husk which known as agricultural waste materials and sometimes used as a source of fuel in the paddy mills. However, the burning of husk could cause environmental pollution and to overcome this circumstance, it is used as a secondary source of materials such as insulator for buildings (Chandrasekhar et al., 2003). With extrusion and pressing processes of husk ashes, thermal insulator can

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be produced where it has low compression strength and low apparent density due to high porosity (Goncalves and Bergmann, 2007).

Visual inspection and manual separating methods are time and labor consuming. Recently, machineries for processing and inspection has been used to fulfill farmer's expectation and demand in getting good quality of paddy seeds from seed distributors. However, the husk cannot fully be separated by the machineries. According to Vadivambal and Jayas (2010), although advanced devices like X-ray machines, optical sensors and metal detectors were used, it has been found that distinguishing foreign materials and the product such as husk and paddy seeds depends on the response of the energy spectrum between them.

Thermal imaging is a non-destructive, non-contact system of recording temperature by measuring infrared radiation emitted by a body surface (Arora et al., 2008). It is a technique which converts the invisible radiation emitted by an object into visible image without making contact with the object. It also allows us to see the variations in temperature because the amount of radiation emitted by an object increases with temperature. Thermal imaging quantifies the changes in surface temperature with high temporal and spatial resolution compared to single point measurements as in the case of other contact methods by using thermometer or thermocouple (Gowen et al., 2010).

These days, thermal imaging has been widely used in agricultural sector. It is a potential method for the remote detection of abnormality in agricultural products based on the temperature changes during cooling and heating (Manickavasagan, 2008). It has been used to discriminate foreign materials in almond (Ginesu et al., 2004), detecting *Callosobruchus maculatus* infestation in mung bean (*Vigna radiata*) (Chelladurai et al., 2012), preliminary study on detection of fungal infection in stored paddy (Khairunniza-Bejo and Jamil, 2013) and also as an approach to estimate moisture content of paddy rice (Farid et al., 2014).

The main objective of this study was to detect paddy husk using thermal imaging technology. The detection was done based on the mean pixel intensity of the paddy and husk. The method will be tested by using 20% husk, 40% husk, 60% husk, 100% husk and 100% paddy seed.

1.1. Sample preparation

Paddy seed of variety MR219 was taken from one of the Malaysia paddy seed distributors located in Sungai Besar, Selangor. They were taken from paddy silo storage after drying by using an inclined bed dryer. The moisture content of the paddy seed was 12% which is the safe moisture content for paddy seed in silo storage. They were then brought to a laboratory and stored at room temperature in a closed tight container and the moisture content of the seeds was checked by using G7 grain moisture meter (Fig.1 (a)).The sample taken consist of paddy seeds and other foreign materials such as paddy husks, soil, chaff, stones, weed, rice straw, stalks, and insects. An air screen cleaner was used to separate seeds and foreign materials as shown in (Fig. 1 (b)). The sample was filtered for five times. Paddy seeds (Fig.1 (c)) and paddy husks (Fig.1 (d)) were later collected to be used in the experiment. Paddy seeds and paddy husks were arranged in a 6x5 array for 20% husk (6 husk and 24 paddy seeds), 40% husk (12 husk and 18 paddy seeds), 60% husk (18 husk and 12 paddy seeds), 100% husk (30 husk) and 100% paddy seeds (30 paddy seeds) with 10 replications.

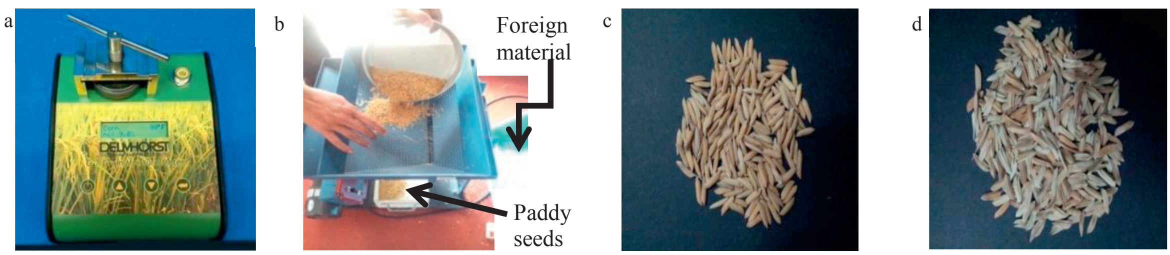

Fig. 1. (a) Moisture content measurement by using G7 grain moisture meter; (b) Sample filtering by using air screen cleaner; (c) Paddy seed; (d) Paddy husk.

1.2. Image acquisition

A thermal camera (Model: FLIR E60, FLIR systems, King Hills, West Malling, Kent, United Kingdom) with a resolution 320 x 240 pixels, temperature range between -20 °C to +650 °C, thermal sensitivity less than 0.05 °C and operated in mid infrared region of wavelength 700nm until 1400nm was used to acquire thermal images of the samples. It was fixed at a distance of 40cm from sample as shown in Fig. 2. Thermal images were captured before the heating treatment to indicate the initial condition of the samples. For heating treatment, two lamps with 240 Volt and 42 Watt power supply each were used to heat the samples. After that, the samples were heated for three minutes (Chelladurai, 2010). Later, samples were allowed to cool to ambient temperature during the cooling treatment and thermal videos were recorded for one minute during this setup. Next, the initial image (image captured before heating treatment, indicated as 0 s) and frame images extracted from FLIR video report player at 1s, 2s, 3s, 4s, 5s, 10 s, 15 s, 20 s, 25 s, 30 s, 35 s, 40 s, 45 s, 50 s, 55 s and 60 s during cooling were analysed.

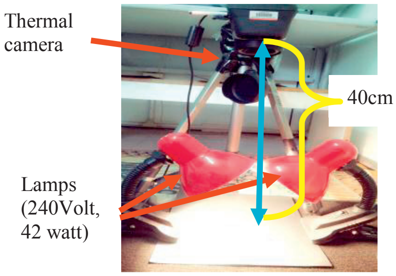

Fig. 2. Experimental setup.

1.3. Image analysis

All of the thermal images were analyzed using a Matlab software version 2012b (The MathWorks, INc. U.S.A) as shown in Fig. 3. Firstly, all thermal images were converted to grayscale images. The mean pixel value of each paddy seed and paddy husk were analysed. The analysis was done by defining each seed and husk as a region of interest and analyzing their mean pixel value using ‘regionprops’ function in Matlab. This analysis were repeated for 20% husk, 40% husk, 60% husk, 100% husk and 100% paddy seeds.

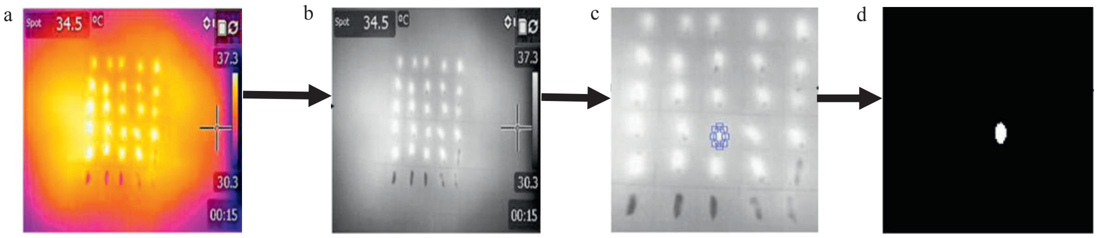

Fig. 3. Samples of image analysis with 20% husk at 15s cooling treatment. (a) Thermal image; (b) Grayscale image; (c) Region of interest selection; (d) Image segmentation.

2. Results and discussion

2.1. Average mean pixel values

Table 1. Average mean pixel values and standard deviation for husk and paddy seeds for 20% husk, 40% husk, 60% husk, 100% husk and 100% paddy seeds.

Time, second (s)		Type of sample							
		20% Husk	40% Husk	60% Husk	100% Husk	100% Paddy seeds	Average		
		Average mean pixel	Average mean pixel	Average mean pixel	Average mean pixel	Average mean pixel	Average mean pixel	*Difference between paddy and husk,$\lvert\Delta_{ph}\rvert$	Standard deviation
0	Husk	153.81	144.20	135.12	144.32	-	144.36		11.03
	Seeds	157.35	141.58	128.68	-	140.71	142.08	2.28	25.82
1	Husk	144.18	137.03	151.78	125.10	-	139.52		25.93
	Seeds	161.19	178.73	171.27	-	179.42	172.65	33.13	32.21
2	Husk	145.66	141.07	152.55	129.06	-	142.09		24.13
	Seeds	167.83	188.60	177.96	-	185.49	179.97	37.88	30.50
3	Husk	147.16	142.08	155.42	128.09	-	143.19		24.27
	Seeds	176.62	198.54	187.30	-	192.09	188.64	45.45	27.53
4	Husk	147.82	139.92	156.75	129.71	-	143.55		22.95
	Seeds	184.41	201.89	192.76	-	195.88	193.74	50.19	27.07
5	Husk	150.38	136.69	156.94	133.18	-	144.30		22.95
	Seeds	192.81	204.19	196.13	-	202.77	198.98	54.68	28.61
10	Husk	153.67	132.93	155.73	139.28	-	145.40		21.52
	Seeds	219.73	215.91	210.58	-	219.12	216.34	70.94	20.41
15	Husk	147.32	120.98	157.65	146.74	-	143.17		17.24
	Seeds	229.53	225.54	217.38	-	223.95	224.10	80.93	15.32
20	Husk	144.76	118.43	157.02	149.03	-	142.31		18.76
	Seeds	231.94	226.12	219.00	-	226.02	225.77	83.46	13.24
25	Husk	144.30	111.54	159.23	149.80	-	141.22		17.81
	Seeds	233.23	224.57	219.77	-	227.85	226.36	85.14	12.74
30	Husk	144.00	113.33	157.99	149.96	-	141.32		18.02
	Seeds	233.68	222.92	220.93	-	227.86	226.35	85.03	12.39
35	Husk	144.21	109.06	158.92	150.31	-	140.63		17.20
	Seeds	232.35	217.54	219.15	-	227.69	224.18	83.55	12.75
40	Husk	144.30	110.44	157.72	147.87	-	140.08		17.71
	Seeds	231.37	212.48	216.85	-	226.02	221.68	81.60	14.17
45	Husk	145.71	110.83	160.78	146.95	-	141.07		17.28
	Seeds	230.87	206.35	216.15	-	224.64	219.50	78.43	14.70
50	Husk	145.39	113.08	161.92	148.96	-	142.34		17.02
	Seeds	228.44	201.08	214.63	-	223.18	216.83	74.49	15.32
55	Husk	148.03	113.94	162.39	148.44	-	143.20		17.46
	Seeds	225.75	196.11	213.70	-	220.31	213.97	70.77	15.40
60	Husk	153.81	115.24	166.31	147.37	-	145.68		17.92
	Seeds	222.35	188.81	206.85	-	218.29	209.08	6.34	16.86

*$\lvert\Delta_{ph}\rvert$: |Average mean pixel paddy –Average mean pixel husk.|

Table 1 shows average mean pixel and standard deviation for every sample at conditions of 20%, 40%, 60%, 100% husk and 100% paddy seeds. From this table, 25 s of cooling time showed as a suitable time to differentiate between husk and paddy seeds. It is based on the higher difference of average mean pixel between husk and paddy seed and small value of standard deviation. At initial condition (0 s), the average mean pixels of husk and paddy seed for 20%, 40% and 60% husk sample condition are 153.81, 157.35, 144.20, 141.58, 135.12 and 128.68 respectively. These shows that the difference between husk and paddy seeds before heating treatment are small and this will not be easier to distinguish them. After heating treatment was applied for 180 s, generally the average means pixel start increasing from 1 s until 15 s of cooling time for both husk and paddy seed for all samples condition. Then, from 20 s until 60 s, the average mean pixels for husk and paddy seed start to change slowly and almost uniform.

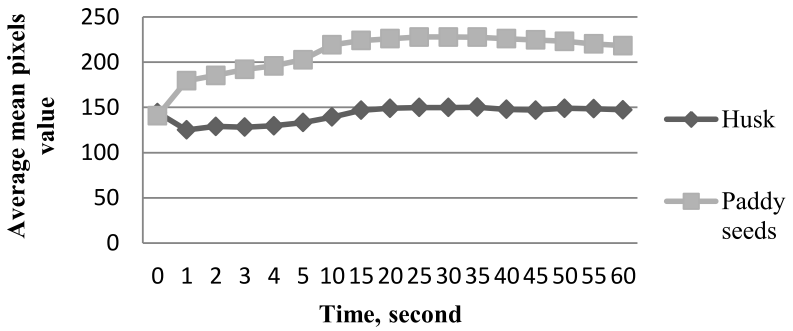

Fig. 4. Graph of average mean pixel values of 100% paddy seeds and 100% husk versus time using thermal camera at initial condition (0 s) and during cooling treatment after 180 s heating treatment.

Fig. 4 show the trend of average mean pixel values for 100% paddy seeds and 100% paddy husks from the initial condition until one minute of the cooling treatment. From the graph, it could be observed that average mean pixel values for 100% paddy seeds are greater than 100% husk through the cooling treatment. At 0 s, before the heating treatment, the average mean pixel value for 100% husk and 100% paddy seeds are not too far from each other at 144.32 and 140.71 with only 3.61 difference. Generally, based on the graph, average mean pixel for 100% paddy seeds and 100% husk shows increasing pattern until 15 s of cooling time. Then, it goes uniform with small differences between the average mean pixels from 20s until 60s of cooling time.

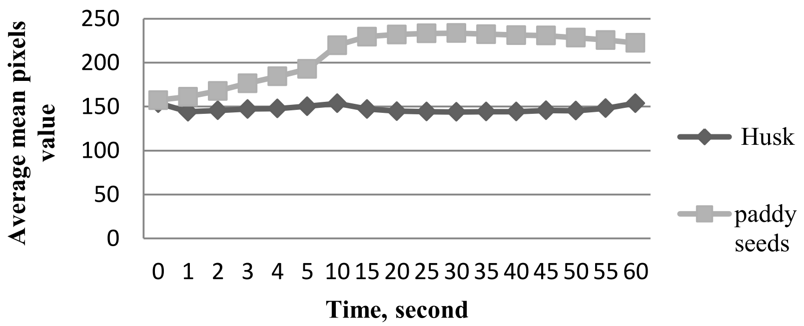

Fig. 5. Graph of average mean pixel values of 20% husk versus time using thermal camera at initial condition (0 s) and during cooling treatment after 180 s heating treatment.

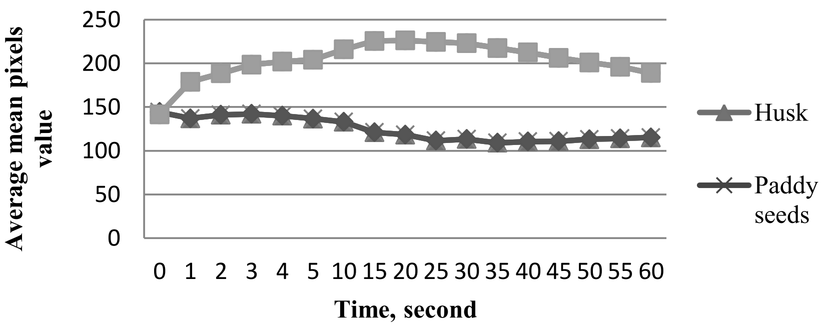

Fig. 6. Graph of average mean pixel values of 40% husk versus time using thermal camera at initial condition (0 s) and during cooling treatment after 180 s heating treatment.

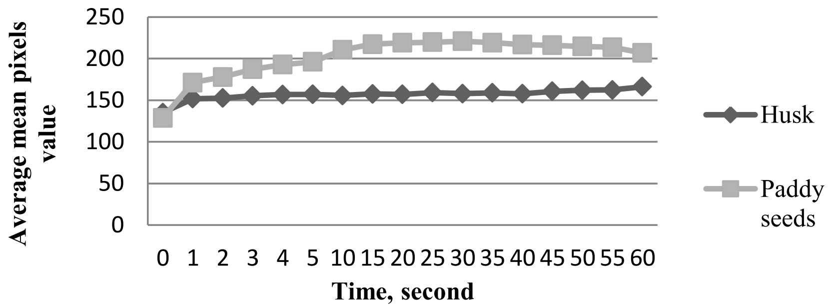

Fig. 7. Graph of average mean pixel values of 60% husk versus time using thermal camera at initial condition (0 s) and during cooling treatment after 180 s heating treatment.

Figs. 5, 6 and 7, shows that the average means pixel values for husk are consistently lower than paddy seeds for 20%, 40% and 60% husk. At the initial condition (0 s), the average mean pixel values for husk and paddy seeds are almost the same. During cooling treatment, the average mean pixel of husk and paddy seed for all samples conditions go in opposition. Paddy seed show higher value for 20%, 40% and 60% husk and generally an increasing pattern is observed and husk shows decreasing pattern and have lower value than paddy seeds.

From these figures, it is shown that paddy husks have darker images than paddy seeds after heating. The main reason is heat transfer where the temperature difference is the driving force. The larger the temperature difference, the higher the rate of heat transfer. Theoretically, heat transfer law states that when a body is left in a medium that is at a different temperature, energy transfer takes place between the body and surrounding medium until thermal equilibrium is established (Cengel and Boles, 2011). In this study, initially, the husk and paddy seeds are in equilibrium state with the surrounding condition. The heating process helps to see the difference between the husks and paddy seeds and also their surroundings. After heating, paddy seeds became hotter which is higher in temperature than the surroundings. As a result, an energy transfer from the higher temperature body to the lower temperature body has occurred. Once the temperature equilibrium is established, the energy transfer stopped (Cengel and Boles, 2011).

Furthermore, husk also acts as an insulator and has low thermal conductivity which is comparable to most excellent insulation materials. Insulating materials are materials that prevent the flow of heat by conserving energy through heat gain or loss. By using transient heat flow method, the thermal properties of paddy husk were investigated by Sreenarayanan et al. (1986) and it was found that paddy husk was useful to be used as a heat resistant material. Thus, thermal image captured shows that husk become darker because it is colder than paddy seeds.

On the other hand, paddy seeds become brighter compared to paddy husks. The increasing temperature of paddy seeds is due to the increase rate of heat transfer by convection and thermal radiation (Dua and Ojha, 1969). Convection is the mode of energy transfer between a solid surface and gas that is in motion (Cengel and Boles, 2011). Heat transfer from the surface of the hot full paddy seeds is by natural convection since any motion in the air in this case is due to the rise of the warmer air near the seed surface and the fall of the cooler air to fill its place. Thus, the thermal images show that the full paddy seeds are brighter than the husk because of the higher temperature.

2.2. Husk detection

Based on values presented in Table 1, the average mean pixel values between husk and paddy seeds have the highest difference at 25 s cooling time as compared to the others, while the average standard deviation shows the smallest difference. Therefore, image of 25 s cooling time is recommended for separation of paddy seeds and husks. A threshold value was set at 190 to separate between background which are the black A4 paper and paddy seeds and object which is the husk. The method has been tested to detect 20% husk, 40% husk, 60% husk, 100% husk and 100% paddy seeds in 50 samples of images. Fig. 8 shows some examples of the results. Detected husk were identified by white pixels in the binary image. Based on these results, it is clearly shown that the method can detect husks in all conditions. It also can identify sample with no husk at all. Table 2 shows summary of the results in all samples.

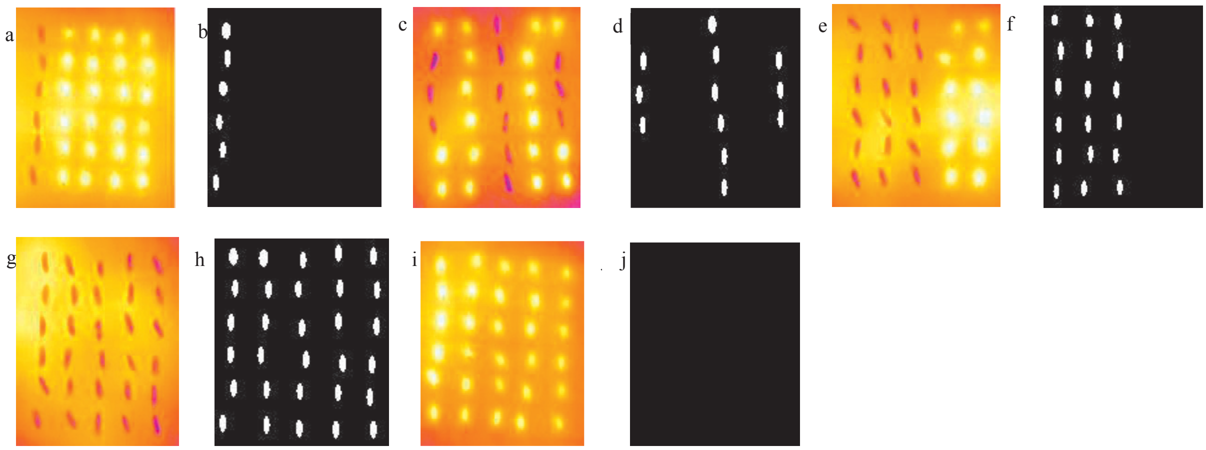

Fig. 8. Example of the sample with 20% husk. (a) Input image; (b) Detected husk; 40% husk. (c) Input image; (d) Detected husk; 60% husk.(e) Input image; (f) Detected husk; 100% husk. (g) Input image; (h) Detected husk; 100% paddy seeds. (i) Input image; (j) Detected paddy seeds.

Table 2.Summary of average percentage of detection and percentage of error.

No.	Sample	Average percentage of detection, %	Average percentage of error, %
1.	20% husk	100.00	11.67[a]
2.	40% husk	100.00	6.67 [a]
3.	60% husk	98.33	1.67[b]
4.	100% Husk	97.67	2.33 [b]
5.	100% Paddy seeds	94.33	5.67 [b]
6.	Average	98.07	5.60

Note: a- False positive. b- False negative

From Table 2, this method can well detect husk and paddy with the average of success of 98.07%. All of the husks taken from samples of 20% husk and 40% husk can be identified 100% correctly. However, there were some misclassified conditions where in certain cases, the paddy has been detected as husk, resulting in false positive error of 11.67% and 6.67%, respectively. This method also can identify husk in the samples of 60% husk and 100% husk with 98.33% and 97.67% successful rate detection. Both conditions suffer small amount of false negative error which is only 1.67% and 2.33%, respectively. The 100% paddy seed detection also gives false negative error of 5.67%. However, the percentage of successful detection is considerably still high, which is 94.33%. Although the percentage of successful detections in all samples is promising, there is still false positive and false negative error. This error might be subject to the selection of threshold value. In the false positive error, some of the paddy has been detected as husk because they have less mean pixel value than the threshold value. In the false negative error, the husk cannot be detected because their mean pixel value is greater than the threshold value.

4. Conclusions

Based on this study, it can be concluded that the mean pixel of husks and paddy seeds at different cooling times can be determined. Heat transfer shows difference in temperature between husk and paddy seeds. This method suitable to be used for removing husk on single layer beds and can help to improve the available machineries for refinement.Thermal images during the 25 s cooling time showed a suitable time to differentiate between husk and paddy seeds based on the higher difference of average mean pixel and small value of standard deviation between husk and paddy seed. In average, the thermal imaging method can be used to detect husk with 98.07% successful detection. The results from this study indicate that thermal imaging technology might be useful in detection of paddy husk. However, in the future work, study on the application of this method can be study and expend to check on its capability on separating a bulk group of mixed paddy and husk.

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