ESTIMATION OF THE END-OF-OPERATION PHASE IN CRUSHING OPERATIONS OF AGRICULTURAL PLASTICS

Takahiro Nishigaki

Department of Computer Science, Takushoku University, Tokyo, Japan

ABSTRACT

This paper examines a method for estimating operation stoppage time of crushing operations in a recycling plant for agricultural plastics in Japan.In light of the growing environmental problems caused by waste plastics around the world, resource recycling of plastics is being promoted.Agricultural plastics are plastics discharged from the agricultural sector. Agricultural plastics have a high recycling rate because the main materials are often the same, even if the manufacturers are different.Companies scattered in rural areas are mainly engaged in the recycling and processing of agricultural plastics, but many of them face a social problem in rural areas: a shortage of workers.In order to address the above issues, there is a need for automation of work in recycling plants, such that machines can replace workers.In this study, we aimed to automate the operation of crushing work in a recycling plant for agricultural plastics.The crushing work is the crushing of agricultural plastics fed into a crusher by rotating blades inside the crusher.Work stoppage is determined by monitoring a current meter that indicates the resistance value of the rotating blades and a camera inside the crusher.In crushing operations, there is a demand for automation of this operation stoppage judgment. In a related study, as a preliminary step to estimating the work stoppage time, we estimated the time period when the current value decreases and the variability decreases, which is indicated in the current value before the operation stoppage.The time period before operation stoppage was defined as the time period from 150 seconds before to the work stoppage time of the crushing operation, and the estimation of the operation stoppage phase was conducted with the name "end of operation phase".

KEYWORDS

Automation, Outlier Detection, Anomaly Detection, Predictive Failure

1. INTRODUCTION

Plastics began to spread around the world after World War II and are now one of the materials that bring many conveniences and benefits to our lives [1].On the other hand, environmental pollution problems caused by improper disposal of plastics are becoming more serious. It is estimated that more than several million tons of waste plastic are discharged from land into the ocean each year.As a result, the environmental pollution problem caused by plastics is getting worse every year, as the concentration of microplastics in the ocean is predicted to increase to about twice the current level in 2030 [2].Figure 1 shows a comparison of plastic concentrations in the global ocean in August 2016 and August 2066 [3].From the figure, it can be seen that the number of areas where the concentration of plastic in the ocean is greater than 1000 mg/m3 may increase in August 2066 compared to August 2016.Therefore, it is estimated that a large amount

David C. Wyld et al. (Eds): SIPO, BDHI, NET, SOEA, CSML, AISCA, MLIOB, DNLP – 2025
pp. 209-215, 2025. CS & IT - CSCP 2025 DOI: 10.5121/csit.2025.150416

of plastic will continue to be discharged into the ocean, which may have a tremendous impact on the marine ecosystem [4].

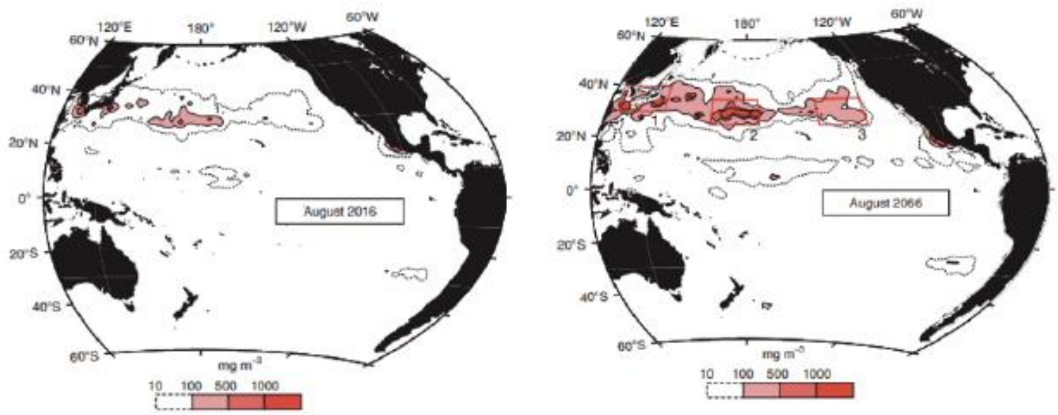


Figure 1. Amount of microplastics leaking into the ocean [3]

One of the fields that use a high percentage of plastics is agriculture, especially horticulture, and it is necessary to ensure the proper disposal of agricultural waste plastics[2][3]. Material recycling is often adopted as an appropriate treatment method for agricultural waste plastics, and it is possible to recycle waste agricultural plastics into raw materials for plastics through processes such as washing, dehydration, and pulverization. However, in the crushing operation, which is a part of the process, the end of the operation is judged by a person, who judges the stage before the end of the operation (hereinafter referred to as the “end of operation” phase) with a long-standing sense by looking at a current meter that shows the resistance value of the crushing blade in the machine that crushes plastics, and then judges the end of operation by looking at a video image of the inside of the machine. After that, the worker judges the end of the work by looking at the images of the inside of the machine. Since the judgment is based on the worker's senses, there is no uniformity in the finished raw materials, and the human cost is an issue. Therefore, it is necessary to solve the above problems by having the machine judge the end of the operation in the same way as the worker does.

2. Related Works

There have been many works[4][5] aiming at having machines make decisions on tasks using current values. One of the methods used in these studies is often SVM[6], which is one of the pattern recognition models with supervised learning. However, SVM requires classification (labeling) of the target research data as a prerequisite. However, in this study, SVM cannot be applied because the judgment of the end of the plastic crushing process is based on individual senses and cannot be classified into the end of the process and other stages as a preprocessing step. Therefore, in this study, we confirm what features of the current meter are used by workers to judge the end-of-operation stage and examine the features that may enable a machine to judge the end-of-work stage. Finally, we analyze whether or not the estimated end-of-operationphase can be actually determined by using the examined features and verify the accuracy of the estimation.

3. Analysis of End-of-Operation Phase

We checked what features of the current value meter were observed by the workers in order to determine the stage of work termination. Figure 2 shows an example of a graph of the current values measured at a sampling interval of 0.25 seconds during one crushing operation. Figure 2 is only an example, and the shape and length of the current waveforms may differ depending on the characteristics of the plastic to be crushed and other factors. As a result of the interview with the workers, it was found that "the judgment of entering the work termination stage is made when the variation of the current value is small and the time period when the value gradually decreases". This is confirmed by the graph in Figure 2, which shows that the workers judge that they have entered the work termination stage in the region surrounded by the red line in the figure. It is also found that this region exists in all the measured data waveforms. Therefore, in order to judge that the worker has entered the stage of work completion, it is necessary to consider the features that can judge that the worker has entered the region surrounded by the red line in Figure 2.

The current waveform of one grinding operation is shown in Figure3.Figure3 shows that the current value initially rises, the variation is large, but the value stabilizes, and then the current value turns from rising to falling again. At that time the variation is high.Finally, when the current value falls, the variation is small.Thus, as shown in Figure4. It can be seen that the band of the current value graph is smaller at the end of the work phase.It was decided to pay attention to this and to study the features.

In order to check the variation of the values, the moving average graph was superimposed, and it was confirmed that the moving average graph was at the center of the band of the current value graph.This is shown in Figure5.The left-hand side of Figure5 shows the moving average for the windows parameter $a = 5$, and the right side is for $a = 15$.The left side of Figure 5 shows the moving average with the windows parameter a=5, and the right side with $a = 15$.Using this result, it can be confirmed that the difference (absolute value) between the current value and its moving average tends to be smaller at the end of the work period than at other time periods.

From the Figure 5, the variance of the difference from the moving average is used as a feature to judge that the work has entered the stage of the end of the work. The variance of the difference from the moving average is the value obtained by calculating the difference between the current value and the moving average during the moving average range a seconds and then calculating the variance of the calculated difference during the calculation time range b seconds. Note that the moving average width a and the calculation time width of variance b are integer parameters to be set in advance. As an example, the formula for the variance of the difference from the moving average at t seconds is shown below.

c_t : Current value at t seconds from start of operation
$m_{a,t}$: Moving average of the last a seconds at t seconds
d_t : Difference from moving average at t seconds$\left(= \left|c_t - m_{a,t}\right|\right)$
$v_{b,t}$: Variance of the difference from the moving average at t seconds immediately before b seconds

$$v_{b,t} = \frac{\substack{The\ sum\ of\ the\ squares\ of\ the\ deviations\ from\ each\ moving\ average \\ from\ the\ time\ t\ seconds\ to\ the\ immediately\ preceding\ b\ seconds}}{Number\ of\ data\ in\ b\ seconds}$$
$$= \frac{\sum_{i=t-4b}^{t}\left(d_i - \frac{\sum_{j=t-4b}^{t} d_j}{4b}\right)^2}{4b}$$

A graph of the current value data graph with $v_{b,t}$ calculated using the variance of the difference from the moving average for $a = 20$, $b = 5$ and $a = 20$, $b = 15$ is shown in Figure 6.It can be seen in Figure 6 that when $a = 20$, $b = 15$, the values at the end-of-work stage were smaller than at other times.Furthermore, as a result of the analysis of all the measured data waveforms, it is found that the variance of the difference from the moving average always remains below the threshold value for at least 19.1 seconds during the work termination phase.

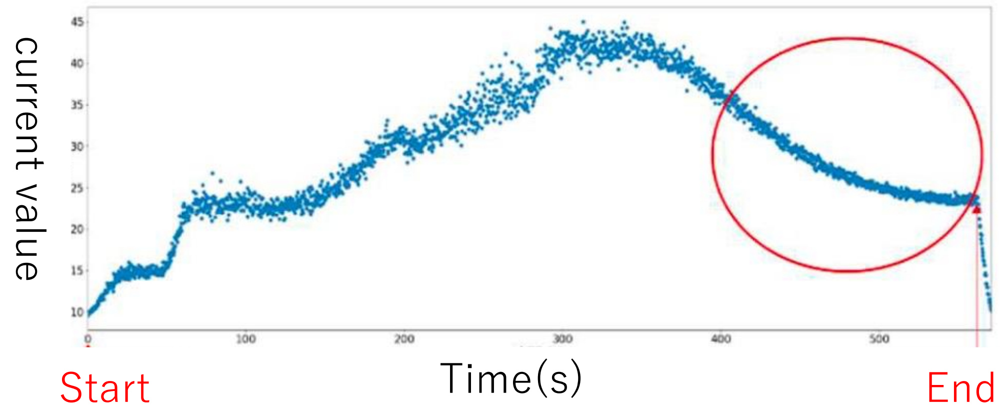
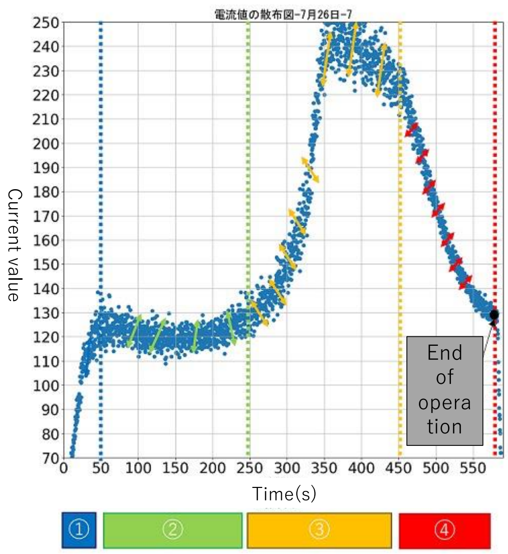


Figure 2. Example of a current waveform of a crushing operation



No.	Current value	Variation
①	Ascend	Big
②	Stability	Big
③	Ascend ↓ Stability	Big
④	Descent	Small

Figure 3. Four states of current waveforms in a crushing operation

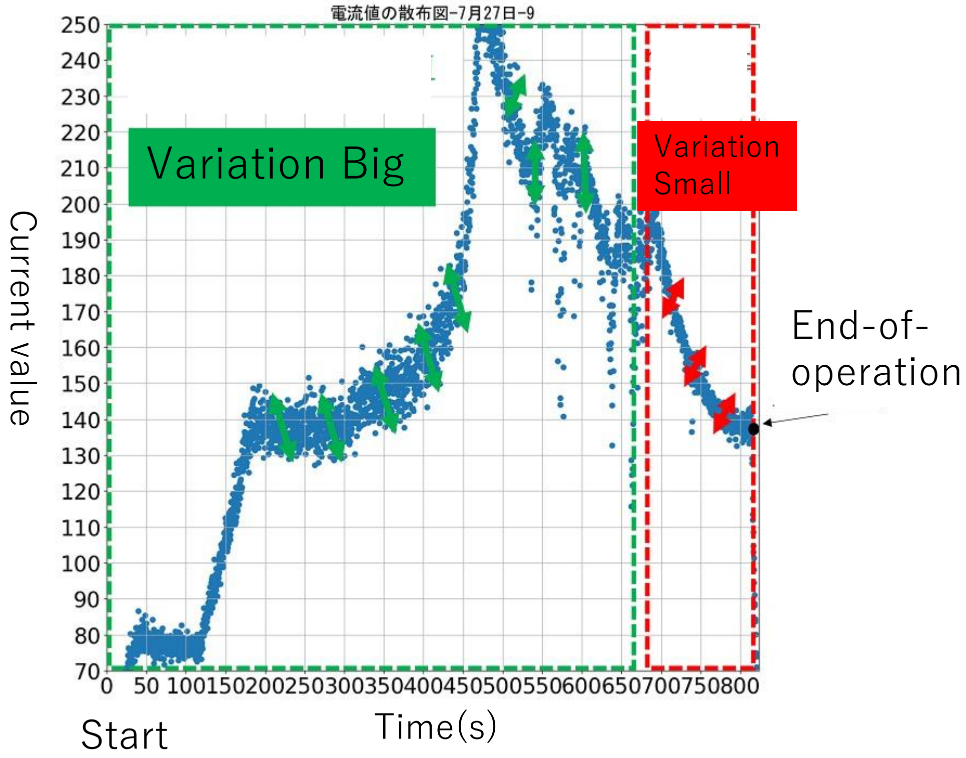


Figure 4. Differences in the variation of current values in current waveforms

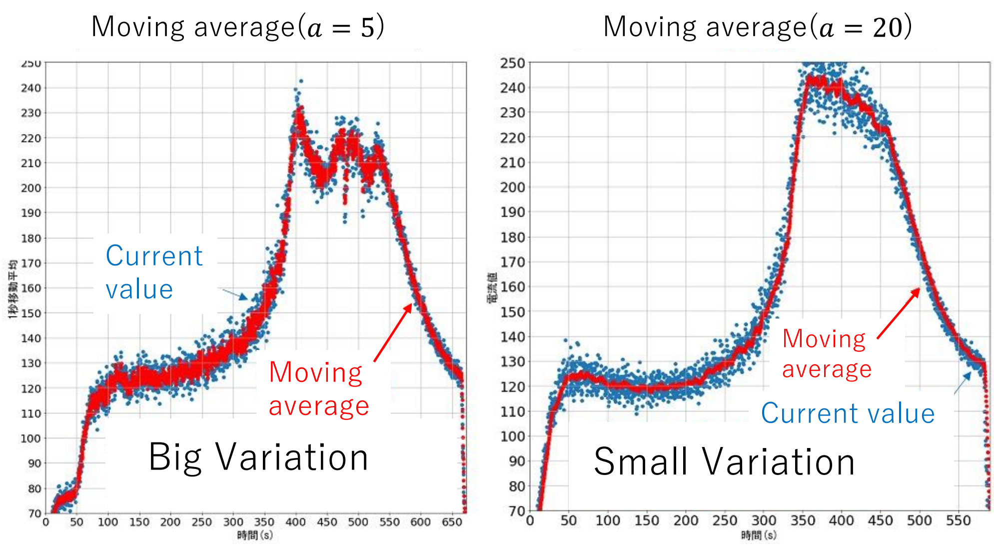


Figure 5. Overlap with the moving average graph when a = 5 and a=20

Therefore, after setting the parameters of moving average width, calculation time width of variance, and threshold, we analyzed the time period when the variance of the difference from the moving average at t seconds remained below the threshold value for more than 19.1 seconds. The data used were 151 waveforms of current waveforms. The parameter conditions are shown in Table 1.

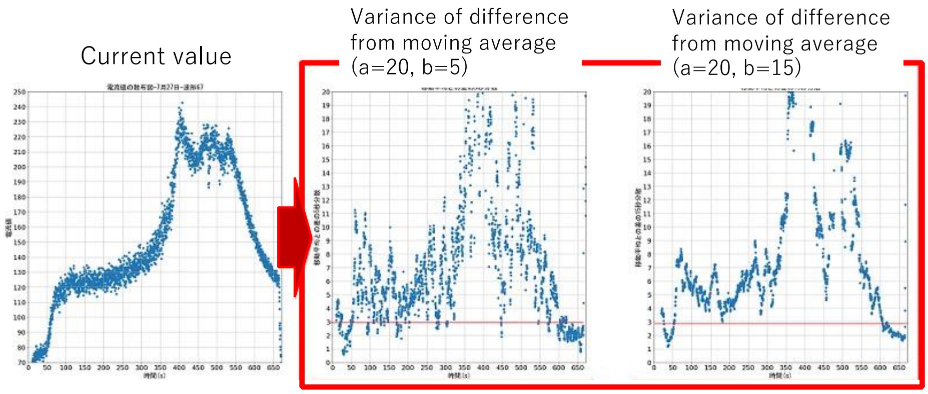


Figure 6. Variance of the difference from the moving average when a=20. b=5 and a=20, b=15

Table 1. Conditions for each parameter

Parameter	Conditions
Moving average window width (a)	1 to 30 seconds (at 5-second intervals)
Computation time window width of variance (b)	1 to 30 seconds (at 5-second intervals)
Threshold (c)	0.5~5 (0.5 interval)

4. Experimental Result and Discussion

As a result of the analysis for each parameter, assuming that the moving average width is 20 seconds, the calculation time width of variance is 15 seconds, and the threshold is 3, it is found that 157 out of 158 waveforms have a time period in which the variance of the difference from the moving average remains below the threshold value for at least 19.1 seconds, at least 8.6 seconds before the end of work. In other words, it can be said that these waveforms are capable of estimating the end-of-operation phase at least 8.6 seconds before the end of operation. The remaining one waveform was a special waveform that remained below the threshold value for more than 19.1 seconds during the crushing process. This waveform is a current waveform in which the current value has a small variation during the grinding process and continues to decrease gradually, making it impossible to determine the end of the grinding process. Figure 7 shows the above waveforms.This waveform shows that when plastic enters the crusher, only the bottom layer is crushed, and as time passes, the uncrushed upper layer falls, causing the crushing time to be extended.As a future work, in order to correctly estimate this waveform, it is important to find the point at which the current value rises again.

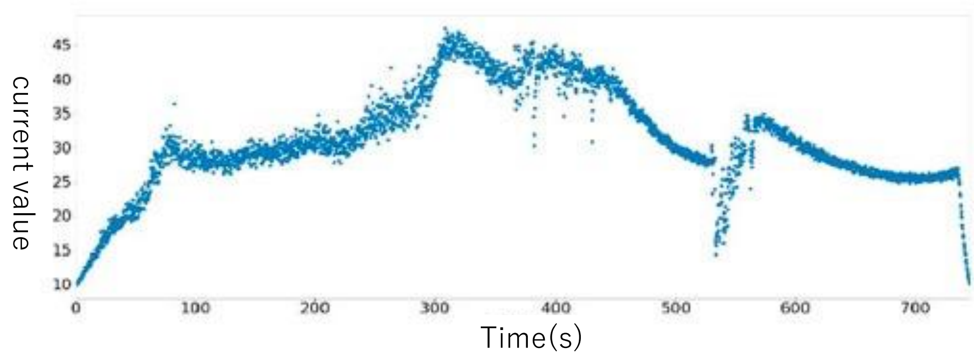


Figure 7. Special waveform with decreasing value in the middle of grinding

5. Conclusion and Future Work

In this study, we analyzed the stage of the end of plastic crushing operation and examined the possibility of estimating the stage of the end of the operation by using the features. The results show that the variance of the difference from the moving average can be used to estimate the stage of work termination at least 8.6 seconds before the end of work for 157 out of 158 waveforms. Further validation of the experiment is needed by increasing the amount of data.In addition, the crushing process consists of primary granulation and re-granulation, and the re-granulation process must also be taken into consideration.

References

[1] Ministry of the Environment, Japan, “Domestic and International Situation Surrounding Plastics”, http://www.env.go.jp/council/03recycle/y0312-01/y031201-2r3.pdf

[2] Hideshige Takada,(2018)“Current Status of Microplastic Pollution, International Trends and Countermeasures”, Material cycles and waste management research, Vol.29,No.4,pp.261-269.

[3] Atsuhiko Isobe, Shinsuke Iwasaki, Keiichi Uchida, Tadashi Tokai,(2019) “Abundance of non-conservative microplastics in the upper oceanfrom 1957 to 2066”, Nature COMMUNICATIONS10, 417.https://www.nature.com/articles/s41467-019-08316-9

[4] Hiroyuki Takeya, Collection and Recycling Usage of Waste Agricultural Plastics in Japan, Agricultural marketing journal of Japan, Vol.19 巻, No.3, pp.37-46, 2010.

[5] Tian Wang,Yuting Yao,Yang Chen, Mengyi Zhang, Fei, Tao, Hichem Snoussi, Auto-Sorting System Toward Smart Factory Based on Deep Learning forImage Segmentation, IEEE SENSORS JOURNAL, VOL. 18, NO. 20, OCTOBER15, 2018

[6] Takashi Onoda, Support Vector Machine (Science of Knowledge), Ohmsha. 2007.

Author

Takahiro Nishigaki, Doctor of Engineering 2017 Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology (Doctor of Engineering) 2017-2021 Assistant Professor, Department of Management Systems Engineering, Faculty of Science and Engineering, AoyamaGakuin University 2022- Assistant Professor, Department of Computer Science, Takushoku University Focusing mainly on data independence, I conduct analysis on the extraction of independent topics from text data.

He is also involved in research on anomaly detection, image recognition, and music information processing using various machine learning methods.