

Bacteria Classification using Image Processing and Deep learning

Treesukon Treebupachatsakul¹, Suvit Poomrittigul²

¹ Department of Biomedical Engineering, King Mongkut's Institute of Technology
Ladkrabang, Thailand

² Department of Software Engineering and Information System, Pathumwan Institute of
Technology, Thailand

E-mail:¹ treesukon.tr@kmitl.ac.th, ² suvit@pit.ac.th

Abstract

An automizing process for bacteria recognition becomes attractive to reduce the analyzing time and increase the accuracy of diagnostic process. This research study possibility to use image classification and deep learning method for classify genera of bacteria. We propose the implementation method of bacteria recognition system using Python programing and the Keras API with TensorFlow Machine Learning framework. The implementation results have confirmed that bacteria images from microscope are able to recognize the genus of bacterium. The experimental results compare the deep learning methodology for accuracy in bacteria recognition standard resolution image use case. Proposed method can be applied the high-resolution datasets till standard resolution datasets for prediction bacteria type. However, this first study is limited to only two genera of bacteria.

Keywords: Bacteria recognition, Image processing, Deep learning, Image classification

1. Introduction

The recognition of various genera and species of bacteria is useful diagnostic process. The classic techniques of bacteria recognition mainly use biological techniques such as gram staining and identify from contained specific metabolism of bacteria. This classical recognition of bacteria species is based on comparative analysis of the obtained samples with referential ones (American Bank ATCC; <https://www.lgcstandards-atcc.org>). Consequently, these methods are time-consuming process and require an expert knowledge and experience of worker. Therefore, automatizing the process of bacteria recognition is attractive to reduce the analyzing time and increase the accuracy of worker [1, 2]. The most important features of bacteria that can be recognized on the images is the color of gram stained and the shape of its cell.

The purpose of this research is to study possibility to use image classification and deep learning method for classify bacteria species by distinguish two basic shapes of long-rod and spherical. For this report, we researched to find the methodology to use deep learning to classify the standard resolution bacteria image for further research in mobile application or tablet use case.

2. Method

2.1 Bacteria cultivation and photomicrography

Two species of bacteria were used in this research, *Staphylococcus aureus* TISTR 746 and *Lactobacillus delbrueckii* TISTR 1339. *S. aureus* TISTR 476 was cultivated in nutrient agar (NA) (0.5% peptone, 0.3% yeast extract, 0.5% NaCl, 1.5% agar) for 24 h at 30°C. While *L. delbrueckii* TISTR 1339 was cultivated in MRS agar (Himedia) for 24 h at 37°C. The cultivated *S. aureus* and *L. delbrueckii* were stained by Gramm's method. The digital images of gram stained bacteria were taken with Optika B-292 Biological Microscope equipped with an Optikam B3, Italy. They were evaluated using a 100 times objective under oil-immersion. We prepare own dataset Digital images of both bacteria.

2.2 Deep Learning with Python Programming

Deep learning is a type of Machine Learning using deep layered structure Artificial Neural Network (ANN). In this paper, we propose deep learning methodology for bacteria images classification using Python programing included Keras API with TensorFlow Machine Learning framework. This paper implemented the LeNet Convolutional Neural Network (CNN) architecture using Python [3].

2.3 Training and Test Datasets

Two type of *S. aureus* dataset and *L. delbrueckii*, each has more than 400 sample images. Each dataset has been separated the training datasets and test datasets by percentage of 80 and 20, consequently.

2.4 Research Methodology

The aim of this study was to develop a system that can immediately and automatically identify and classify bacteria image in standard resolution for mobile and tablet use cases. To first observation, we try to use and prepare own datasets of bacteria in standard resolution for studying possibility to using deep learning for classify the bacteria images with practical LeNet CNN method.

3. Experimental results

Experimental results have shown that deep learning methodology can use to classification high-resolution bacteria images by existing research [4] and standard resolution bacteria images which prepare by authors as shown in Figure 1 and Figure 2

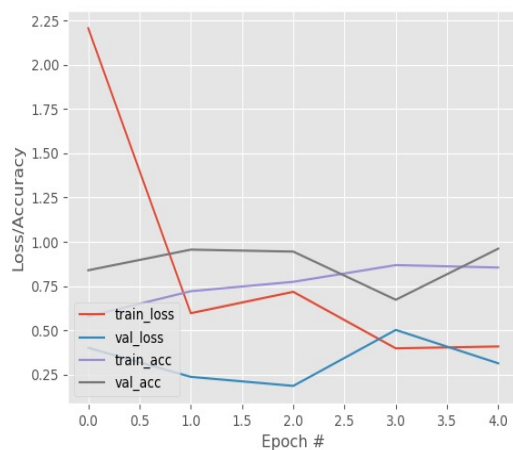


Figure 1 Training Loss and Accuracy existing research datasets

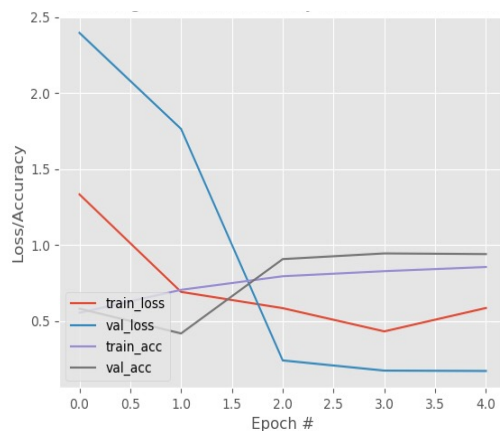
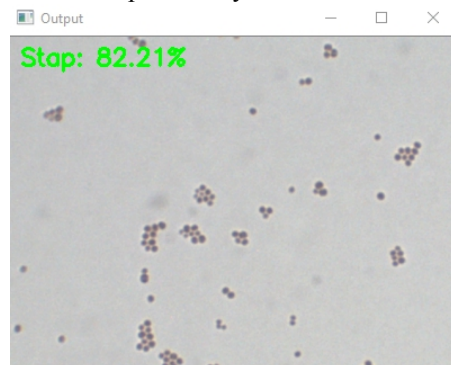


Figure 2 Training Loss and Accuracy own datasets

Figures 1 and 2, the results confirmed that the standard resolution bacteria images which prepare by authors could be used for training by supervised learning method with LeNET method.



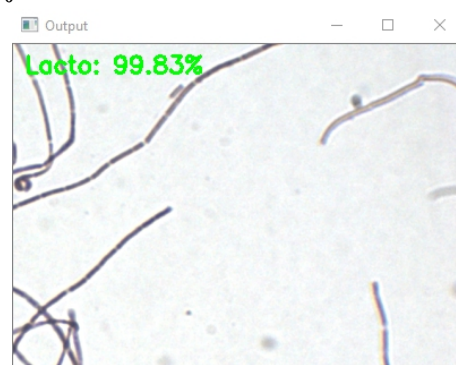
(a) *Staphylococcus* Correct Prediction with probability 85.82%



(b) *Staphylococcus* Correct Prediction with probability 82.21%



(c) *Lactobacillus* Correct Prediction with probability 100%



(d) *Lactobacillus* Correct Prediction with probability 99.83%

Figure 3 Experimental Results of bacteria detection output and the percentage of possibility bacteria prediction

Figure 3 (a) (b) (c) (d) show examples of bacteria detection output and the output can detect type of bacteria and inform the percentage of possibility bacteria prediction.

Figures 1-3, the results have confirmed that the training method Training accuracy and validation accuracy have reached more than 75 percent by more training times of 4 Epoch both of high-resolution and standard resolution bacteria image.

4. Comparison of Experimental Results and Discussion

Moreover, the trend of improvement for better accuracy could be investigated by implementing more numbers of Epoch and activation function variables choosing.

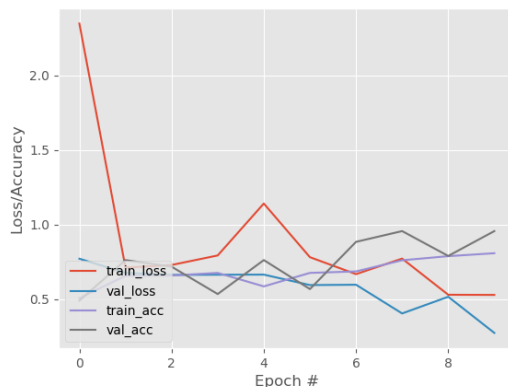


Figure 4 Training Loss and Accuracy in 10 Epochs with Sigmoid Activation Function

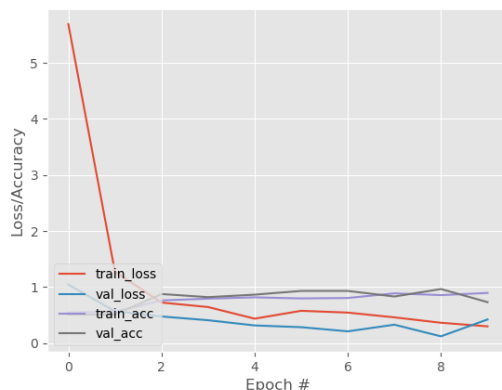


Figure 5 Training Loss and Accuracy in 10 Epochs with Softmax Activation Function

The results of Figures 4 and 5 confirmed that when applying more numbers of epochs, Training Loss and Accuracy would be better. Training Loss and Accuracy in 10 Epochs with Softmax Activation Function methodology is better than Sigmoid Activation Function, which reached 96% of validation accuracy.

5. Conclusion

The experimental results have confirmed that two species of bacteria in different cell shape, *Staphylococcus aureus* (spherical or round shaped) and *Lactobacillus delbrueckii* (long-rod shaped) are able to automatically predict using machine learning by image classification and deep learning method. The experimental results compare results using existing research dataset and own prepared dataset for accuracy in bacteria prediction use case. Training accuracy and validation accuracy has reached more than 75 percent by more training times of 4 Epochs both of high-resolution and standard resolution bacteria image.

Accordingly, this research also tries to modify LeNET methodology and observe the trend to make more training with greater number of Epochs. The results have confirmed that standard resolution bacteria images datasets could be improve more accuracy in future. It can be more apply another CNN methodology for comparison such as ResNET, AlexNET and etc.

However, this first study is limited to only two species of bacteria in different cell shape. We will propose more than two genera of bacteria and improve the accuracy for using with mobile and tablet use cases in future.

5. Acknowledgement

This research also was financial supported by KMITL Research and Innovation Service (KRIS).

References

- [1] K. Lim, S. Hyun Park, et al., Cell image processing methods for automatic cell pattern recognition and morphological analysis of mesenchymal stem cells – An algorithm for cell classification and adaptive brightness correction, *J. of Biosystems Eng*, 38(1), pp. 55-63 2013, February 2013.
- [2] L. Shamir, J. D. Delaney, et al., Pattern recognition software and techniques for biological image analysis, *Plos computational biology*, 6(11), November 2010.
- [3] Y. LeCun, L. Bottou, Y. Bengio, and P. Haffner. Gradient-based learning applied to document recognition. *Proceedings of the IEEE*, November 1998.
- [4] B. Zielinski, A. Plichta, et al., Deep learning approach to bacterial colony classification, *Plos one*, 12(9), September 2017.