GARBAGE CLASSIFICATION USING DEEP LEARNING TECHNOLOGY

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ABSTRACT

Garbage classification has always been an important issue in environmental protection, resource recycling, and social livelihood. However, garbage classification takes a lot of time and effort. Moreover, garbage classification directly affects the health of workers. Currently, due to the development of artificial intelligence, advanced garbage classification robots are being used more and more in recycling factories. With the sufficient support of robots integrated with artificial intelligence technology, garbage will be more and more quickly processed and accurately classified. Therefore, this study presents an efficient and simple garbage classification model based on deep learning technology. This model will automatically and accurately classify garbage, thereby freeing up human labor. In this paper, the ResNet-50 model was used to develop the system. The input data includes images of garbage types to perform classification, and 3 different groups of garbage will be classified. The experimental results demonstrate the effectiveness of this model.

Keywords: Artificial Intelligence; convolutional neural network; deep learning; garbage classification; machine learning.

1. Introduction

Currently, the issue of environmental protection and waste management at source is increasingly concerned by the Government and the society. Waste is currently one of the major sources of environmental pollution. Garbage collection as well as garbage classification has become a pressing issue in urban areas and industrial zones. There is a large amount of garbage in the collection points near residential areas, which reduces the beauty and affects the quality of the environment and human health [1].

Garbage segregation has always been an important issue in environmental protection, resource recycling and social livelihoods. Realizing that the classification of waste takes a lot of time and effort, while garbage classification directly affects the health of workers. Garbage classification workers are twice as likely to suffer health damage as other industry workers and have high mortality rates in many countries. However, with the development of current artificial intelligence, advanced garbage classification robots are being used more and more in recycling factories. Analysts believe

that thanks to the effective support of robots integrated with artificial intelligence technology, garbage will be more and more quickly processed and accurately classified. Acting like a real worker, but the productivity of the robot is many times higher. With improvements in their ability to detect and recognize specific materials, robots integrated with artificial intelligence technology are gradually becoming a new tool in efforts to classify recyclable materials from landfills and incinerators [2]. Figure 1 is a garbage classification model using a robotic arm with a camera and 3D sensing and metal detection system that will pick up waste pieces and drop them into the corresponding boxes [3].

Deep neural networks are under active research and deep learning models have been widely used in the field of computer vision, especially in object classification. Deep learning has significant advantages over traditional object classification. Traditional methods are used to manually extract features, and experts process them manually through accumulation and long-term experience. Deep learning-based methods extract features directly from the data. Relevant features are learned during the training of the network from the collected data. Such automatic feature extraction ensures the accuracy of deep learning-based methods for computer vision problems, such as object classification. Deep learning-based methods can provide very high accuracy [4].

Figure 1: *Garbage sorting using a robot arm [3]*

In recent years, the classification of garbage has attracted a great deal of research. Torres-García et al. [5] have proposed a waste classification device that combines embedded multimedia processing, image processing and machine learning, which will automatically classify garbage into different containers. Huang et al. [6] introduced a garbage classification system that uses optical sensors to detect the size, location, color and shape of each type of garbage. Besides, the method of garbage classification applying neural network models is being studied by numerous authors [7]-[12]. This classification method usually has high accuracy.

In this paper, an efficient and simple garbage classification model, using deep learning technology, will be presented. This model will perform automatic and accurate garbage classification, thereby freeing up human labor. Besides, this model can be integrated into high-tech industrial garbage classification robots.

The main contributions of this research include:

(i) Presenting a garbage classification model based on deep learning;

(ii) Collect a database of types of garbage;

(iii) Evaluate the effectiveness of the garbage classification model.

The remaining content of this research paper will be arranged as follows: Section 2 describes in detail the model of garbage classification. Section 3 presents the experimental results. Finally, conclusions and development orientation of the research are presented in Section 4.

2. Garbage classification model

2.1. System structure

The overview of the garbage classification model is shown in Figure 2. The input data is images of garbage types to perform classification. 3 different groups of garbage will be classified, including organic, inorganic and recyclable garbage. In particular, organic garbage includes spoiled foods, vegetables and fruits, etc. Inorganic garbage is those that cannot be used anymore and cannot be recycled, such as broken cup and glass vase, damaged clothing, etc. Recycled garbage includes types of paper, cartons, cans, etc. The database of images is collected from the Internet and manually. First, the system will extract the characteristics of each type of waste automatically based on neural network technology. The ResNet-50 model will be used for system implementation and development, which won first prize in the 2015 ILSVRC and COCO competitions [13]. That demonstrates the outstanding performance of this model. Then, the object classification step will be performed and the result is an image of the types of garbage that have been classified and labeled.

2.2. Neural network model used

As the design and construction of neural networks deepens, the complexity at the layers increases, the ability to represent the network also becomes more difficult and prone to the problem of vanishing gradient, leading to bad training process [14]. Gradient vanishing is a problem that occurs when training multilayer neural networks. When training, the derivative value is the feedback of the backpropagation process. This value becomes extremely small at the first layer of neurons, making it impossible to update the weight values of the network. Moreover, the initial ogirinal features are also easy to get lost when traversing too many layers. ResNet network is proposed to solve that problem. ResNet structure has many variants with different number of layers such as ResNet-18, ResNet-34, ResNet-50, ResNet-101, ResNet-152, etc.

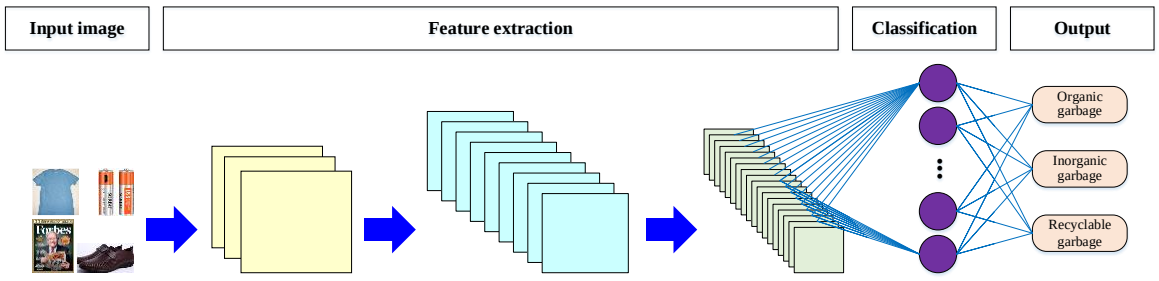

Figure 2: *Overview of the garbage classification model*

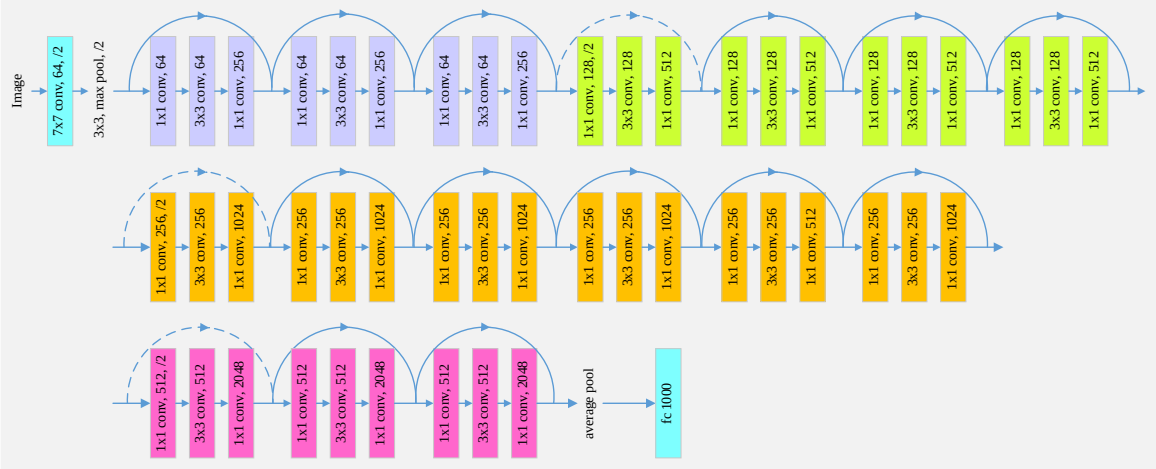

Figure 3: *ResNet-50 model*

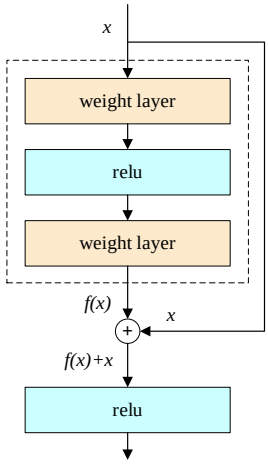

Figure 4: *Residual block*

In this study, the system was built using ResNet-50 model, which was suggested by He [13]. Figure 3 shows the structure of the ResNet-50 model. The core idea of ResNet is the bottleneck architecture by using a stack of three layers. These three layers consist of 1×1, 3×3 and 1×1 convolutions. Two 1×1 layers can reduce and then increase (restore) in size. The 3×3 layer has a smaller input/output size and is a bottleneck. This network model uses a uniform "off" connection to traverse one or more layers. Such a block is called a Residual Block, as shown in Figure 4.

3. Experimental results

3.1. Model training results

Hardware devices: This system is deployed on a computer with 3.10 GHz core i5 CPU, 64-bit Windows operating system, 16 GB RAM, GPU (NVIDIA GeForce RTX 3050 Laptop GPU) and Logitech C920 Webcam.

Figure 5: *Illustration of 3 garbage groups in the database*

The database of garbage types includes 1,500 images of 3 different groups, each with 500 images as shown in Figure 5, including organic, inorganic and recyclable garbage as described in Section 2.1. This database is divided into 3 parts: the training dataset, the validation dataset and the testing dataset, with the proportions of 70%, 20%, and 10%, respectively. The image database is collected from the Internet and manually.

After collecting the database, the neural network model training will be conducted, which is very important because it directly affects the quality of the proposed system. Figure 6 shows the accuracy of the model during training. Accuracy improves after every epoch. At the end of the 20th epoch, the accuracy of the model reached a high level, on the training dataset and on the validation dataset, respectively, 0.9664 and 0.9225.

3.2. User interface design

In this section, a simple interface is designed to make it easier for users to manipulate, based on the PyQt5 library and the Qt Designer tool. Qt is a cross-platform library written in C++ language, used to develop desktop, embedded and mobile applications; support for platforms including Linux, Windows, Android, iOS and several others. PyQt is the Python interface of Qt, a combination of the Python programming language and the Qt library, which is a library consisting of console components [15].

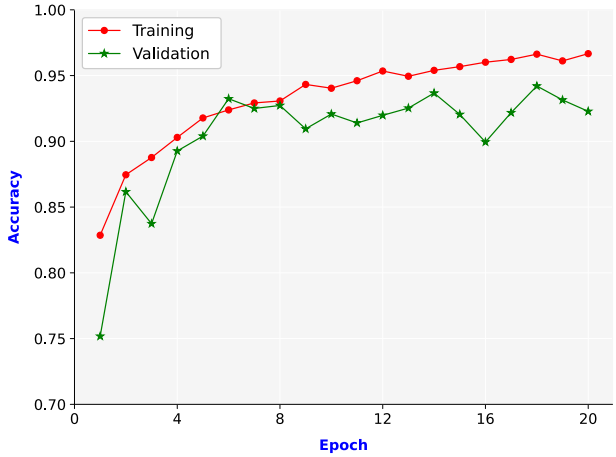

Figure 6: *Accuracy of the model during training*

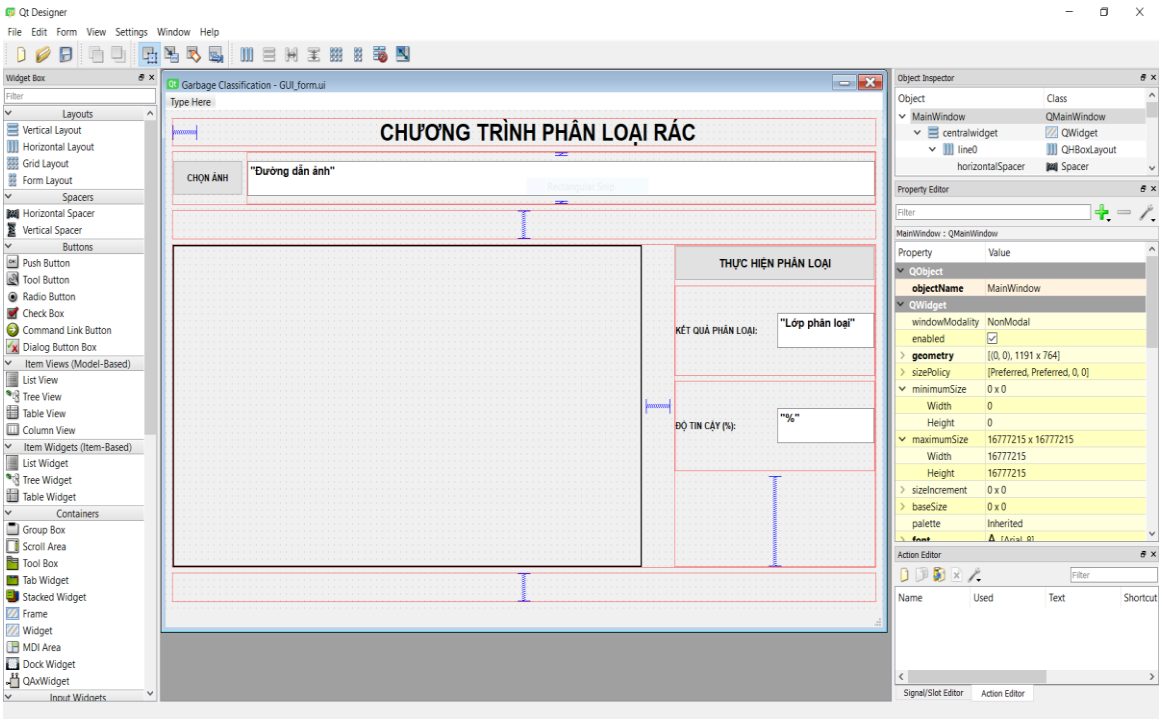

Figure 7: *User interface design (GUI)*

Figure 7 shows the user interface of the program, designed using the Qt Designer tool. The design of the interface can be done by dragging and dropping elements and arranging the layout. After designing the interface, the conversion to python code is done easily and saves time.

3.3. Evaluate actual application results

In this section, the actual garbage classification results will be evaluated. During the test program, a simple interface has been designed to make it easier for users to manipulate. The first step is to select and display the images, then perform the classification and display the classification results.

Figure 8 shows the accurate and reliable classification results of some types of garbage. Figure 8(a) is an image of organic garbage including food and fruit, which has a completely correct classification result with a confidence level of 98.49% and 99.99%, respectively. Similarly, the images of inorganic garbage, including clothing and glass in Figures 8(b) are also correctly classified with confidence of 100% and 99.38%, respectively. Figure 8(c) is a recycled garbage consisting of newspaper and cans, which gives a completely correct classification with a confidence level of 99.98% and 99.92%, respectively.

During the test, the garbage classification processing time was recorded. With the test hardware device configuration as in Section 3.1, the average time to perform garbage classification per image is 147 milliseconds (ms).

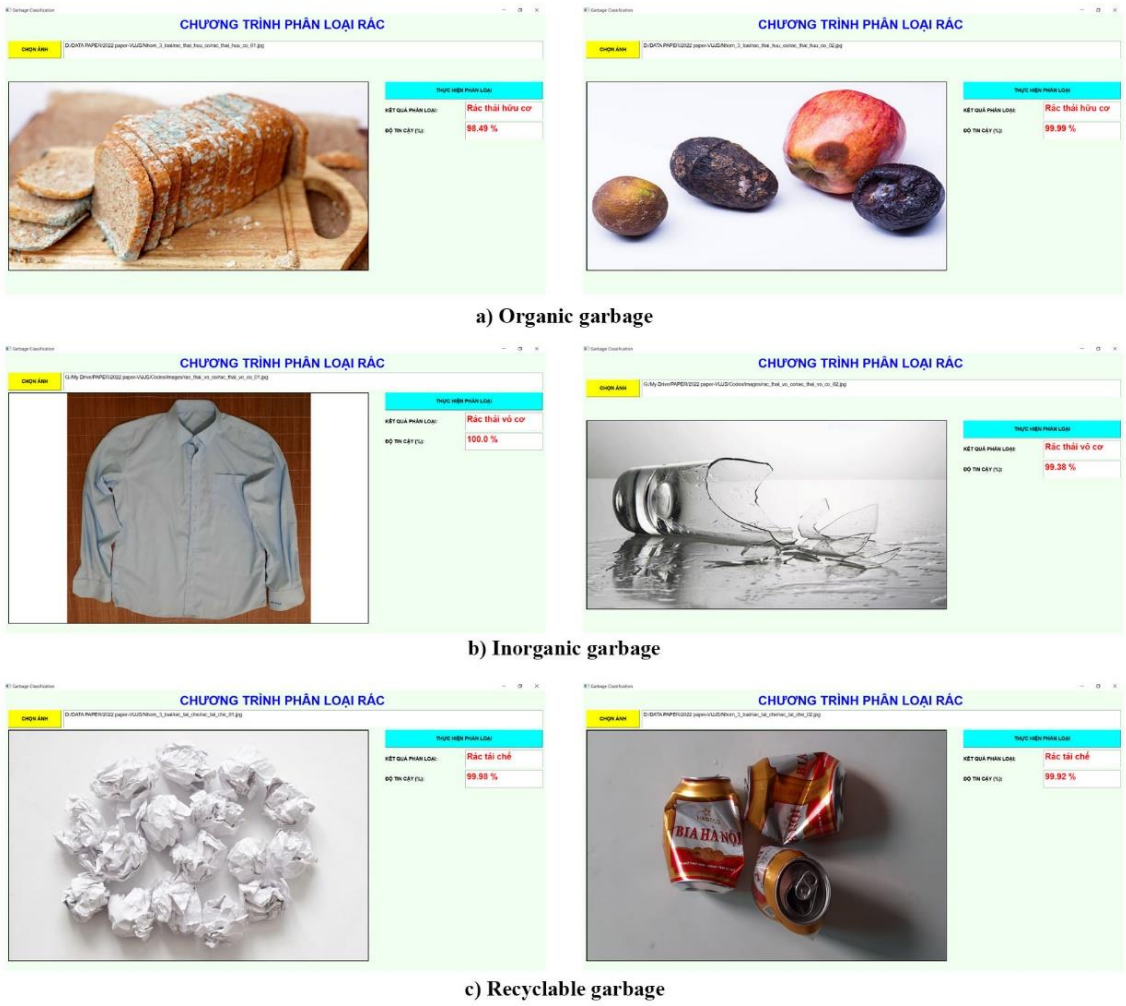

Figure 8: *Classification results of some types of garbage*

3.4. Some error classifications

Figure 9: *Incorrect garbage classification results*

The test results show that some cases are not classified correctly as shown in Figure 9. In this picture is an unbroken glass bottle, so this object actually belongs to the group of recyclable garbage, but the result is classified as inorganic garbage. Thus, one of the limitations of this program is that it is not possible to accurately classify broken or not broken glass bottles and jars for accurate classification.

4. Conclusions

This study presented an efficient and simple garbage classification model, using deep learning technology. The garbage classification will be done automatically and accurately, thereby freeing up human labor. In this study, ResNet-50 model was trained and used for system development. In addition, the experimental results show the effectiveness of the proposed model.

In the future, the model is expected to continue to be improved by collecting data on more garbage types. Since then, the model can classify many types of garbage. On the other hand, the robotic arm model and the neural network model proposed in this study will be integrated to develop an automatic garbage classification system in practice on a small scale.

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TÓM TẮT

PHÂN LOẠI RÁC THẢI SỬ DỤNG CÔNG NGHỆ HỌC SÂU

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Ngày nhận bài 19/12/2022, ngày nhận đăng 10/02/2023

Phân loại rác luôn là một vấn đề quan trọng trong bảo vệ môi trường, tái chế tài nguyên và sinh kế xã hội. Tuy nhiên, việc phân loại rác thải mất nhiều thời gian và công sức. Hơn nữa, công việc phân loại rác lại gây ảnh hưởng trực tiếp đến sức khỏe người lao động. Với sự phát triển của trí tuệ nhân tạo hiện nay, các robot phân loại rác tiên tiến đang được sử dụng ngày một nhiều hơn ở các nhà máy tái chế. Với sự hỗ trợ đắc lực của robot tích hợp công nghệ trí tuệ nhân tạo, rác thải sẽ ngày càng được xử lý nhanh gọn và phân loại chính xác hơn. Do đó, nghiên cứu này sẽ trình bày một mô hình phân loại rác thải hiệu quả và đơn giản, sử dụng công nghệ học sâu. Mô hình này sẽ thực hiện phân loại rác thải một cách tự động và chính xác, từ đó giải phóng sức lao động của con người. Trong bài báo này, mô hình ResNet-50 sẽ được sử dụng để phát triển hệ thống. Dữ liệu đầu vào là hình ảnh các loại rác thải để thực hiện phân loại và nghiên cứu này thực hiện phân loại 3 nhóm rác thải khác nhau. Các kết quả thực nghiệm cho thấy tính hiệu quả của mô hình này.

Từ khóa: Trí tuệ nhân tạo; mạng nơ-ron tích chập; học sâu; phân loại rác thải; học máy.