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Review Star Hotels Using Convolutional Neural Network

Edward Sze[1)*], Handri Santoso[2)], Djarot Hindarto[3)]
[1)2)3)] Universitas Pradita, Serpong, Banten, Indonesia
[1)]edward.sze@student.pradita.ac.id, [2)]handri.santoso@pradita.ac.id, [3)]sosbuk@gmail.com

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Abstract: Currently the Deep Learning algorithm is developing very rapidly, where its application has helped a lot in individuals and businesses. One of its uses in conducting any review can be used this method. The review used in this case is to review five-star hotels. The hotel image is used as input for a review. So from the image of the hotel, it can be immediately known the level of the hotel. Usually the review is done using good sentences with compliments that tend to be positive sentiments. Meanwhile, sentences in the form of complaints tend to have negative sentiments. This study does not use sentences in conducting a review and uses a simple method in conducting the review process. The use of images as input is classified into five classes, namely one-star hotel class, two-star hotel class, three-star hotel class, four-star hotel class and five-star hotel class. The purpose of this research is to conduct a review on five-star hotels with image as input and hotel review as the output of the Deep Learning algorithm process. Deep Learning algorithm process using Convolutional Neural Network (CNN). The datasets used are public datasets and private datasets. The use of these datasets is a way to get better training model results. So that the accuracy in reviewing the image becomes better. The results of this study resulted in an accuracy reaching 98.48%, while for Loss it reached 0.0554.

Keywords: Convolutional Neural Network; Image Classification; Review Image; Deep Learning; Dataset Hotel Review

INTRODUCTION

Hotels in this world actually provide many services, what hotel management does is do good service to customers. In addition to services within the hotel, the management is also doing renovations with beautiful buildings to attract customers to come to the hotel. In addition, many companies engaged in hospitality in carrying out daily operations already have a company information system. The company also conducts an Information Technology Plan by including various methods and frameworks. Which aims for the sustainability of the company's information system. Because sustainability using Enterprise Architecture (Hindarto et al., 2021) can support the sustainability of the hotel business.

One way to increase sales from the hospitality industry in addition to improving customer service is by providing quality food and beverages. In sales brochures often display photos of food and beverages. Provide food and beverage ratings. There are many studies in conducting food and beverage reviews using Deep Learning algorithms. This review is intended to speed up predictions or speed up reviews of food or drinks(Andrew & Santoso, 2022).

This research uses a hotel image dataset only on physical buildings. Not a food or beverage image dataset. This is intended so that customers can see the physical building of the hotel building and immediately know that this hotel is at a certain level. So it is hoped that customers will not be wrong in choosing the hotel they are staying in during the tour. Many research using the Convolutional Neural Network algorithm have been carried out. But still need to be improved in terms of accuracy and reduce loss for training. Because by increasing the accuracy, if the training model is applied to an application, the prediction results will be better. One of the components to improve the performance of the training model is to improve the dataset. Because this study uses supervised learning, a better dataset label is needed. Label the dataset on the image by grouping the image dataset into folders of each label. For example in this research there are five folders to group datasets. One-star folder, two-star folder, three-star folder, four-star folder and five-star folder.

A problem arises that can be summarized in a research question. The next research question is given the name RQ. Of course, from the description above, several questions arise. How to obtain the dataset used in this

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research? (RQ1). A simple Deep Learning method or algorithm in solving review problems? (RQ2). What about the evaluation results mainly focus on accuracy and loss? (RQ3).

The purpose of this study is to review five-star hotels, from one star to five stars, using the Deep Learning algorithm. The algorithm chosen is the Convolutional Neural Network algorithm which is very useful for reviewing star hotels.

LITERATURE REVIEW

Various research that have discussed sentiment analysis, review using image datasets. Most researchers in conducting research use classification or supervised learning. In this case, it makes trending in classification method research. This research is not to find the weaknesses of previous studies, but this research is used as a complement or improvement in terms of accuracy and loss resulting from the training model using the Convolutional Neural Network (CNN) algorithm.

Table 1. Literature Review

Topic	Author	Advanced	Disadvanced
Visual Sentiment Analysis Using Deep Learning Models with Social Media Data	(Chandrasekaran et al., 2022)	The advantages of this research are using various Deep Learning methods for classification such as using VGG-19, ResNet50V2, and DenseNet-121.	The accuracy is as follows: VGG-19 achieves accuracy=73%, ResNet50V2 achieves accuracy = 75%, and DenseNet-121 achieves accuracy 89%.
Emotion detection and sentiment analysis of static images	(Doshi et al., 2020)	This research uses a facial image dataset as input to obtain a classification model using the Convolutional Neural Network (CNN) algorithm.	The results of the research "Emotion detection and sentiment analysis of static images" using the Convolutional Neural Network (CNN) reached 80% for the testing set and 60% for the validation set.
Sentiment Analysis of Images using Machine Learning Techniques	(Gherkar et al., 2022)	"Sentiment Analysis" research uses Machine Learning such as Support Vector Machines, Naive Bayes, Haar Cascade, Local Binary Pattern (LBPH) and Deep Learning Convolutional Neural Network (CNN).	The results of this research achieved an accuracy of 80.46%.
Visual Sentiment Analysis from Disaster Images in Social Media	(Hassan et al., 2022)	Research with the topic "Visual Sentiment Analysis from Disaster Images in Social Media" uses the Deep Learning algorithm. The algorithms are VGGNet (ImageNet), VGGNet (Places), Inception-v3 (ImageNet), ResNet-50 (ImageNet), ResNet-101 (ImageNet), DenseNet (ImageNet), EfficientNet (ImageNet), VGGNet (places + ImageNet)	The results of this research achieved accuracy, VGGNet (ImageNet) = 92.12%, VGGNet (Places) = 92.88%, Inception-v3 (ImageNet) = 82.59%, ResNet-50 (ImageNet) = 90.61%, ResNet-101 (ImageNet) = 90.90%, DenseNet (ImageNet) = 85.77%, EfficientNet (ImageNet) = 91.31%, VGGNet (places + ImageNet) = 92.83%
Transformer-based deep learning models for the sentiment analysis of social	(Tabinda Kokab et al., 2022)	Sentiment analysis research on social media using Bi-directional	This research has the following accuracy, Word2vec CNN = 0.93,

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media data		Encoder Representation from Transformers (BERT) based Convolution Bi-directional Recurrent Neural Network (CBRNN) mode	Glove CNN = 0.91, BERT CNN = 0.91
HistoClean: Open-source software for histological image pre-processing and augmentation to improve development of robust convolutional neural networks	(McCombe et al., 2021)	HistoClean uses images to detect stromal maturity. This model is used to improve the accuracy of the patient model. Using Convolutional Neural Network (CNN) algorithm.	The accuracy of the model produces Balanced Embossed Tile = 0.774, Balanced Embossed ROI = 0.835, Balanced Embossed Patient = 0.857

In table 1. Most researchers use the Convolutional Neural Network algorithm. Actually the research in table 1 can be improved in accuracy. So this research only focuses on improving in terms of accuracy, using the Convolutional Neural Network algorithm and making minor improvements or sorting the image dataset according to the dataset class. The dataset in this study was modified first by removing the image dataset that did not match the class in the dataset. And adding hotel image datasets from google and kaggel to replace the discarded datasets. Because it really determines the results of the training if each class has a significant difference. Image datasets that have class similarities will be selected so that they can clearly provide different hotel image datasets. This state-of-the-art research that distinguishes it from other studies, this research focuses more on manually looking at datasets that match the actual class dataset. Suppose there is a first class dataset that has similarities with the second class dataset. Then this condition will make changes to the dataset according to the class of each dataset. So it is unlikely that the class datasets have similarities. If you have similar datasets in the class, it is likely to experience a decrease in accuracy.

METHOD

Convolutional Neural Network is one of a collection of Deep Learning algorithms. Convolutional Neural Network hereinafter referred to as CNN. This algorithm is inspired by the concept of the human brain whose way of thinking is like interconnected neurons. In contrast to machine learning, the process of extracting datasets is carried out by human intervention. For example, dataset extraction is still done manually by humans, even though using scripts or programs. After that, the extraction process is carried out according to the needs or objectives in carrying out the next process. Such as prediction, clustering, classification and others.

In contrast to the Convolutional Neural Network (CNN) (Du et al., 2022) algorithm, this algorithm performs direct extraction without human assistance. Image data as input to the Convolutional Neural Network algorithm is carried out in a process as shown in fig 1. This process distinguishes between Machine Learning and Deep Learning. In the Convolutional Neural Network to perform feature extraction lies in the convolution layer and the pooling layer. So the Convolutional Neural Network algorithm, the image will be carried out on the convolution layer can be seen in fig 2 A. The hotel image as input is used as a map matrix, then filtered to produce a smaller matrix map. In fig 2 A, the matrix size 6x6 is filtered by a 3x3 matrix to produce a 4x4 matrix map, where the contents of the matrix are multiplication and addition. In Convolution there is padding which aims to The output dimension of the conv layer is always smaller than the input The output is reused as input from the next conv layer, so that more information is wasted. Using padding, the user can set the output dimensions to remain the same as the input dimensions. So that the function of the conv layer is deeper so that it can produce features that are successfully extracted. In addition, the performance of the training model will increase further.

The pooling layer (Rodriguez-Martinez et al., 2022) takes the maximum value, resulting in a smaller matrix map. In the example of fig 2 B, the matrix size 4x4 produces a matrix map size of 4x4. Pooling layer is used to reduce the dimensions of the feature map (H. Kim et al., 2022) (downsampling), resulting in speed in computing because the parameters that are updated are few and overcomes overfitting.

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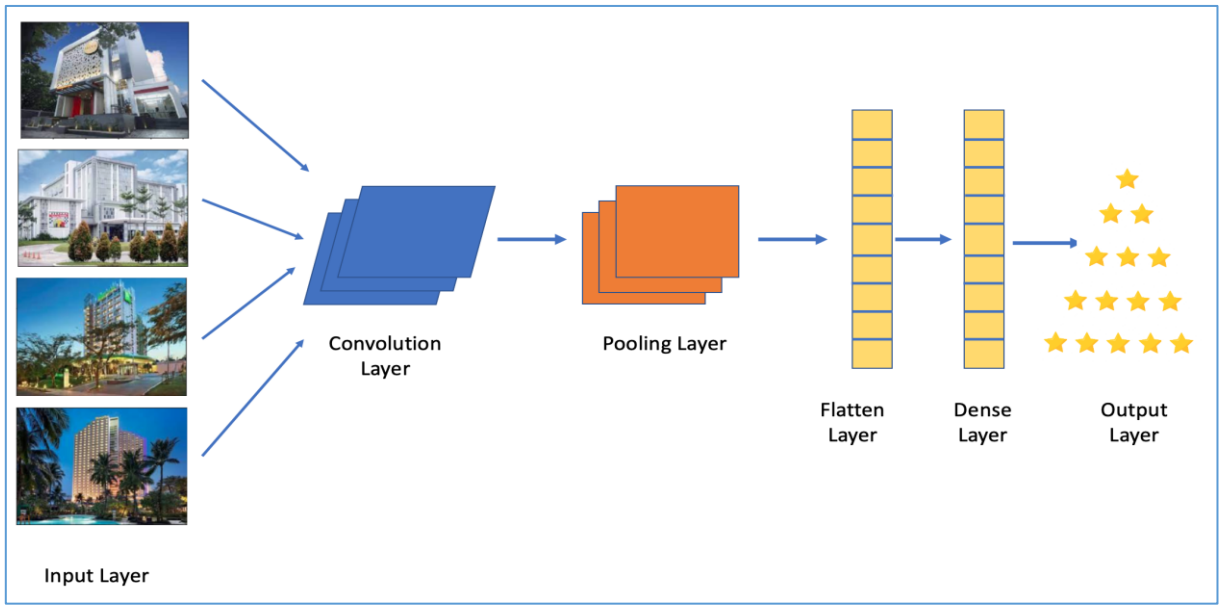

Fig 1. Proposed method with CNN Architecture
Source: researcher property

As in fig 1, the Convolutional Neural Network (Valentino et al., 2021) process works by reading the input image, then Convolution layer is done, then Pooling is done. After the Pooling layer is processed, then the Flatten and Dense layers are carried out. This process ends by classifying using Fully Connected (FC). Convolution, Polling, Flatten and Dense processes are feature extraction processes. Fully Connected is a classification process which is the development of Multi Layer Perceptron (MLP) (Opěla et al., 2021).

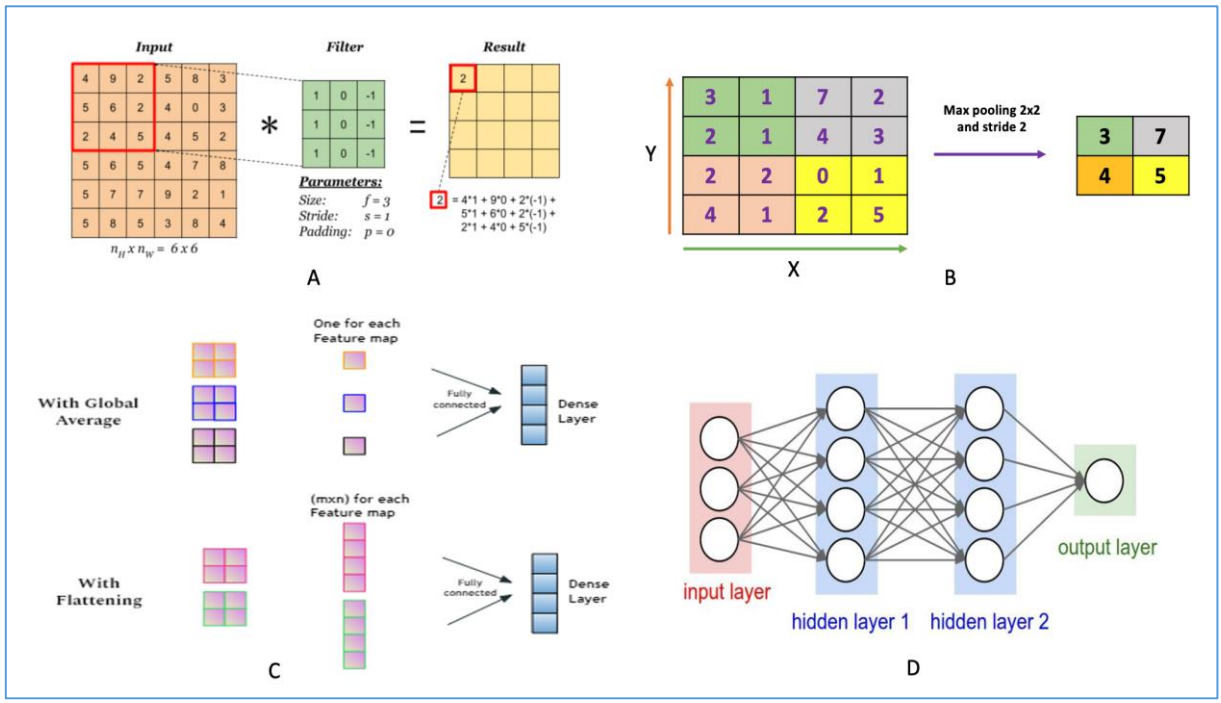

Fig 2. Fase dari CNN, A Convolution, B Max Pooling, C Flatten and Dense, D Full Connected (FC)
Source : Google Property

In fig2 are the steps of the Convolutional Neural Network (CNN) algorithm, where this is the process of training to get a model from CNN. Fig2 is taken from google which is a search engine information provider. In google there are various image algorithms from the Convolutional Neural Network. The image is sequenced to become an image that aims to explain the steps of the Convolutional Neural Network (CNN) algorithm. Fig 2 C explains about Flatten, Flatten is a reshape process to convert a feature map into a vector as input from Fully Connected. The flatten is processed into While Fully Connected (FC) is a classification process which can be

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seen in fig 2 D. The function of Dense is to run a Fully Connection (FC) neural network (Mukhopadhyay et al., 2022). Fully Connected is inspired by the Multi Layer Perceptron (MLP) (Gao et al., 2022), which consists of an input layer, a hidden layer and an output layer that determines the class of the classification.

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_10 (Conv2D)          (None, 198, 198, 16)      448

 max_pooling2d_10 (MaxPoolin  (None, 99, 99, 16)       0
 g2D)

 conv2d_11 (Conv2D)          (None, 97, 97, 32)        4640

 max_pooling2d_11 (MaxPoolin  (None, 48, 48, 32)       0
 g2D)

 conv2d_12 (Conv2D)          (None, 46, 46, 64)        18496

 max_pooling2d_12 (MaxPoolin  (None, 23, 23, 64)       0
 g2D)

 conv2d_13 (Conv2D)          (None, 21, 21, 64)        36928

 max_pooling2d_13 (MaxPoolin  (None, 10, 10, 64)       0
 g2D)

 conv2d_14 (Conv2D)          (None, 8, 8, 64)          36928

 max_pooling2d_14 (MaxPoolin  (None, 4, 4, 64)         0
 g2D)

 flatten_2 (Flatten)         (None, 1024)              0

 dense_4 (Dense)             (None, 128)               131200

 dense_5 (Dense)             (None, 5)                 645

=================================================================
Total params: 229,285
Trainable params: 229,285
Non-trainable params: 0
_________________________________________________________________
```

Fig 3. Model Architecture CNN
Source: keras.io

Convolution layer is the accumulation of each layer in the image. Where the image is used as input, the dataset is scaled to 200 x 200 pixels. CNN uses an input filter in the form of a box consisting of length, width and height. In this study, the image that has been scaled is 200x200 (input shape) and the conv2d_10 (Conv2D) process is carried out, the output becomes (None, 198, 198, 16). With Param being 448. Next process is max_pooling2D and output is (None, 99, 99, 16) With Param being 0. Next process is conv2d_11 (Conv2D), output is (None, 97, 97, 32). With Param it becomes 4640. The next process is max_pooling2D and the output becomes (None, 48, 48, 32). Next process conv2d_12 (Conv2D), the output becomes (None, 46, 46, 64). Para becomes 18496. Process max_pooling2d_12 (MaxPooling2D), output becomes (None, 23, 23, 64). The output param becomes 0. The next process is conv2d_13 (Conv2D), the output becomes (None, 21, 21, 64) and the param value is 36928. The max_pooling2d_13 process (MaxPooling2D), the output becomes (None, 10, 10, 64) and the param value becomes 0 And so on until the convolution becomes (None, 8, 8, 64) with max_pooling2D and the output becomes (None, 4, 4, 64), as shown in fig 3. Total param 229,285, trainable param 229,285.

Layer Pooling is done after the convolutional layer process is finished. This Pooling layer is divided into filters of a certain size and strides that are used to shift calculations in the map. There are two commonly used pooling methods, namely maximum pooling and average polling. If maximum pooling means finding the highest value in a map and average pooling is looking for the average value in a map. The purpose of the pooling layer is to perform computational calculations quickly so that the parameter updates are small and to solve the problem of overfitting the dataset (J. Kim & Park, 2022).

The hotel image dataset is obtained from a combination of the Kaggle dataset and the Google image dataset. The purpose of mixing public datasets with datasets from Google Image is to obtain the best quality dataset according to the classification of each class. Elements of the similarity of one class with another class are sorted out. This is so as not to cause confusion in the extraction process and the classification process. For

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classes that have similarities, they will be discarded before the Convolutional Neural Network (CNN) classification (Yeşilmen & Tatar, 2022) process is carried out.

The image dataset will be entered into a folder according to their respective class folders. For example, the image of a three-star hotel will be included in the three-star folder. Likewise with other classes according to the hotel image dataset.

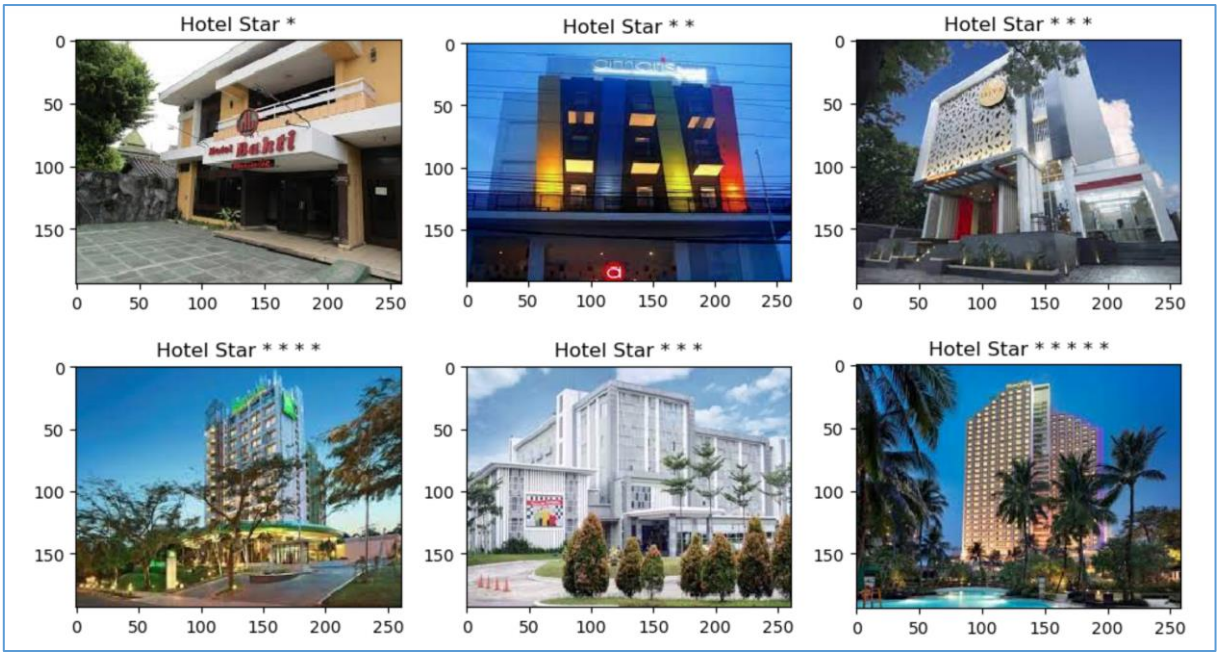

Fig 4. Dataset Star hotel ranging from 1 star to 5 star
Source: Google and Kaggle Dataset

In fig 4 is a display of the dataset that has been selected for the dataset according to the class of the dataset. In this case, the selection is strict by looking at the image dataset whether it is in accordance with the image dataset class. If it does not match it will be discarded and replaced with the appropriate one. The dataset selection process is a very long process, considering that there are many datasets. The number of datasets in the one-star class is 420 datasets. The number of datasets for two-star hotel classes is 236 datasets. The number of three-star class datasets is 413 datasets. The number of four-star class datasets is 438 datasets. The number of five-star class datasets is 503 datasets. Total number of dataset 2010 dataset image hotel.

RESULT

Experiment Setup. In this study we used a Macbook Air with 8 GB of RAM. The dataset is divided into five folders containing hotel images. From the classification process using the Convolutional Neural Network (CNN) algorithm, the result is a model. The training model achieves good accuracy and the loss is smaller.

The results of the training model, can reach 98.48% accuracy and loss reaches 0.0554. This means that the resulting model is feasible to use, so that if a probability test is carried out it becomes more accurate in predicting a hotel image. In addition to accuracy, it also produces a fairly low loss, where the loss shows the level of similarity between the actual image data and the image data to be predicted. The hotel review size prediction is as shown in figure 5. In terms of accuracy, this research is better than previous research.

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Fig. 5 Star hotel review results (prediction)
Source: researcher property

Fig 5 is the prediction result used in the training model using the Convolutional Neural Network (CNN) algorithm. The test has involved several sample images that will predict the level of star hotels. The results are quite good even though there are still errors, but some tests have shown accurate predictions. The accuracy of the Convolutional Neural Network training model in the study showed 98.48% and the loss showed 0.0554.

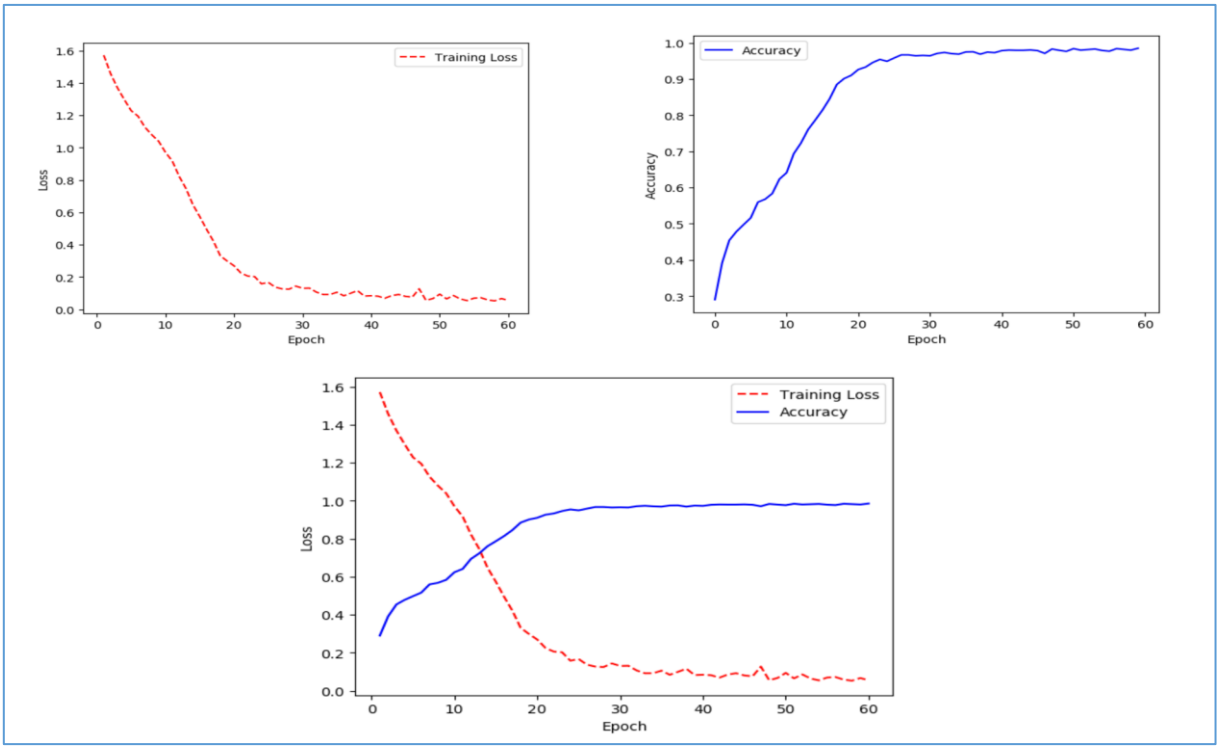

Fig 6. The results of the CNN training model
Source: researcher property

In fig 6 is a graph of the image dataset training process. The training process for the Convolutional Neural Network algorithm uses epochs up to 60, where at the beginning of the epoch around 3, the loss is still high around 1.12. After the 20th epoch, it has shown a decrease of 0.232. And so on until the 60th epoch decreases, namely 0.0554. Likewise for the accuracy of the training process. The accuracy of the 10th epoch is still 50.1%, the 30th epoch has started a significant improvement, which is around 80.9%. The 60th epoch has maximum results with an accuracy of 98.48%.

DISCUSSIONS

The discussions section will address the research questions. So that this research can provide solutions for research questions. How to get the dataset used in this research? (RQ1). The solution to the research question

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(RQ1), has been described in the dataset section. The dataset used is a dataset from Kaggle and a dataset from Google Image.

A simple Deep Learning method or algorithm in solving review problems? (RQ2). This research uses a simple Deep Learning algorithm, namely Convolution Neural Network (CNN). The application for training datasets is easier and simpler. The results are also quite good in determining predictions or reviews of a five-star hotel.

What about the evaluation results which mainly focus on accuracy and loss? (RQ3). The evaluation of this research resulted in an accuracy of about 98.48% and a loss of about 0.0554. This result is very encouraging where if the model is used to make predictions or hotel reviews, it is very good.

CONCLUSION

The conclusion of this study is that a review of five-star hotels can be done by classifying the hotel image. The results of these predictions in the process, can use the Deep Learning algorithm, namely the Convolutional Neural Network (CNN) algorithm. The CNN algorithm in carrying out the process is simple but powerful in terms of accuracy and loss. The limitation of this research is that the dataset used is only the hotel building exterior dataset, not the food and beverage dataset in the hotel. The hope of this research will be to develop an amalgamation of the image dataset and the Natural Language Processing (NLP) dataset (Corpus), so that this sentiment analysis is more complete. In addition, it is also developed by evaluating the performance of the training model such as precision, f1-score. In addition to research limitations, this journal can be applied to a hotel review system, if this model is to be developed with an application system for prospective hotel customers who will stay or seek hotel facility services..

REFERENCES

Andrew, A., & Santoso, H. (2022). Compare VGG19, ResNet50, Inception-V3 for Review Food Rating. *SinkrOn*, *7*(2), 845–494. https://doi.org/10.33395/sinkron.v7i2.11383

Chandrasekaran, G., Antoanela, N., Andrei, G., Monica, C., & Hemanth, J. (2022). Visual Sentiment Analysis Using Deep Learning Models with Social Media Data. *Applied Sciences (Switzerland)*, *12*(3). https://doi.org/10.3390/app12031030

Doshi, U., Barot, V., & Gavhane, S. (2020). Emotion detection and sentiment analysis of static images. *2020 International Conference on Convergence to Digital World - Quo Vadis, ICCDW 2020*, *Iccdw*. https://doi.org/10.1109/ICCDW45521.2020.9318713

Du, R., Liu, W., Fu, X., Meng, L., & Liu, Z. (2022). Random noise attenuation via convolutional neural network in seismic datasets. *Alexandria Engineering Journal*, *61*(12), 9901–9909. https://doi.org/10.1016/j.aej.2022.03.008

Gao, L., Xie, R. H., Xiao, L. Z., Wang, S., & Xu, C. Y. (2022). Identification of low-resistivity-low-contrast pay zones in the feature space with a multi-layer perceptron based on conventional well log data. *Petroleum Science*, *19*(2), 570–580. https://doi.org/10.1016/j.petsci.2021.12.012

Gherkar, Y., Gujar, P., Gaziyani, A., & Kadu, S. (2022). *Sentiment Analysis of Images using Machine Learning Techniques Yash*. *03029*, 1–6.

Hassan, S. Z., Ahmad, K., Hicks, S., Halvorsen, P., Al-Fuqaha, A., Conci, N., & Riegler, M. (2022). Visual Sentiment Analysis from Disaster Images in Social Media. *Sensors*, *22*(10), 1–21. https://doi.org/10.3390/s22103628

Hindarto, D., Indrajit, R. E., & Dazki, E. (2021). Sustainability of Implementing Enterprise Architecture in the Solar Power Generation Manufacturing Industry. *Sinkron*, *6*(1), 13–24. https://jurnal.polgan.ac.id/index.php/sinkron/article/view/11115

Kim, H., Jung, W. K., Park, Y. C., Lee, J. W., & Ahn, S. H. (2022). Broken stitch detection method for sewing operation using CNN feature map and image-processing techniques. *Expert Systems with Applications*, *188*, 116014. https://doi.org/10.1016/j.eswa.2021.116014

Kim, J., & Park, H. (2022). Limited Discriminator GAN using explainable AI model for overfitting problem. *ICT Express*, *xxxx*. https://doi.org/10.1016/j.icte.2021.12.014

McCombe, K. D., Craig, S. G., Viratham Pulsawatdi, A., Quezada-Marín, J. I., Hagan, M., Rajendran, S., Humphries, M. P., Bingham, V., Salto-Tellez, M., Gault, R., & James, J. A. (2021). HistoClean: Open-source software for histological image pre-processing and augmentation to improve development of robust convolutional neural networks. *Computational and Structural Biotechnology Journal*, *19*, 4840–4853. https://doi.org/10.1016/j.csbj.2021.08.033

Mukhopadhyay, A. K., Majumder, S., & Chakrabarti, I. (2022). Systematic realization of a fully connected deep and convolutional neural network architecture on a field programmable gate array. *Computers and Electrical Engineering*, *97*(October 2020), 107628. https://doi.org/10.1016/j.compeleceng.2021.107628

Opěla, P., Schindler, I., Kawulok, P., Kawulok, R., Rusz, S., & Navrátil, H. (2021). On various multi-layer

*name of corresponding author

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p-ISSN : 2541-044X

perceptron and radial basis function based artificial neural networks in the process of a hot flow curve description. *Journal of Materials Research and Technology*, *14*, 1837–1847. https://doi.org/10.1016/j.jmrt.2021.07.100

Rodriguez-Martinez, I., Lafuente, J., Santiago, R. H. N., Dimuro, G. P., Herrera, F., & Bustince, H. (2022). Replacing pooling functions in Convolutional Neural Networks by linear combinations of increasing functions. *Neural Networks*, *152*, 380–393. https://doi.org/10.1016/j.neunet.2022.04.028

Tabinda Kokab, S., Asghar, S., & Naz, S. (2022). Transformer-based deep learning models for the sentiment analysis of social media data. *Array*, *14*(April), 100157. https://doi.org/10.1016/j.array.2022.100157

Valentino, F., Cenggoro, T. W., & Pardamean, B. (2021). A Design of Deep Learning Experimentation for Fruit Freshness Detection. *IOP Conference Series: Earth and Environmental Science*, *794*(1). https://doi.org/10.1088/1755-1315/794/1/012110

Yeşilmen, S., & Tatar, B. (2022). Efficiency of convolutional neural networks (CNN) based image classification for monitoring construction related activities: A case study on aggregate mining for concrete production. *Case Studies in Construction Materials*, *17*(April). https://doi.org/10.1016/j.cscm.2022.e01372

*name of corresponding author