Innovative Classification of Eclipsing Binary Systems Using Convolutional Neural Networks Based on the Roche Model

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CLASSIFICATION ECLIPSING BINARY SYSTEM

ABSTRACT

Classification of the evolution of eclipsing binary systems can be studied from the characteristics of the light curve data to classify the eclipsing binary systems according to the physical characteristics that appear in the light curve. Base on Roche model, eclipsing binary are classified into three types: Detached binary, Semi-detached binary and Contact binary. However, classification of the evolution of a large number of eclipsing binary systems takes a long time to analyze the data, leading to delays in research. This project aims to create an artificial intelligence model that can classify eclipsing binary systems using Deep Learning to reduce the time required for preliminary classification of eclipsing binary systems. We uses a Convolutional Neural Network (CNN) model to classify images of light curves from the three types of eclipsing binary systems. CNN are capable of recognizing image features and apply them in tasks related to image processing for distinguishing image types. We used a Multi-class image classification method with 5 different CNN models are Basic CNN, Inception-V3, VGG-16, AlexNet and ResNet-50. These models were implemented using the Keras and TensorFlow. The models were trained on a dataset of 900 images of light curves, with 80% for training and 20% for validation. The results of the study showed that the Inception-V3 model achieved the highest accuracy in classifying eclipsing binary systems at 85.15%. This was followed by VGG-16 and ResNet-50, with accuracy at 80.13% and 72.85%, respectively. AlexNet and Basic CNN had the lowest accuracy of 33.33%. These results suggest that the Inception-V3 model yielded a reasonably high accuracy. This can be applied as an algorithm for studying the evolution of eclipsing binary systems in the future.

OBJECTIVES

1. To develop an AI model for classifying Eclipsing binary systems from images of light curves.
2. To use the AI model for studying Eclipsing binary systems have more conveniently.

METHODS

STEP 1: Data preparation

Collecting Data (Collecting light curve images from The ASAS Catalogue of Variable Stars and ASAS-SN Variable Stars Database by 900 images for training model and 180 for testing model)

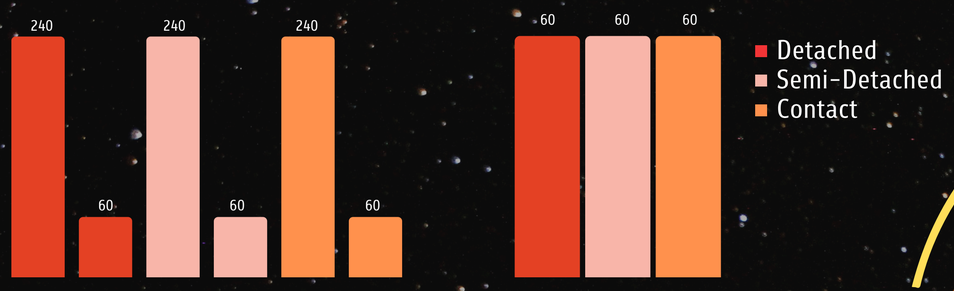


Fig 2 . 80% for training set(240 images), 20% for validation set(60 images) and 60 images for testing each type.

Fig 3 . Detached Binary System

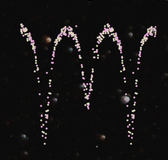
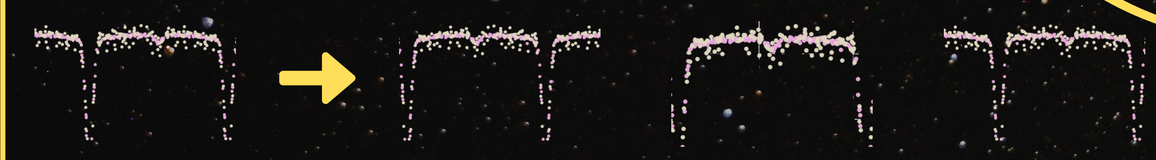


Fig 4 . Semi-Detached Binary System

Fig 5 . Contact Binary System

Data Augmention (Increase a size of dataset and reduce overfitting)



Original Horizontal flip Zooming Reseale

ARCHITECTURE

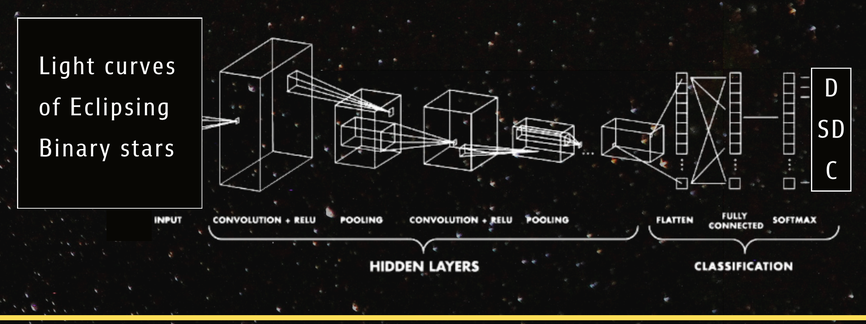


Fig 1 . A convolutional neural network (CNN), is a network architecture for deep learning which learns directly from data.

STEP 2: Trainning model

Set Hyperparameter (Set parameter to tuning model before training process)

```
1 img_width=224; img_height=224
2 batch_size=64
3 learning_rate = 0.001
```

Fig 5 . All model have use a same Hyperparameter.

Training process (Training the model for 5 different CNN models)

```
Epoch 1/10
15/15 [==============================] - ETA: 0s - loss: 0.8018 - accuracy: 0.6771WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 62s 706ms/step - loss: 0.8018 - accuracy: 0.6771 - val_loss: 1.6455 - val_accuracy: 0.3833
Epoch 2/10
15/15 [==============================] - ETA: 0s - loss: 0.3429 - accuracy: 0.8687WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 6s 407ms/step - loss: 0.3429 - accuracy: 0.8687 - val_loss: 203.0398 - val_accuracy: 0.3333
Epoch 3/10
15/15 [==============================] - ETA: 0s - loss: 0.1916 - accuracy: 0.9250WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 6s 388ms/step - loss: 0.1916 - accuracy: 0.9250 - val_loss: 54.2414 - val_accuracy: 0.3333
Epoch 4/10
15/15 [==============================] - ETA: 0s - loss: 0.2026 - accuracy: 0.9229WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 5s 323ms/step - loss: 0.2026 - accuracy: 0.9229 - val_loss: 207.6111 - val_accuracy: 0.3333
Epoch 5/10
15/15 [==============================] - ETA: 0s - loss: 0.1012 - accuracy: 0.9729WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 6s 407ms/step - loss: 0.1012 - accuracy: 0.9729 - val_loss: 44.0797 - val_accuracy: 0.3750
Epoch 6/10
15/15 [==============================] - ETA: 0s - loss: 0.0911 - accuracy: 0.9667WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 5s 327ms/step - loss: 0.0911 - accuracy: 0.9667 - val_loss: 11.6495 - val_accuracy: 0.5917
Epoch 7/10
15/15 [==============================] - ETA: 0s - loss: 0.0329 - accuracy: 0.9854WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 5s 352ms/step - loss: 0.0329 - accuracy: 0.9854 - val_loss: 2.6534 - val_accuracy: 0.6833
Epoch 8/10
15/15 [==============================] - ETA: 0s - loss: 0.0365 - accuracy: 0.9896WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 5s 328ms/step - loss: 0.0365 - accuracy: 0.9896 - val_loss: 3.8064 - val_accuracy: 0.6500
Epoch 9/10
15/15 [==============================] - ETA: 0s - loss: 0.0382 - accuracy: 0.9833WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 6s 386ms/step - loss: 0.0382 - accuracy: 0.9833 - val_loss: 3.1040 - val_accuracy: 0.5667
Epoch 10/10
15/15 [==============================] - ETA: 0s - loss: 0.0496 - accuracy: 0.9854WARNING:tensorflow:Can save best model only with val_acc available, skipping.
15/15 [==============================] - 5s 340ms/step - loss: 0.0496 - accuracy: 0.9854 - val_loss: 2.8572 - val_accuracy: 0.6250
```

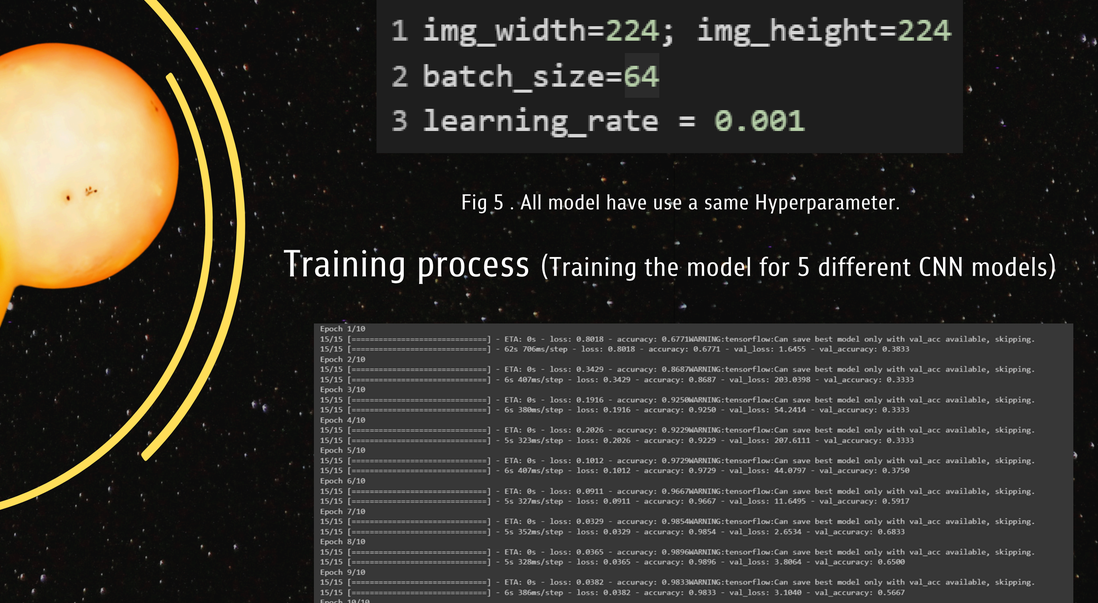
Fig 6 . Training model with 10 epoch (10 round).

RESULT

Model	Detached	Semi-Detached	Contact	Accuracy(%)	Loss(%)
Basic CNN	60	0	0	33%	100%
AlexNet	0	60	0	33%	100%
VGG-16	0	60	3	80%	60%
ResNet-50	12	15	30	72%	65%
Inception-V3	40	49	41	85%	55%

Fig 7 . The test results of image classification for each model show the values of accuracy and loss. If the loss value is lower, the accuracy value will be higher.

Confusion Matrix



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Improving the Performance of an Image Classification with Convolutional Neural Network Model by Using Image Augmentations Technique(Online) Accessed from : https://ph01.tci-thaijo.org/index.php/TNIJournal/article/view/182318
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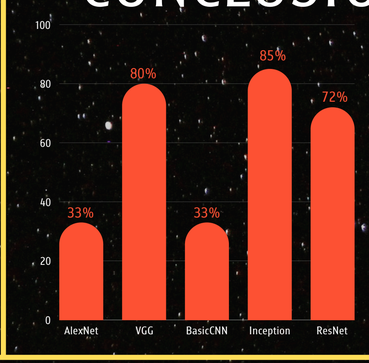
CONCLUSION



The classification of eclipsing binary systems based on the Roche model using convolutional neural networks (CNN) was studied. This is comparative analysis of model accuracy showed that Inception-V3 with 85% accuracy is the best model for classifying eclipsing binary systems based on the Roche model.

The reason why Inception can classify light curve images of binary stars most accurately is it uses 1x1 convolutions and have more complex architecture than other model, so it make the model more invariant.