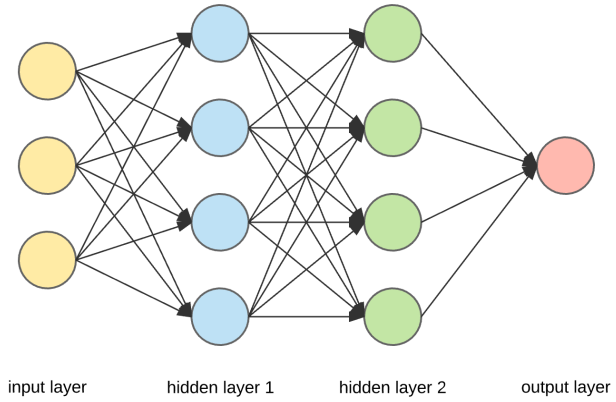
Introduction

In this report we will go over the results of the various combinations of features and classifiers used to tackle the problem of recognising handwritten mathematical symbols. One of our classifiers is an Artificial Neural Network alongside a Support Vector Machine, through which we analysed three particular features: the raw input pixels, the Histogram of Gradients and the Local Binary Pattern features.

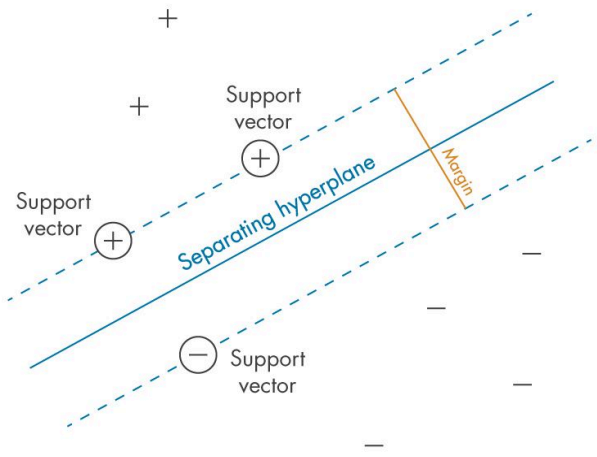
ANN

The basis of the ANN computational model is designed after the structure of the brain; they consist of nodes and neurons that are interconnected and placed into layers. They are they trained algorithmically to adjust the connections between these neurons to learn and improve the patterns and relationships found between the data.



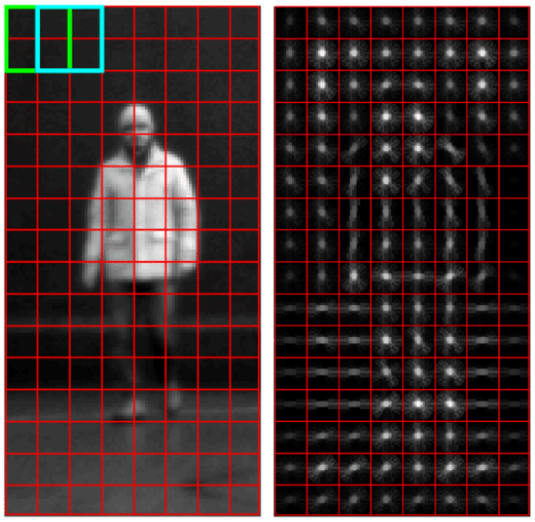
SVM

The Support Vector Machine models are a form of supervised learning models that are primarily used for classification tasks. They work by finding the best possible hyperplane that separates the classes best, the goal of which is to find the largest possible margin between the feature classes.



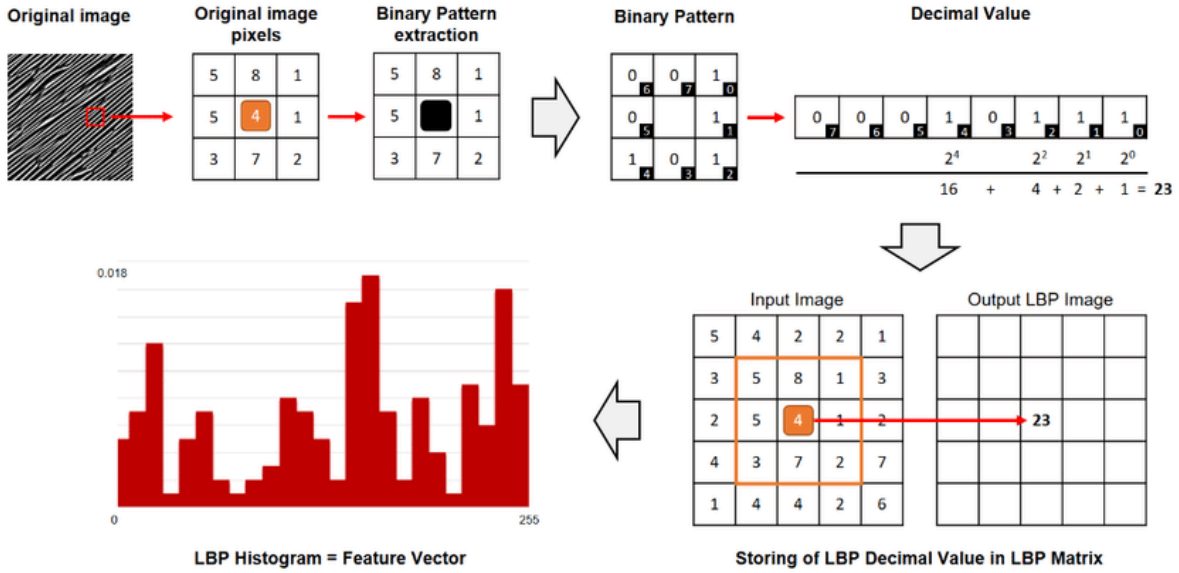
HOG and LBP

The Histogram of Gradient is a feature extraction technique that captures the local intensity of the gradient by dividing up an image into smaller sections and thereby computing a histogram of gradients.



(a) (b)

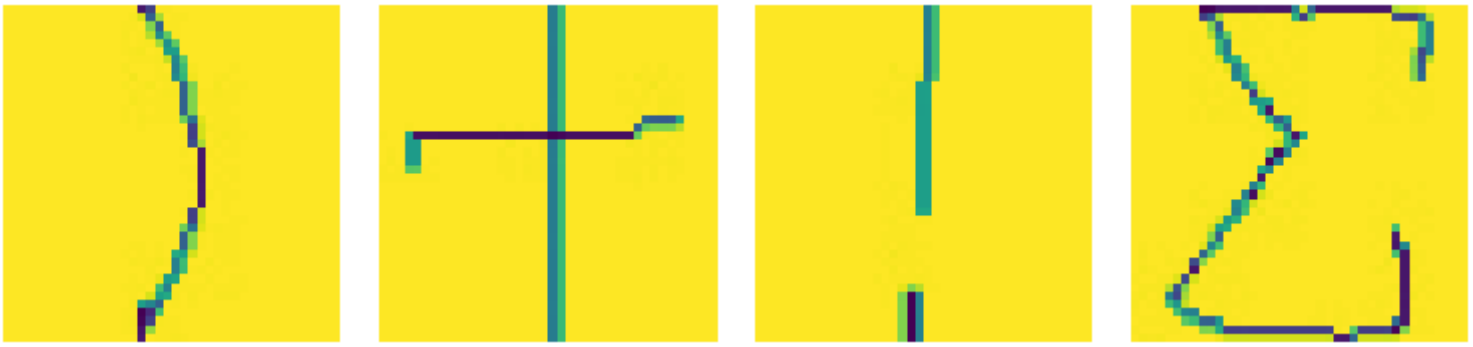
The Local Binary Pattern feature extraction technique operates by encoding the local pattern of a set of pixels in its neighbourhood with that of a central pixel.



Dataset

The dataset is a uniquely generated set of handwritten mathematical symbols consisting of 5000 data points. The categories of the handwritten symbols are `'!', ')', '[', '+',`

'=', 'cos', 'div', 'sum', 'tan', 'times'. The described task is to be able to construct an optimal machine learning approach to effectively recognise these handwritten mathematical symbols.



Experimental results and discussion

Experimental settings

SVM

Setting Name	Details
Kernel	Radial Basis Function
Regularisation	100
Random State	42

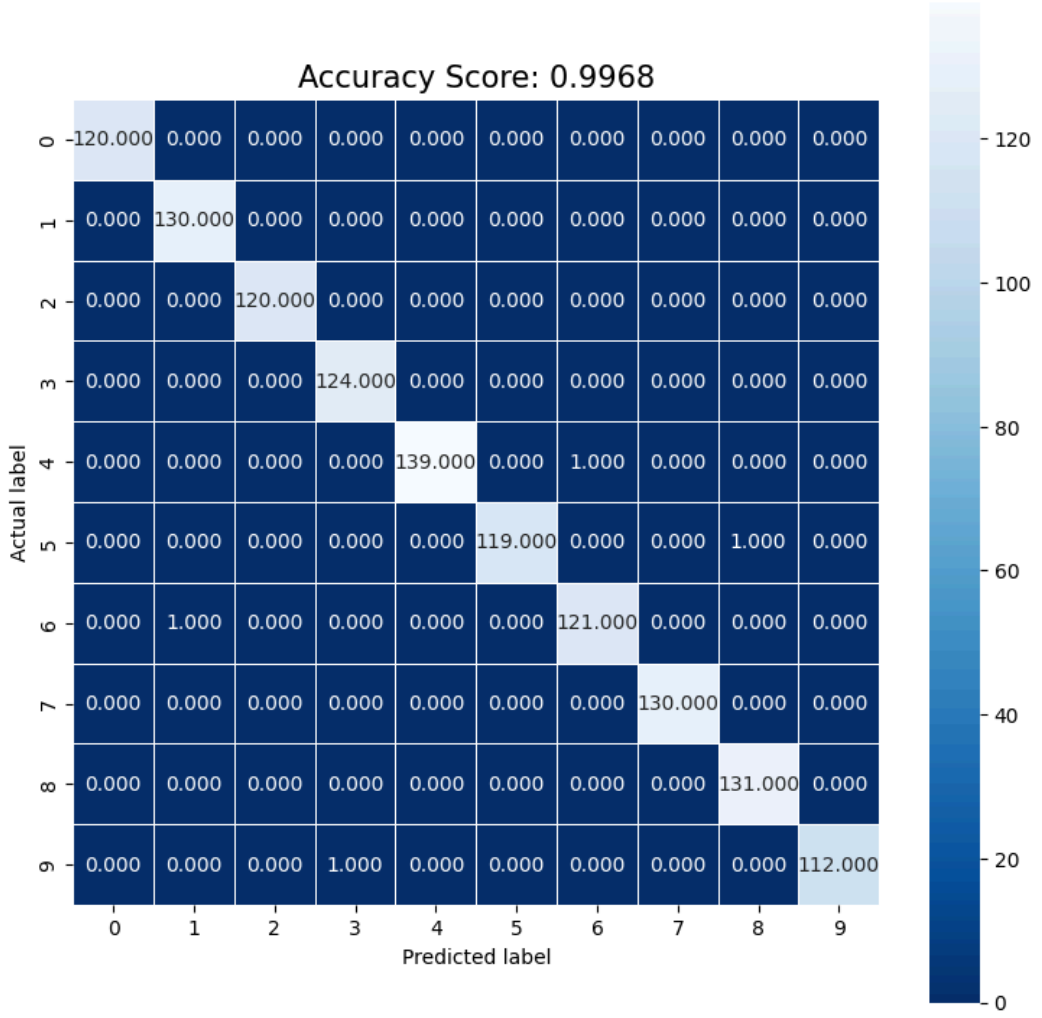
ANN

Setting Name	Details
Input Neurons	3
Activation Function	ReLu, SoftMax
Loss Function	Sparse Categorical Cross Entropy

Experimental results

Confusion matrix

The highest performing classifier + feature combination was the SVM using the HOG feature extraction technique. It achieved close to a perfect accuracy in terms of effectiveness in this task making it easily the best combination of all the ones tested.

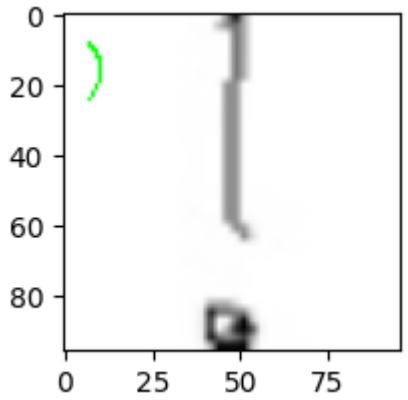


Comparative study

Classifier/Feature	HOG	LBP	Raw Input
SVM	0.9968	0.8336	0.9784
ANN	0.8960	0.8408	0.8528

Discussion

Overall the SVM model performed better than the ANN model, whilst the HOG feature extraction showed the highest performance across both models. A possible reason for this could be due to the fact that ANN's perform better with a larger dataset SVMs as they are known for being computationally expensive. A reason for a lower performance for this task is the fact that some of the symbols bear striking resemblance to one another if drawn in a particular way, such as this exclamation mark that was recognised as a bracket by one of the models. Similar errors were found where the models would mistake the exclamation mark for an equals sign or vice versa. A plausible reason for the higher performance for the HOG feature over the raw input and LBP, is due to the fact that the main strength in HOG feature extraction is its effective ability to capture edges. This combined with the simplistic characterics of the data set having no lighting changes and being consistent all the way through allowed for the HOG to perform better than the other features.



Conclusion

In conclusion for the task for recognition of handwritten mathematical symbols, we found that the combination of HOG + SVM model had the highest performance and accuracy, however the rest of the models did not vastly underperform and still hold some credibility in this use case. If there were a case of a larger dataset the ANN models may have outperformed the SVM models.