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A Research Based on Machine Learning of Satellite Data Modelling and Image Deep Convolution Learning Model

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Abstract: *The issue of fires causing damage in the life of people has been especially prevalent in the past year around the world in larger events and through this project computer learning models are able to detect and recognize them with high accuracy and functions as a potential solution towards the reduction of damage caused by fires. During the first stage we use satellite imaging in order to detect the areas where a wildfire could be started and then after the areas are identified we move to stage 2 of the program where we would use closer monitors over the area in the form of images in order to identify whether or not there is a fire in the area or not. Once the it is confirmed that there the area the local fire department could then be contacted to resolve the issue.*

Keywords: *wildfire detection, data preprocessing, machine learning, convolutional neural network, image classification, satellite real-time prediction*

1. Introduction

During the recent year, we bore witness to the devastation of fires from around the globe starting with the Amazon Forest of Brazil, to California and Australia. Each fire devastating the area and lives of people there. During the 2020 year 9917 incidents were recorded for fires in California with 10488 structures destroyed and 17230km^2 (4,257,863 acres) of land burnt[1].

Therefore, it should be crucial for us to be able to recognize the occurrence of these fires in order to prevent them or to minimize the losses for the people that resides within the area. First, for a fire to start there needs to be heat, fuel and oxygen. While, the latter two are more prevalent we are able to detect heat through infrared imagery from satellites from outer space.

Through this process, I took three models, Artificial Neural network (ANN) model, a K-earest Neighbors (KNN) model and a Support Vector Machine (SVM) with interpretation of the infrared image to determine whether or not there is a temperature high enough for the start to a fire. Afterwards, the images in the areas with potential fires are input into a convolution neural network based deep learning to determine whether or not there is a real fire at the site. To accomplish this the deep learning model kernels and pooling layers are used on pre-existing images of fires and non-fires to learn about the patterns within the image with fires and then the pattern can then be applied in order to detect whether or not a fire exists at the site.

2. Related Works

During the process to predict the occurrence of a wildfire there are often different parameters that eliminate impossible options in order to give out the feedback of whether or not there is a fire in the area. From an article written about a program for Cambodia the learning process was based on the meteorological data and the temperature of the area in order to determine whether or not there is a fire[2]. While, they used many different sets of data in order to achieve a specific pin-point on data, I saw the usage for meteorological data and decided to utilize it as a preliminary criteria in order to eliminate any area where there isn't enough heat to begin a fire.

To do so and ensure that there isn't any error in the process, three regression models are used in order to cross-check one another to prevent error, the first method being a constructed neuro-network that is able to generate outputs based on the input data through a process that would shift the input data into different values to eventually determine the output. This was selected as it included complexity within

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the program that could be shifted to achieve better results. In order to prevent overfitting of the model, the two simpler regressions of KNN and SVM are used in order as efficient methods that double checks the accuracy of the first. After determining whether or not there is sufficient temperature.

The second step to the process is determining whether or not a real fire exists at these locations for this area of image processing through this process the images needs to be classified. The methodology of using images as the basis for the prediction of fires was also used in a study in 2012 revolving around fires in the coal mine, a Discrete Fractal Brownian Incremental Random field was used for it and while the system was proven effective [3] there were still relatively high false positive and leakage forecast, so a convolutional neural network was utilized here.

First it has a far smaller parameter compared to other neural networks and so the calculation process with CNN is much faster. At the same time, the convolutions in the network allows details within the image to be captured such as the outline, the contrasting colors and other characteristics thereby allowing more accurate predictions [4]. Within convolutional neural networks, ResNet was chosen as the variant as it could perform well even with low quantities of parameters and runs more efficiently overall while still retaining accuracy [5].

3. Methodology

3.1. ANN

The detection of high enough temperatures with the satellite image are done with 3 methods first is the Artificial Neural Network (ANN). The ANN functions through acquiring the input applying changes to it for it to become a function that can then determine the output from the input. In order to generate the layers the functions are created through the computer using multiple variables of the input taken together to create a hidden layer, repeating that step with the hidden layer and processing through as many layers as it takes, in this case only 3 in order to obtain the output. To ensure that the end function is accurate for prediction the output each time while learning is compared with the actual observed data and the end accuracy and loss are printed to show that the regressed equation has accuracy to real life.

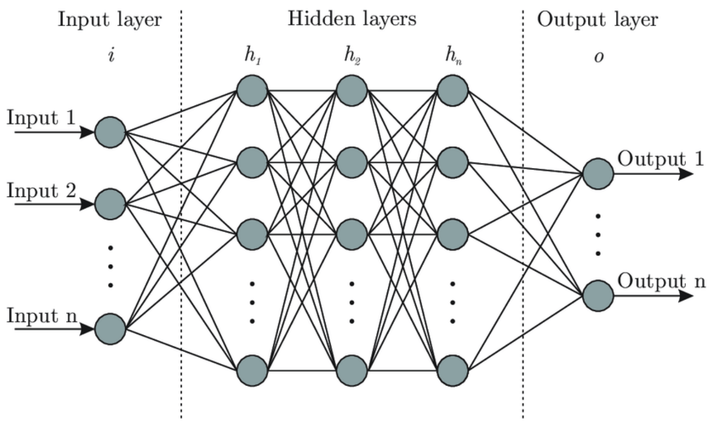

Figure 1: Model of ANN.

For the forward-propagation phase, the output of the model is :

$$\hat{y}=f(wx+b) \tag{1}$$

Where, $f(x)=\max(0,x)$, the activate function I used is Relu.

Based on the output calculated by the model, we can calculate the loss between it and the true label value. The definition of the loss function varies from task to task. For regression forecasting tasks, the loss function is usually MSE (mean square error). In classification problems, cross entropy error is generally used.

Regression MSE(mean square error):

$$\text{mse} = \frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i) \tag{2}$$

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Classification Softmax (categrocial_crossentropy):

$$S_i = \frac{e^i}{\sum_j e^j}$$

$$J(\theta) = -\frac{1}{n}\left[\sum_{i=1}^{n}\sum_{j=1}^{k} 1\{y^{(i)} = j\}\log\frac{e^{\theta_j^T x^{(i)}}}{\sum_{l=1}^{k} e^{\theta_l^T x^{(i)}}}\right] \quad (3)$$

3.2. KNN

The second model for regressing the temperature check is the KNN model, the KNN regression is one where the function is generated based on the proximity of all the other data points that are placed in to the input. This model is more straight forward from the input to the output as the function created by the value is generated through a averages of values within a certain a range.

3.3. SVM

The last model for regressing the preliminary values is the SVM, it takes the value of all the data points within the set to generate a vector that is able to best separate the two groups of data with a distinct character such as in this case once the temperature of the graph reaches a certain point where there is potential for a fire vs when the temperature is not high to have a fire.

3.4. CNN

Once the models that estimates the location of the fires are finished running, the imagery of the area could then be viewed through the Convolutional Neural Network in order to see whether or not a real fire is occurring. This is a classification model rather than a regression as the only thing that it needs to distinguish is whether or not there is a fire as the output from the image that is the input while the previous step while also having only one final output needs to take different variables into account thus demanding a regression and a function in order to function properly. The actual network itself begins with a convolution layer which takes a kernel that acts as a filter over the original image in the process shrinking down the original image and condensing its information. To avoid the image from being shrunk a packing layer could be used which adds an additional outer rim to the image that will be used as deductables for the application of the kernels (see Figure 2).

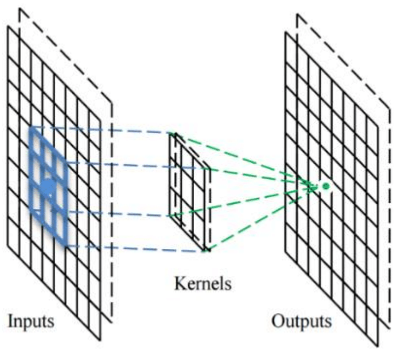

Figure 2: Kernels filters the inputs.

A second layer is a pooling layer, this layer further shrinks down the information within the image through the division of it into different squares where within each square either the average value or highest value could be taken and used.

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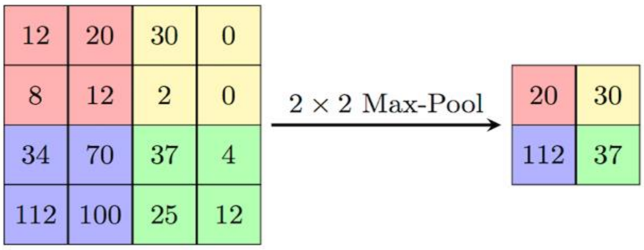

Figure 3: Pooling reduces the amount of calculation.

This makes the process of calculating each layer take less computing power and expedites the process. The process of a convolutional layer then a pooling layer then convo then pooling can repeat themselves and to finish off the process the CNN uses the softmax layer and prepares it as information for the classification processes coming out with the output.

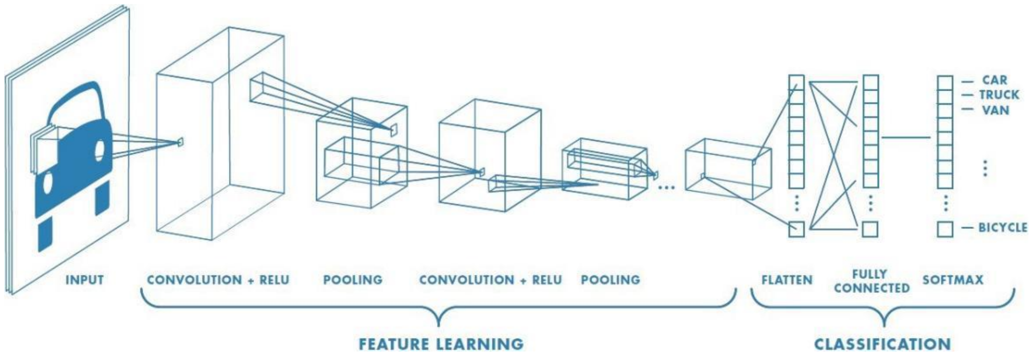

Figure 4: Full process of CNN.

4. Datasets Process

4.1. Datasets Description

In order to accomplish the learning process data sets were needed so on the basis of temperature graphs and images of fires an Online search was conducted to find two data sets. One containing a spreadsheet of temperatures and other information and the other with images with fires and images without fires. To continue the project, the datasets needed to be processes to be more effective while training.

4.2. Data Processing to Find Temperature

- For the first data set, there were multiple different detections with different satellites on the temperature of the earth, the datasets that was collected with more channels was used for this project.
- The information from the datasets such as date and time when it was collected was deleted as they were not useful to the training process.
- The information reflected with words are encoded into strings to be placed in functions.
- For the project, the x was set as the temperature which was looked for to the next step with y being all the other characters of the data.
- The X is standardized to a range of from zero to one through Xi-mean/ max-min and the data was ready to function.

4.3. Image processing for CNN

- For the images in order for them to work with the CNN they had to be first resized to 224 x 224.
- The images within the datasets are augmented in order to increase the quantity of data used for training.

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5. Experiment Process

5.1. Satellite Temperature detection

In order to create the fire detection system first the three models for regressing the initial data set were all used in training and the for the ANN the epoch numbers batch sizes and data were all adjusted slowly while looking at different functions such as ReLu and sigmoid functions and the end results along with the accuracy and loss are both printed out at the end. The other two models are established on prior code with simpler modeling so there was not much adjustments their results were also printed to cross reference with the ANN.

For the image learning process the model of convolution layer into pooling layer were used to process the images and the large datasets was processed in order to generate accurate classification for whether or not there is a fire occurring. In all three models the data are imported into the learning models the computation process occurs and the final formula is regressed with the data. For the KNN model two graphs are printed using uniform and distance which predicts the output from inputs through either looking at a web formed the datasets without and with distance between the new data point and one in the datasets as apart of the regressed calculations to produce the outcome.

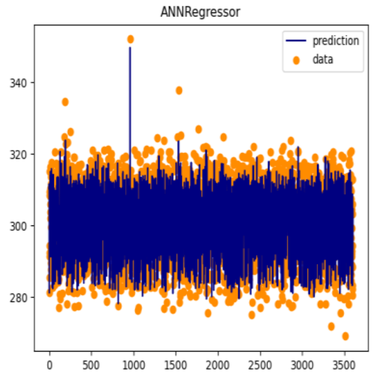

Figure 5: The prediction versus data of ANN.

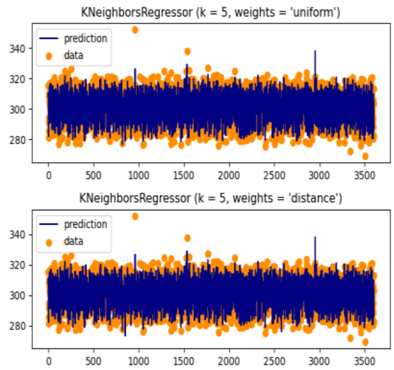

Figure 6: The prediction versus data of KNN.

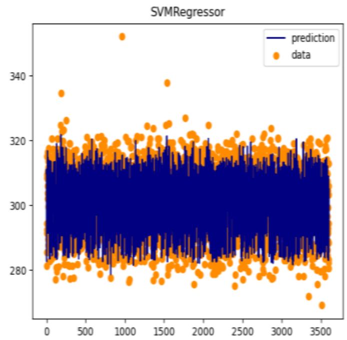

Figure 7: The prediction versus data of SVM.

Table 1: MAE of models.

	ANN	KNN (Uniform Weight)	KNN (Distance Weight)	SVM
MAE	3.70	3.35	3.23	3.55

The graphs (Figure 5-7) showed the prediction from the model when compared to the data that was given and the model can be seen to be able to locate the data points even if there are some outliers. The above data shows the loss of each model compared to testing data. The entire data set was taken on a scale from around 280 to at most 360 so the loss of around three when cross referenced with four different models meant it was accurate enough for a preliminary check on fires.

5.2. Fire detection

For the image detection, the images modified from the prior step are placed into the model for training and come up with classification for images. The classification with run with early stopping of epochs if the loss was detected to decrease after a set of learning too much so in the end around 52 epochs were ran for models based on loss while accuracy would remain to run 200 epochs to improve it.

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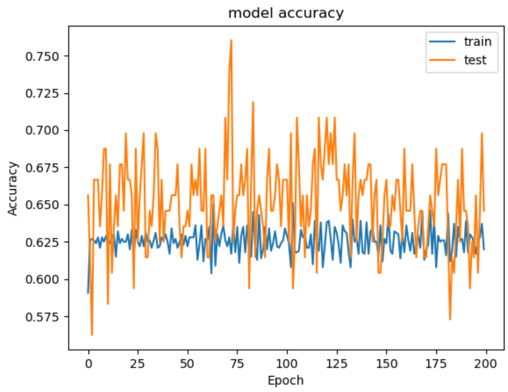

Figure 8: Accuracy of CNN learning without Augmentation.

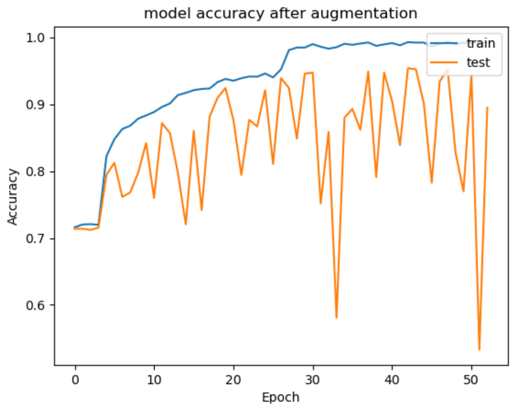

Figure 9: The Accuracy of CNN learning After Augmentation.

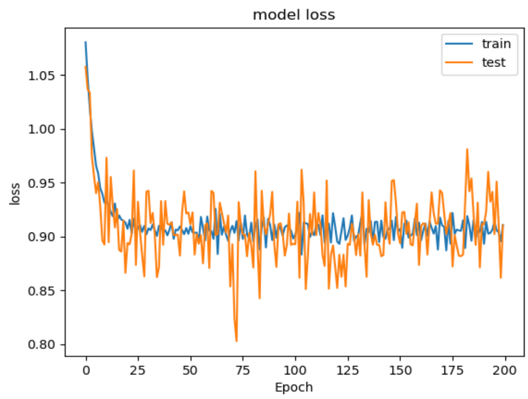

Figure 10: CNN model loss without augmentations.

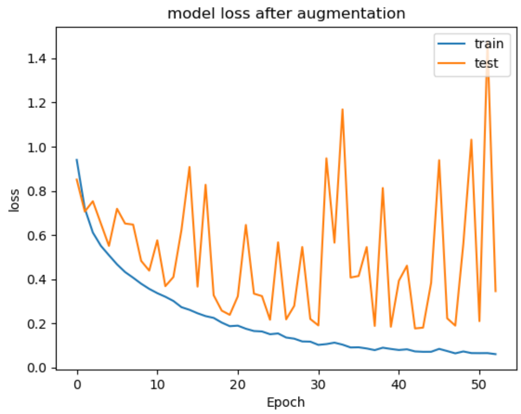

Figure 11: The CNN model Loss after augmentation.

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Within the graphs it could be seen that the model before the addition of augmentation was barely making any progress to improve its detection and would just oscillate back and forth, so the addition of the augmentation was necessary for the program to learn through the data set and through those graphs we can see that the loss was lower and the accuracy was higher. Through the learning while the classification was able to improve in decreasing its loss down to around 0.3 and increasing its accuracy up to around 0.9.

Figure 12: Sample images with and without augmentation in testing.

During the testing process the model was successfully able to pick up images with fires even with images that had lighting which closely resembled a fire the model successfully determined that as no fire so the programming was successful in its demonstrated learning and theoretical values.

6. Conclusion

In conclusion through the models established during the project, the initial step is able to accurately determine the regions where temperatures are enough for the conditions of a fire and the second step can with high accuracy recognize the areas with fires and areas without. The model offers another approach to the prevention of fires in detecting them through images in areas that may not be frequently seen and could help to prevent some of the damages of fires. While there is already a high accuracy to the prediction of areas where fires could occur and detection of fires, the data set could still be limited and the model could be further finetuned to enable a higher accuracy when analyzing fires. Through the program, we hope to offer a solution to the stopping of fires before the tragedies that we witnessed last year could unfold again and hope that through this or other methods the negative impacts of fires could be minimized.

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