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Image Defect Detection Using Machine Learning

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Abstract: Defect detection has been revolutionized by the use of Convolutional Neural Networks (CNNs) for identifying defects in objects through image processing. While traditional CNN-based object detection algorithms have shown success in identifying natural objects, they often struggle when it comes to defect data. To tackle this challenge, a shared weight binary classification network is implemented to determine the presence of defects in images. This is then followed by a detection network that accurately locates the defects within the objects.

By utilizing this approach, the speed and accuracy of defect detection are significantly improved compared to conventional CNN-based object detection methods. This has been supported both theoretically and experimentally, demonstrating the effectiveness of the shared weight binary classification network in enhancing defect detection using CNN technology.

Keywords: CNN (Convolutional Neural Network), Image processing, Defect detection, Object detection, Shared weight binary classification network.

I. INTRODUCTION

In the field of computer vision, object detection stands as a primary task aiming to detect and identify regions of interest within an image. The advent of deep convolutional neural networks (CNNs) in recent years has led to a surge in success within the field of [1] object detection, giving rise to a plethora of exceptional algorithms. While most algorithms strive to establish a universal object detection framework with unparalleled accuracy and efficiency, addressing specific challenges, such as defect detection in industrial products, requires a different approach.

When it comes to defect detection, the focus shifts from merely identifying and locating defects in an image to preemptively determining whether an image contains defects. This distinction poses a binary classification problem as opposed to the traditional object detection problem. In the context of defect detection, the prevalence of non-defective images far outweighs that of defective ones. As a result, enhancing the judgement ability on defective images translates to reduced computing costs, lower product defect rates, and increased enterprise benefits. The unique nature of defect detection sets it apart from conventional object detection challenges. While state-of-the-art object detection algorithms may offer solutions, they often rely on subjective confidence thresholds for detecting defects. This inherent reliance on human judgement leaves room for errors and inaccuracies, highlighting the need for improvement.

In addressing the limitations of existing methods, a novel approach emerges. By leveraging a binary classification network to ascertain the presence of defects in an image and training an object detection network to pinpoint defects, a comprehensive solution can be achieved. However, the traditional two-model method involving separate networks poses challenges in terms of computing time and cost. To overcome these challenges, the integration of binary classification and object detection networks into a single framework offers a promising solution. This holistic approach aims to streamline defect detection processes, reduce errors, and optimize computing resources, paving the way for enhanced efficiency and accuracy in [2] object detection tasks.

II. LITERATURE REVIEW

[1] The authors of the paper are Gorbunov Vladimir, Ionov Evgen, Naing Lin Aung. The title of the paper is "Automatic Detection and Classification of Weaving Fabric Defects Based on Digital Image Processing". Implemented two kinds of fabric defect detection methods using image processing: the comparison method which uses the correlation of fabric images and defect detection using Hough Line Transform. These two methods result in performing efficiently in detecting defects from fabric images. Advantage: Fabric Defect Detection, Reduced Human Intervention Disadvantage: Less accuracy when used with large datasets and require more computational resources.

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[2] The authors are Anna Litvintseva, Oleg Evstafev and Sergey Shavetov. The title of the paper is "Real-time Steel Surface Defect Recognition Based on CNN". The method employed is for improving production standards and process efficiency. In this paper, Deep Learning (DL) and Computer Vision (CV) techniques are used to solve the problem of defect detection on the steel surface sheets. The advantage is Facilitates to do work of a person, Improving production standards. The disadvantage is it lacks in the Correct classification of small defects.

[3] The authors are Kai Su, Qiangfu Zhao, Lien Po Chun. The title of the paper is "Product Surface Defect Detection Based on CNN Ensemble with Rejection". The methodology involves utilizing the effect of "rejection" for defect detection. Experimental results demonstrate that a CNN ensemble with a proper rejection rate can have a very low FN error rate and can reduce human labor significantly. Advantages: Low error rate, Accuracy Improvement, disadvantages it fails to identify the defects if the image has multiple objects of same type, less accurate when the detecting object is small

[4] The authors are S.Durai1, T.Sujithra2, Athmakuri Sai Charan1 , Sai Kiran pulyala1 and Battula Vishnuwardhan Satyam. The title of the paper is "Car Defect Detection Using Image Processing". This project uses high-resolution cameras to capture car images and a Convolutional Neural Network (CNN) to look for dents and ripples (macro defects). The trained CNN model can then be used to automatically detect such defects in newer images. Advantages are that it has faster and so much more consistent defect detection compared to human inspectors. Can identify microdefects that are totally invisible to the human eyeball.

III. METHODOLOGY

Sequence Of Work

A. Text Input

Users will provide an image which may contains defects or non-defects. The idea is to identify weather the image contains defect or not.

B. Algorithms Used

Convolutional neural network: The foremost common utilize for CNNs is picture classification, for illustration distinguishing partisan pictures that contain streets or classifying hand composed letters and digits. There are other very standard errands such as picture division and flag preparing, for which [3] CNNs perform well. Object detection is one of the elemental importance in computer vision, the reason of which is to recognize and find the locale of intrigued in the picture.

In later a long time, profound convolutional neural networks (CNNs) have accomplished extraordinary victory within the field of object location, and a tremendous number of prevalent object discovery calculations have emerged. Most of them center on setting up a bound together and all-inclusive protest discovery system with tall exactness and productivity, and they can meet the wants of most protest discovery issues.

A convolution is basically sliding a channel over the whole input. One supportive way to think about convolutions is this cite from Dr Prasad Samarakoon: "A convolution can be thought as looking at a function's environment to create better/accurate forecasts of its outcome." [4] visually realistic but also semantically coherent with the input text.

CNN is a very, very powerful algorithm for image processing. These algorithms are currently, the best algorithms we find for processing of images and also for object detection tasks. Many, many companies use these algorithms to do things like identifying the objects in an image.

Image Data Representation

Images contain data of RGB combination. Matplotlib can be used, like, to import an image into memory from a file. The computer doesn't see an image, all it sees is an array of numbers, you know? Color images are stored in 3-dimensional arrays, like. The primary and secondary dimensions [5] are related to the height and width of the image (the number of pixels). The last dimension, it corresponds to the red, green, and blue colors present in each pixel, you see.

Three Layers of CNN

Convolutional Neural Networks specialized for, you know, applications in image & video recognition. CNN is mainly used in image analysis tasks like, you know, Image recognition, Object detection & Segmentation. Convolutional Neural Networks constitute of three main layers:

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1. **Convolutional Layer:** In a typical neural network each input neuron is connected to the next, like, hidden layer. In CNN, only a small region of the input layer neurons connect to the neuron hidden layer.

2. **Pooling Layer:** The pooling layer is used to, like, reduce the dimensionality of the feature map, you know? There will be multiple activation & pooling layers inside the hidden layer of the CNN.

3. **Fully-Connected layer**: Fully Connected Layers form the last few layers in the network. The output from the final Pooling or Convolutional Layer is given as input to the fully connected or last layer, which is flattened and then fed into the fully connected layer.

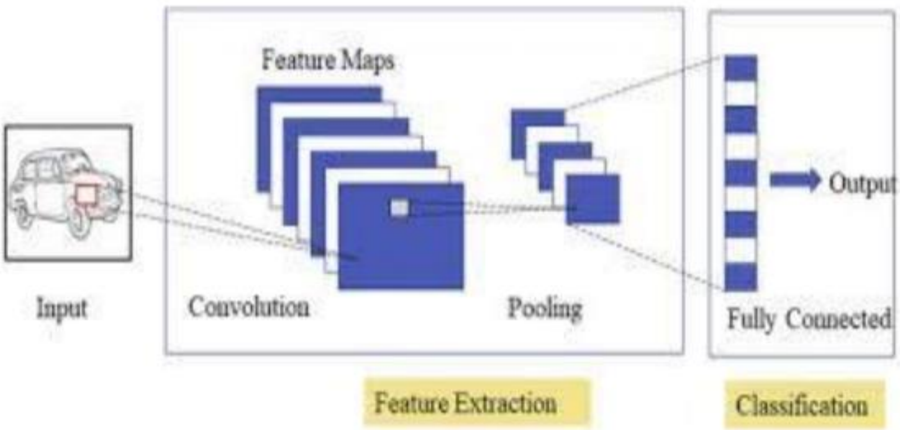

Fig: CNN Model

Binary classification network: Binary classification generally refers to the classification of tasks that have two different class labels. Based on the class they belong the classification is done.

There are various different types of main stream classification algorithms used for modeling classification predictive modeling problems, but no good theory exists on how to map algorithms onto problem types. Instead, it is generally recommended that practitioners use controlled experiments to discover which algorithm and algorithm configuration results in the best performance for a given classification task.

Classification prescient modeling algorithms are assessed based on their results. Classification accuracy, despite not being perfect, serves as a good starting point for many classification tasks.

Instead of class labels, some tasks may necessitate the prediction of a probability of class membership for each example, adding additional uncertainty in the prediction for interpretation by applications or users.

Popular algorithms used for binary classification include:

- k-nearest neighbors
- logistic Regression
- Voting Classifier
- neural network

IV. PROPOSED ALGORITHM

In the vast majority of object detection algorithms based on CNN, it is difficult to utilize these normal images without any defects, but the proposed method in this project successfully makes full and effective use of these images and avoids the waste of these data resources by defect finding network. We propose a strategy to balance two networks with different complexity for three different learning tasks, namely, binary classification network and object detection network.

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The exploratory results appear that the proposed strategy can solve the synchronous convergence problem of two networks with different complexity and the effect of which is better than that of a single binary classification network, and it does not damage the convergence effect of the object detection network.

The purpose of our method is not to replace and surpass the current object detection algorithms, but to make up for their imperfection in some specific object detection problems. Our contribution may be small, but it better solves the problem of defect defection in industrial products, and promotes the deep convolutional network to be more systematic and perfect in the field of object detection.

We propose a strategy to balance two networks with different complexity for three different learning tasks, namely, binary classification network and object detection networks. The experimental results show that the proposed strategy can solve the synchronous convergence problem of two networks with different complexity [6] and the effect of which is better than that a single binary classification network, and it does not damage the convergence effect of the object detection network.

System Development Methodology: The proportion of normal images. From the DFN network model, we can see that the speed increase is from the short-circuit judgment of the normal image. For verification, we set up several experiments with different proportions of normal images in the test set. Since there are fewer normal images and defective images in the test set, we set different proportions of normal images by reducing the number of normal images or the number of defective images. The proportion of normal images in the data set, the map shows a state of first being stable and then oscillating up and down. The further it goes to the back, the fewer samples of defective images and the less representative.

Binary Classification Network: On the other hand, we can come up with another direct solution. First, we can train a binary classification network to determine whether the image contains defects, and then train an object detection network to detect defects in the image, but this method we called it two-model method in this article is too cumbersome, two different networks will bring more computing time and cost.

Convolutional Neural Network: First, it uses DFN to judge whether the image contains defects or not and then decides whether to carry out defect detection in the image based on the judgment results. If the image does not contain defects, the final detection result without any defects is directly returned, otherwise, further defect detection is needed. The experimental results show that the Defect Net's defect finding the ability to defective images is 7.2% higher than the one model method.

Defect Detection: However, for some object detection problems, especially for the defect detection of industrial products we not only focus on identifying and locating the defects in an image, and it is more important to judge whether an image contains defects in advance than to directly detect all kinds of defects in an image. The former is a binary classification problem, and the latter is an object detection problem.

Loss balance: For most defect detection problems, only a small part of the images contains defects, while most of the images do not contain defects. We have carried out experiments and analysis on our network model on the industrial product data sets, and the experimental results show that [7] Defect Net's defect finding ability of defective images exceeds that of the one-model method (object detection algorithms based on CNN) and two model method, and its inference speed is faster than them.

Object detection: The defect data set also includes a large number of images that do not contain detection targets, that is, normal images. Second, the processing principle of defect data set first is actually a binary classification problem, that is, whether the image contains defects, and then an object detection problem. Therefore, the general object detection algorithm may not be optimal in solving the problem of defect detection.

System Architecture

The architecture of the defect-Net is shown below:

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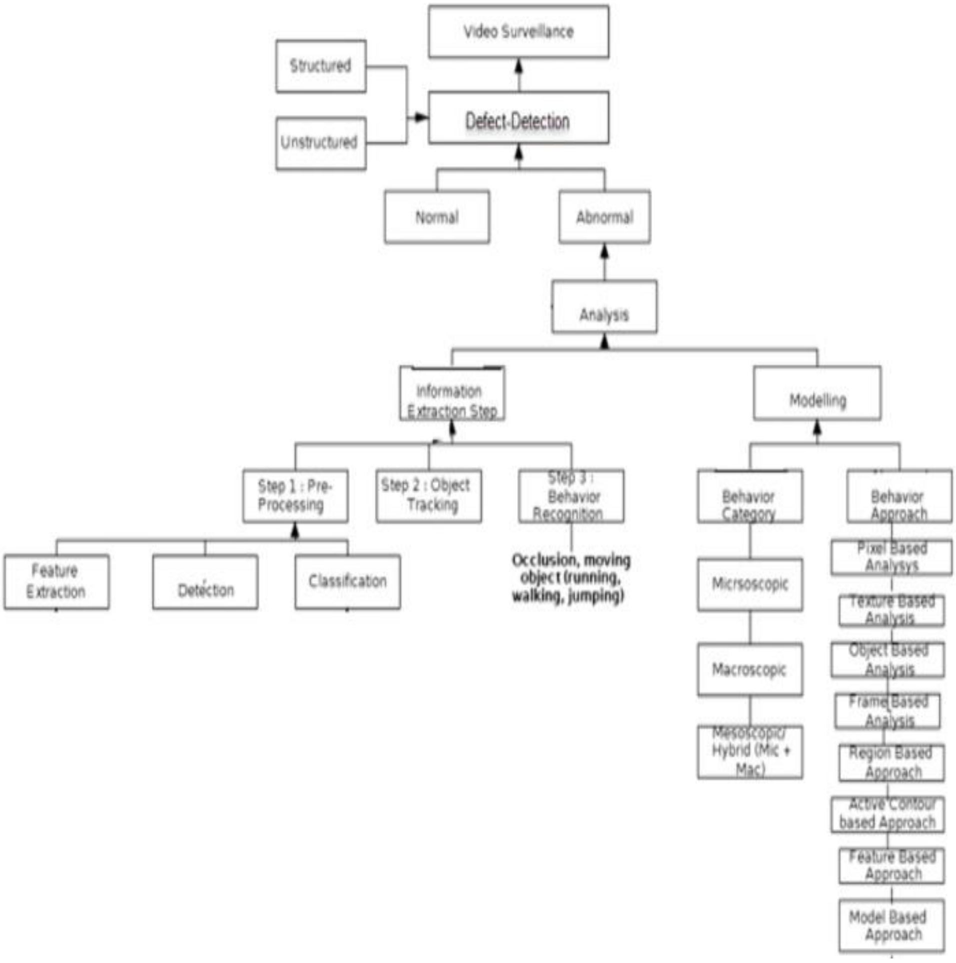

Fig: System Architecture

DATASET: In the dataset we have set of images which are used to train the model for the image defect detection in the testing purpose. Defect detection of image is based on the results comparison between Defect net and SOTA networks in fabric dataset. Both the model one and model two are used in defect identification of images, so we are using Three different forms of variables loss weights[8]. There are constant loss weights, variable loss weight and different normal image proportion.

1. Constant loss weights: we are use grid search method to find the best balanced loss weight by setting different values at intervals of 0.05 from 0.00 to 2.00.

2. Variable loss weight: We can set three loss weight strategies of different decreasing forms. For the linear form. Let

- K = 1/12.
- w_0 = 1, then the loss weight strategy is
- (-1/12+1)
- g (n, w_0) = 1/n+1
- ½ power

3. Different normal images proportion: The speed of the defect network is related to the proportion of normal images. From the DFN network model we can see that the speed increase is from the short-circuit.

DATA PRE-PROCESSING: Data pre-processing is a process of preparing the raw data and making it suitable for a machine learning model. It is the first and crucial step while creating a machine learning model. When creating a machine learning project, it is not always a case that we come across the clean and formatted data. And while doing any operation with data, it is mandatory to clean [9] it and put in a formatted way. So, for this, we use data pre-processing task. We are using four basic methods for data pre-processing they are:

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- Data Cleaning
- Data Integration
- Data Transformation
- Data Reduction

V. EXPERIMENTAL RESULTS

The following is the screenshots representing the input image given by the user and the expected output generated by the Defect-Net.

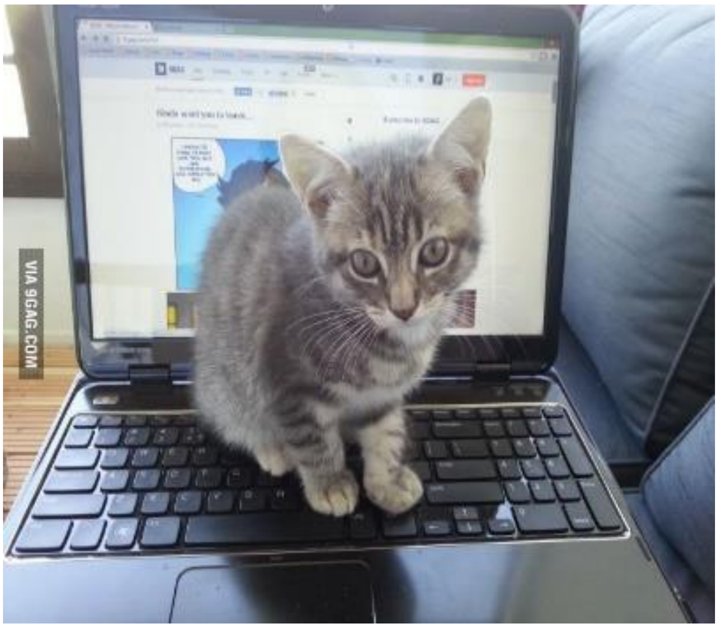

Fig: Image given as input by the user

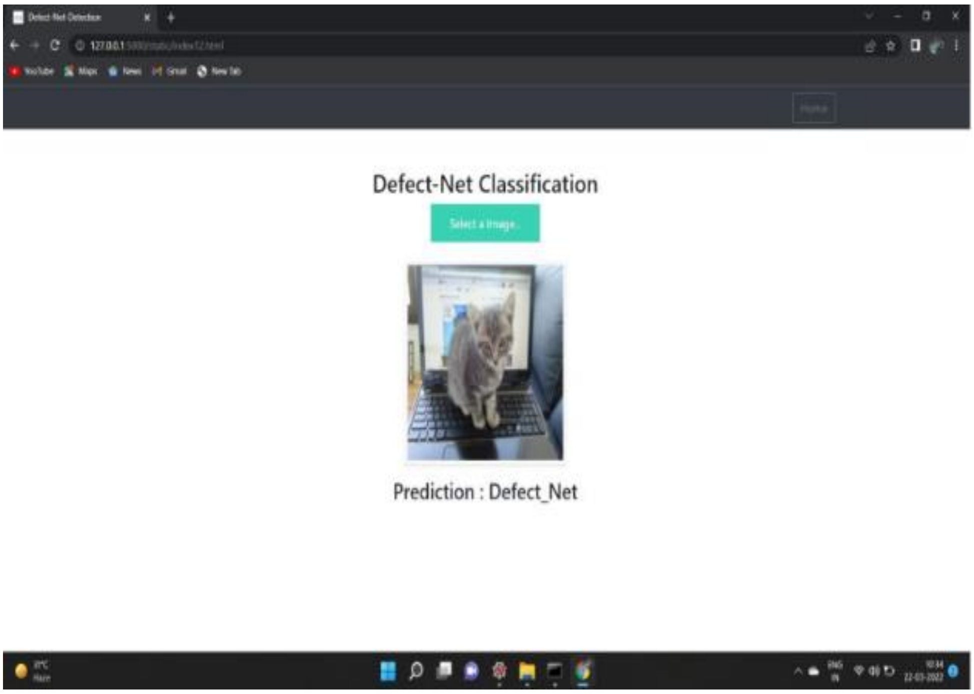

Fig: Output given by Defect-Net

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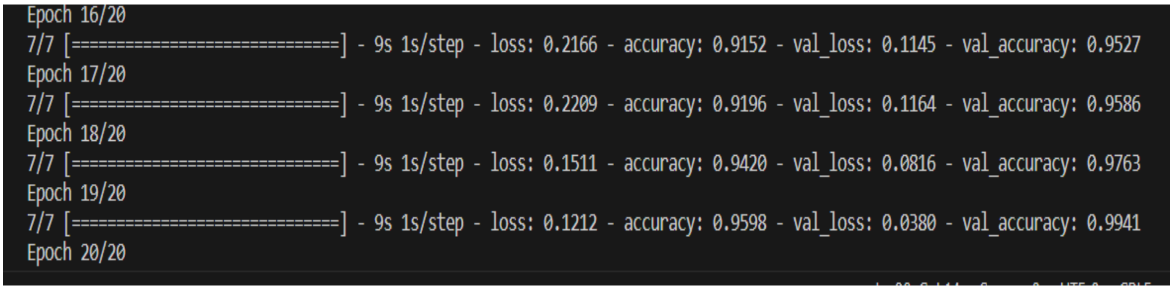
The Accuracy of the Defect-Net application is shown below, it is calculated for more than 20 epochs and the model is trained [10] with more than 2000 images, which contain both defective and non-defective images.



```
Epoch 16/20
7/7 [==============================] - 9s 1s/step - loss: 0.2166 - accuracy: 0.9152 - val_loss: 0.1145 - val_accuracy: 0.9527
Epoch 17/20
7/7 [==============================] - 9s 1s/step - loss: 0.2209 - accuracy: 0.9196 - val_loss: 0.1164 - val_accuracy: 0.9586
Epoch 18/20
7/7 [==============================] - 9s 1s/step - loss: 0.1511 - accuracy: 0.9420 - val_loss: 0.0816 - val_accuracy: 0.9763
Epoch 19/20
7/7 [==============================] - 9s 1s/step - loss: 0.1212 - accuracy: 0.9598 - val_loss: 0.0380 - val_accuracy: 0.9941
Epoch 20/20
```

Fig: Accuracy of the Defect-Net model

VI. CONCLUSION AND FUTURE WORK

In this paper, we propose the Defect-Net model by harnessing the usage of defect detection we are able to find the defect things with the help of defect network in images. In the defect Net, binary classification is used to identify whether the image is defective or non-defective. By using this algorithm in the images, we are getting data with high accurate and more efficient images. Planning to train the model with perfect images and then we are finding the images which are related to the model trained images, with binary classification of model one and model two methods in the defect detection. When the tested image is not relevant one, then model identifies as defected image in the output screen. These kind of implementations helps to reduce the man power in the industries and many working areas and so on.

In this way the project aims to help the industries in many ways such as identification of industrial products quality with defect efficiency of the product, It is also used in the image processing to identify the defects in the image or not, Used in industries for better identification of defects, To enhance product quality, improve manufacturing processes, and ensure compliance with quality standards, ultimately leading to higher customer satisfaction and cost savings.

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