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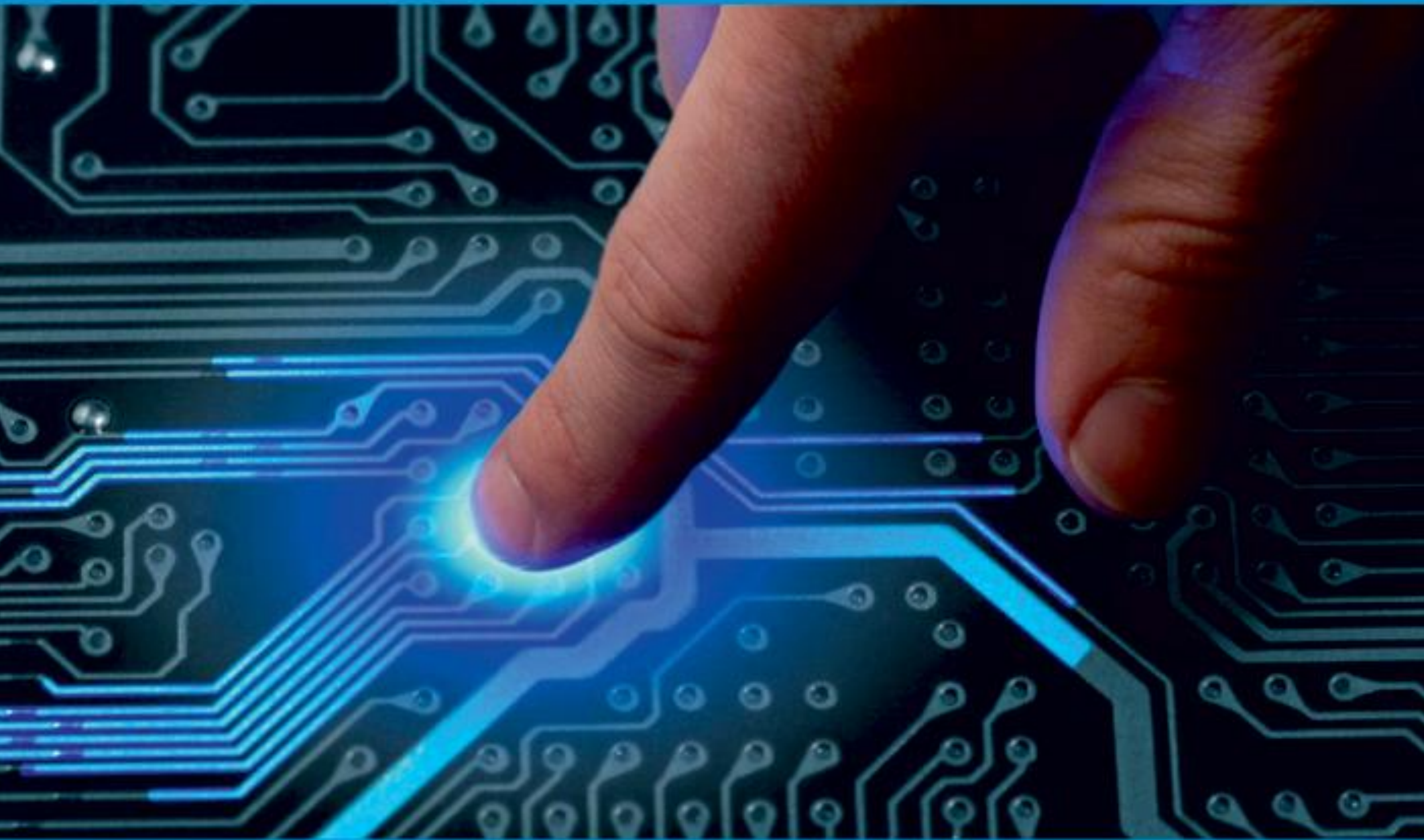

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Defect Detection in Manufacturing

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ABSTRACT: Computer vision has advanced significantly in recent years and is now commonly used in manufacturing. One of the many applications is quality inspection, for which we employ several object identification models such as Yolo-v5, v7, and detectron2.

Traditionally, defect detection and quality inspection were performed under human supervision, but with the growth of technology and the advent of Industry 4.0, an automated defect detection system is required. The goal of the research is to help the industry reduce the human intervention required in the manufacturing process and eliminate the losses caused by unchecked faulty products.

This research paper gives a brief overview about how the YOLO v7 algorithm is used to detect objects with an accuracy of almost 95%.

KEYWORDS: YOLO, Computer Vision, Bounding box, object detection, R-CNN, SVM, Convolution

I. INTRODUCTION

Deep learning has made significant advances in recent years, particularly in computer vision. Defect detection is one of several application cases for the development of different object detection models. An essential step in the production and maintenance processes is quality inspection. The use of surface defect detection in quality inspection is fairly broad. The testing of a variety of models, including Yolov5, v7, and detectron2 was carried out. Companies suffer significant financial losses as a result of defective items being produced and sent to clients without quality inspection.

The study intends to reduce these losses by detecting several types of defects. Mechanical parts are put on the conveyor belt and using cameras and sensors our trained model tests the part for various parameters like if the welds are properly done, all the nuts are present and others.The motivation behind the research was to find a one stop solution for the problem that is faced in everyday life at the core level of every manufacturing industry. The defect detection process is simplified and made effective, which will save a lot of time and money for various manufacturers and make the production process fruitful. The manufacturing parts which are defective in the production phase can cause serious tragedy after integration if not treated well. Thus, ensuring the safety and quality of the final product built is the goal of this project.

II. RELATED WORK

The research paper [1] gives a brief overview of the You Only Look Once (YOLO) algorithm and its subsequent advanced versions. Through the analysis, many remarks and insightful results are reached. The results show the differences and similarities among the YOLO versions and between YOLO and Convolutional Neural Networks (CNNs).In the research paper [2], deep learning-based object detection techniques have produced some excellent results. However, there are numerous issues with images when shooting in the real world, like noise, blurring, rotational jitter, etc. The impact of these issues on object detection is significant. Improved the average precision (AP) of traffic sign detection in real scenarios by training a strong model with the help of the YOLO network for object detection.The study [3] describes how to detect car models based on a deep learning model. This paper introduces Faster-RCNN, YOLO, and SSD, which are capable of real-time processing and have relatively high accuracy. We trained each algorithm using the car training dataset and analyzed the performance to determine how the optimized model performed in vehicle type detection. The Yolov4 model outperforms the other methods, showing a vehicle model recognition accuracy of 93 percent.The research [4] focuses on deep learning and how it can be applied to object detection and tracking. Deep learning works with algorithms that are influenced by thelayout and function of the brain. The advantage of using such an algorithm is that the performance improves as the amount of data increases. This is not the case with traditional learning algorithms whose performance stabilizes as the amount of data increases. RCNN has better accuracy compared to other algorithms, but YOLO is better when considering speed over accuracy. In YOLO, object detection is implemented as a Defect Detection in manufacturing regression problem, providing class probabilities for the detected images. The research [5] gave a thorough analysis of the current situation of the techniques used in manufacturing industries. The most popular techniques, including feature detection, recognition, segmentation, and three-dimensional modelling, are covered in this article. A production system, a sensing module, a

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decision-making module, an actuator, and a lighting module make up the suggested system framework for CV in the manufacturing environment.The study [7] gives us a deeper outlook of the YOLO algorithm. This paper studies the previous work done on object detection and comes up with YOLO. YOLO is a more unified algorithm. It is used for real time object detection. This paper helps us understand how Yolo works, its working steps like splitting into grid, bounding boxes, IoU and final detection. It also proposes the architectural diagram of the same. It also talks about the training of the model and limitations of the Yolo. It also compares the YOLO algorithm to other object detection systems in the real time. It also states faster RCNN and compares and combines it with the YOLO algorithm.The paper [8] describes defect detection in the various mechanical parts using the technology of computer vision. This paper proposes a novel methodology for the same. It talks about the five step defect detection mechanism or the pipeline which includes the following steps: collecting, processing, analysing, understanding of the images and then the industrial control. The paper then proposes a SVM based model for the defect detection in the various parts of a machine. It suggests how the experiment is carried out for the SVM model and also proposes the result on the testing data sets and evaluates them.

III. PROPOSED ALGORITHM

A. *Description of the Proposed Algorithm:*

The dataset used in the study consisted of various images for different parts of the automobile industry. The images were generated manually under expert supervision. The dataset had about 3500 images comprising 20 different types of parts. Further, the dataset was divided into training, validation and testing for evaluation purposes. To extend the size of the dataset, data augmentation was carried out based on properties like brightness, rotation, zoom, fill, lights, etc.

Yolo algorithm stands for 'You Only Look Once'. Yolo is an algorithm for real-time object detection that makes use of neural networks. The popularity of this algorithm is due to its accuracy and quickness. It has been applied in a variety of ways to identify animals, humans, parking metres, and traffic lights. A much quicker algorithm, YOLO can operate at up to 45 FPS.

The image is first separated into several grids. S x S are the dimensions of each grid. Every grid cell will be able to detect items that enter it. For instance, a grid cell will be in charge of detecting an object if its centre appears within that cell.

An outline that draws attention to an object in a picture is called a bounding box. The following characteristics are present in each bounding box in the image: Height, Width (bw) (bh), Class (for instance, human or car) is denoted by the letter C and the centre of the bounding box (bx,by).

Box overlapping is described by the object detection phenomena known as intersection over union (IOU). IOU is used by YOLO to create an output box that properly encircles the items. The ratio of the overlap to the total area, which is obtained by dividing the intersection by the union, offers us a decent indication of how well the bounding box resembles the original prediction.

The YOLO (You Only Look Once) algorithm is a state-of-the-art object detection algorithm that can be used for defect detection in manufacturing. YOLO algorithm has several advantages over other traditional computer vision algorithms for defect detection in manufacturing.

First, YOLO algorithm is very fast, and it can process images in real-time. This makes it ideal for applications in manufacturing where high-speed inspection is required.

Second, YOLO algorithm has high accuracy and can detect defects of various sizes and shapes in the manufacturing parts. YOLO algorithm uses a single neural network that predicts the bounding boxes and class probabilities for each object in the image. This allows the algorithm to detect multiple defects in the same image.

Third, YOLO algorithm is very robust and can handle a wide range of lighting conditions and backgrounds. It can detect defects even in low light conditions, which is critical for manufacturing plants where lighting conditions may vary.

Overall, YOLO algorithm is a very effective and useful algorithm for defect detection in manufacturing. It can significantly improve the quality of the products and reduce the amount of waste in the manufacturing process.

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However, the effectiveness of the algorithm depends on the quality of the dataset used for training, the accuracy of the labels, and the hyper parameters of the model.

Defect detection in mechanical manufacturing parts using deep learning and computer vision with YOLOv7 algorithm can be accomplished through the following steps:

1. Data collection and preparation: Collect a dataset of images of the mechanical manufacturing parts. Label the images with bounding boxes around the defects.

2. Data augmentation: Augment the dataset to increase the variety of images and improve the generalization ability of the model. Common techniques for data augmentation include flipping, rotating, cropping, and changing the brightness and contrast.

3. Model selection and training: Select the YOLOv7 algorithm as the model for defect detection in mechanical manufacturing parts. Train the model on the prepared and augmented dataset. Optimize the hyper parameters of the model to achieve optimal performance.

4. Model evaluation: Evaluate the performance of the model on a separate testing dataset. Calculate the precision, recall, and F1-score of the model. Adjust the hyper parameters of the model as needed to improve the performance.

5. Deployment: Deploy the model to the manufacturing plant. Integrate the model with the manufacturing process so that it can detect defects in real-time.

6. Monitoring: Continuously monitor the performance of the model and make adjustments as needed to ensure that it is detecting defects accurately.

Some additional tips for improving the performance of the model include:

1.Use transfer learning: Start with a pre-trained model on a similar dataset and fine-tune it on the mechanical manufacturing parts dataset.
2.Use multiple scales: Use multiple scales to detect defects of different sizes in the mechanical manufacturing parts.
3.Use an ensemble of models: Use an ensemble of models to improve the accuracy of the defect detection.
4.Use a human-in-the-loop approach: Use a human-in-the-loop approach where the model detects potential defects, and a human expert verifies them. This approach can improve the accuracy of the defect detection while reducing the number of false positives.
The laboratory setup consists of conveyor belts, high-quality cameras for image acquisition and other hardware support. The IoU and confidence threshold can be used for tuning purposes. These hyperparameters are useful in getting the best result possible.

The proposed system requires Graphical Processing Unit (GPU) and CCTV cameras along with sensors in the Hardware. The software requirements of the proposed system includes Python V3, PyTorch, CUDA, OpenCV, Google Colab or Jupyter notebook.

The hardware system consists of:
1. Conveyor belt: A conveyor belt is used to transport the mechanical parts through the inspection area. The belt should be smooth and free from vibrations to ensure accurate defect detection. The speed of the conveyor belt should be adjustable to accommodate different inspection requirements.
2. Camera system: A camera system is mounted above the conveyor belt to capture images of the mechanical parts as they pass through the inspection area. The camera should be positioned at an optimal distance and angle to capture clear and high-quality images. The camera should be equipped with a high-resolution lens to ensure that the details of the mechanical parts are captured accurately.

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3. Lighting system: A lighting system is used to illuminate the mechanical parts uniformly and reduce shadows and reflections. The lighting should be adjustable to accommodate different inspection requirements.

4. Computer system: A computer system is used to process the images captured by the camera system. The computer system should be equipped with a high-performance graphics card to handle the deep learning algorithms required for defect detection. The software used for defect detection should be able to process the images in real-time and detect defects accurately.

5. Communication system: A communication system is used to alert the operators when a defect is detected. The system can be integrated with the manufacturing process to automatically remove defective parts from the production line.

Overall, this setup can be very effective in finding defects in mechanical parts using a conveyor belt. The setup can be customized based on the specific requirements of the manufacturing plant and the types of mechanical parts being inspected.

IV. SIMULATION RESULTS

Model Used	Yolov7				
Number of Epochs	200				
Number of Images					
Test	28				
Train	200				
Validation	56				
Size of Images					
		conf_thresh=0.6		**conf_thresh-0.8**	
Dataset(iou)	val	test (0.7)	test(0.95)	test(0.7)	test(0.95)
nut_present					
P	0.999	1	0.63	1	0.63
R	1	1	0.554	0.839	0.554
TP	86	56	31	47	31
FP	0	0	18	0	18
FN	0	0	25	9	25
nut_missing					
P	0.998	-	-	-	-
R	1	-	-	-	-
TP	26	-	-	-	-
FP	0	-	-	-	-
FN	0	-	-	-	-
weld_ok					
P	0.998	1	0.896	1	0.896
R	1	1	0.924	1	0.924
TP	62	56	52	56	52
FP	0	0	6	0	6
FN	0	0	4	0	4
weld_missing					
P	1	-	-	-	-
R	1	-	-	-	-
TP	50	-	-	-	-
FP	0	-	-	-	-
FN	0	-	-	-	-
Model Results					
Precision	0.999	1	0.763	1	0.763
Recall	1	1	0.739	0.92	0.739
F1-score	0.999	1	0.75	0.95	0.75
mAP@.5	0.996	1	0.832	0.922	0.832
TP	224	112	83	103	83
FP	0	0	24	0	24
FN	0	0	29	9	29

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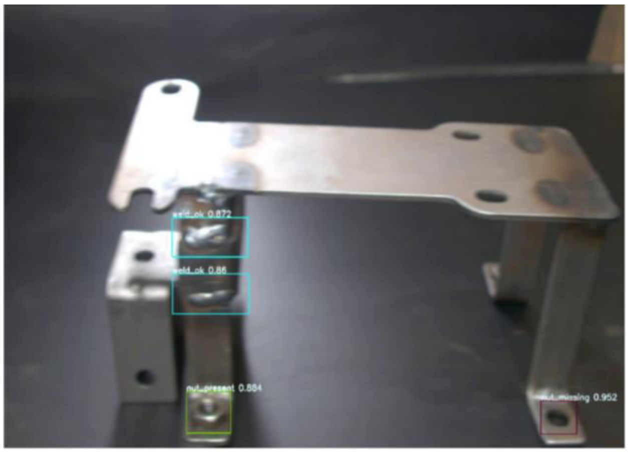

Fig 1. Nut present, not present and weld ok, not ok

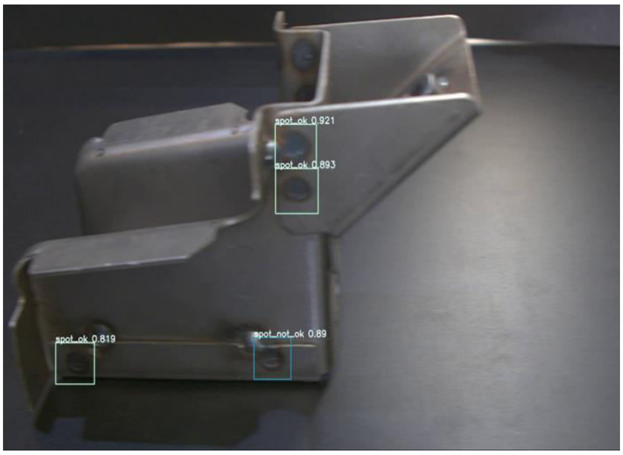

Fig 2. Spot ok, not ok

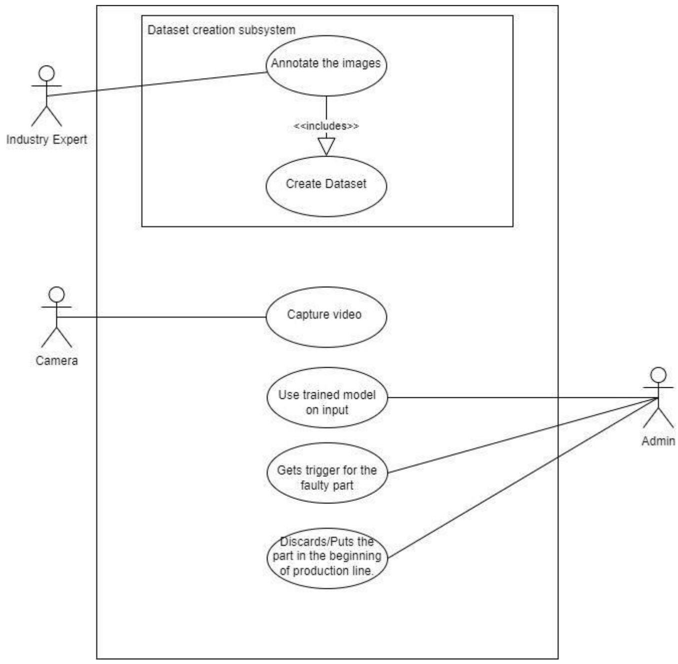

Fig 3. Use Case Diagram

V. Conclusion and Future Work

The study explored the domain of deep learning and computer vision. Deep analysis and study of object detection in real time was carried out. The You Only Look Once (YOLO) algorithm was used for the same. The object detection is used to find out and detect the defects in the manufacturing parts. These are the mechanical parts of the industry which are analysed in real time.

A model which helped to serve the purpose of defect detection is developed. This has helped to make the process efficient and effective. The model is trained, validated and tested. The results of the model were evaluated, and satisfactory outcomes were obtained. YOLO v7 reduces the number of parameters as compared to the previous YOLO versions and other models. YOLO v7 works with a faster fps rate and is able to achieve a theoretical Precision and Recall values of about 0.99. Practically, the values of precision and recall were about 0.95.

As the world is automating, this study does the same in the field of manufacturing. The model and the project can be used by industries across various domains to make their manufacturing process effective. In the future, the plan is to deploy this model in the industry and understand and improve the shortcomings.

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