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Automated Quality Inspection Machine Using Computer Vision System

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Abstract: In any organization, quality has a prime importance and the ability to visually detect the quality of a product is one the most important issues for a manufacturing industry because of the demand of product by customer is increasing. This process is typically carried out by quality experts, unfortunately experts frequently make mistakes because this process could be tedious and tiring even for the most trained operators. A lot of solutions have been proposed to solve this problem such as lean manufacturing. But Computer Vision can solve this problem and can help us to detect the defects and can verify the quality in mean time. Computer Vision is a branch of artificial intelligence which can be used to automate and integrate a wide range of processes used for visual perception. It includes many techniques such as image processing, statistical pattern recognition, feature extraction, neural network training and testing, object detection and recognition, etc. The use of Computer Vision and AI is currently restricted to only some basic visual and numerical based applications because of hard problems to solve or lack of computational power, but in future this field can be extended to other processes and fields such as detection of properties of materials using this technology, design and analysis of products, automation of critical manufacturing processes, fault diagnosis in product and process, so on and so forth. Computer Vision and AI has ability to solve all kind of problems. A lot research and development are being carried out in this field one of them is Reinforcement Learning, which will be the able to solve all sort of problems in future.

Keywords: Computer Vision, Artificial Intelligence, Reinforcement Learning, Statistical Pattern Recognition

I. INTRODUCTION

In today's intense competition of highly competitive global market, success of any product requires near-perfect quality. As a result, Inspection has become an integral part of manufacturing system. It is the means of rejecting non-conformities and assuring good quality products. The problems associated with traditional approaches are overcome with the rise of technologically updated inspection equipment. Traditional approach used for labor-intensive methods that results in the increase of manufacturing lead time and production cost. Furthermore, there have been a significant delay in determining an out-of-control limit. Hence the products that do not confirm to the specified standards result to the additional cost of scrap and rework.

To create a more coherent approach, in the quality domain, most successful organizations have merged other quality-oriented philosophies with lean production, standards conformity, business excellence, six sigma and design for six sigma. Therefore, the manufacturing processes of these organizations generate only a few defects per million of opportunities. The detection of these rare quality events represents not only an opportunity to move the manufacturing quality forward and also a research challenge (Carlos and Ruben, 2012).

In industries, products are generally mass produced. In mass production, there are various challenges like efficiency, costs, quality issues and time consumption. Many industries have employed to automation to resolve these problems. There has to be a system at the end of the production line for maintaining the quality of the products that can scan the end products for defects. To overcome the above-mentioned challenges automated systems that apply image processing are adopted by most of the industries (Nematullo et al., 2019).

Computer vision is the tool of automating and integrating representations used for vision perception and a wide range of processes. It includes many techniques that are useful for processes such as image processing (transforming, transmitting and encoding images) and statistical pattern classification. Moreover, it also includes tools for cognitive processing and geometric modeling (Tushar and Meenu, 2013). In industrial automation Computer vision is playing a significant role in providing innovative solutions. The manufacturing sector has been revolutionized by the introduction of automation. In automation, complex operations can be disintegrated into simple step-by-step instructions that can be repeated by a computer.

The need for the systematic assembly and inspection have been realized in such a mechanism in different manufacturing processes. The human workers have been usually doing these tasks, but these types of deficiencies have made a computer vision system more alluring. To perform the operations like the recognition of certain features or objects within that image, image acquisition and analysis and the exploitation and imposition of environmental constraints a visual system is required.

A Computer Vision System plays a crucial role in automated industrial production processes. In recent times, with the availability of highly efficient communication interfaces, modern digital cameras and image processing and computer vision has become faster and more productive (Nematullo et al., 2019).

The application of computer vision technology has benefited a huge amount of industrial activities in manufacturing processes. These activities include, among others, manufacturing, metal product finishing, machine parts, delicate electronics component, quality textile production, glass manufacturing, printing products and granite quality inspection, integrated circuits manufacturing and many others. Computer vision technology improves quality management and productivity and provides a competitive advantage to industries that employ this technology (Tushar and Meenu, 2013).

Automated Quality Inspection is defined as the process of automating the quality operations to eliminate the defects with the integration of Computers and Smart Systems. Computer Vision is a flexible system which can be integrated various applications like IoT and other embedded systems which can be used further used to automate the processes. Automated Quality Inspection can be applied in real-world applications to improve the efficiency of various quality operations in less time and consumption of resources.

II. PROBLEM STATEMENT AND IDENTIFICATION

In manufacturing industry, for manufacturing of components like gear, it is observed that conventional physical inspection process is critical to quality and time consuming. In manufacturing industry, inspection of gear is carried out manually by physical inspection for cracks, holes, surface deformations, gear profile and rusting.

Problems Identified

1. In conventional quality inspection process, there are certain limitations which reduces the accuracy of the inspection process and affect the quality of production process.
2. The manual inspection process includes human errors and it is a time-consuming process.
3. It becomes very difficult to check each and every component as the process will be costly and time consuming.
4. In manual inspection the accuracy is based on the skill of the worker performing the inspection process.
5. To overcome the limitations in the conventional quality inspection process, automated quality inspection using computer vision is introduced.
6. Below is the problem statement which includes details regarding the components and parameters to be check

Objective of work

1. To automate the process of quality inspection

2. To increase efficiency of the process.

3. To increase accuracy of inspection and eliminate human errors.

4. To reduce time of inspection.

Scope of Work

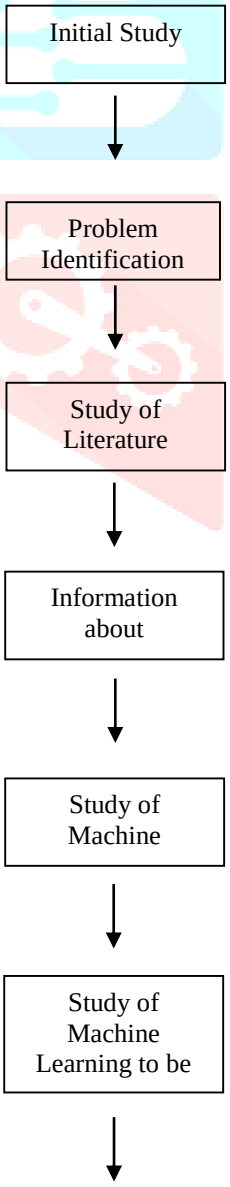
1. Quality is the most important parameter for any manufactured part in the industry. We cannot comprise with the quality of product.

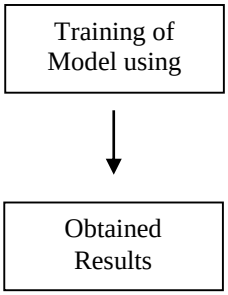
2. Inspection process ensures the quality of the manufactured product.

3. But manual quality inspection has some limitations in it; hence Automatic inspection can be widely employed in industries.

4. The objective of the work shows the significance of Automatic quality inspection. Automatic quality inspection has a wide scope of application in industries.

Methodology





III. FRAME DESIGN

Table 1: Component Details

Component no.	Component
1	Base Plate
2	Frame Stand
3	Platform
4	Camera (Slot)
5	Conveyer
6	Conveyer Roller
7	Conveyer Stand
8	Transparent Sheet

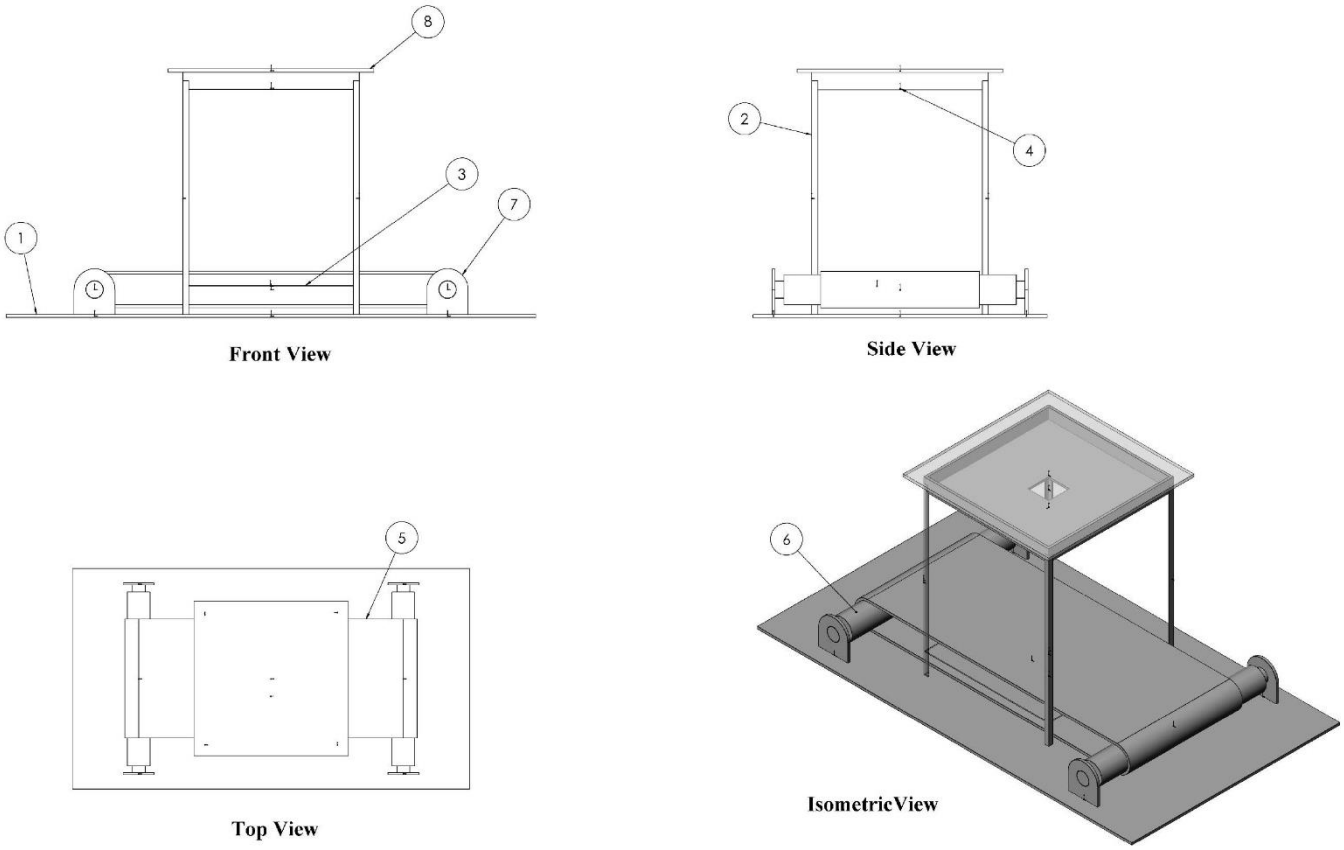


Fig 1: Frame Design

IV. LITERATURE REVIEW

Rahmatov et al., (2019) reviews system with automatic quality assessment of industrial product. A widely used technology is to use industrial image processing that is based on the use of special cameras or imaging systems installed within the production line. Thus, with the help of such technologies system automates the central processing production line in such a manner that scanning of images of production line are done and abnormalities & defects in their assembly are pointed out by the model and further information is transferred to the system administrator via a cyber-physical cloud system (CPCS) network. The whole system is based on machine learning approach for better classification. This model is not only used for identifying the abnormalities but also used for configuration of angles at which the images are captured and the accuracy of this method is up to 92%.

Vahid Torkzadeh and Saeed Toosizadeh (2019) defines a solution for automated inspection system for detecting the location and measuring the size of existing dipping or buckling on the sandwich panel surface. In this paper it is seen that this method can precisely defect the dipping and buckling of surface of sandwich panel without any human intervention. After successful processing of the panel by system a 3D (surface plot) and 2D (heat map) is produced as output for better understanding to supervisor of production line and to easily inspect the quality of the surface. The experimental results shows that the proposed system can effectively measure the defects present on the surface including buckling and dipping with good accuracy. Tushar Jain and Meenu (2013) presents automation and integration of processes with the help of computer vision system. It includes many techniques that are useful image processing and statistical pattern classification. The system also includes cognitive processing and geometric modelling. Discussion of different considerations is done for computer vision system such as image representation, computational methods and algorithms, modelling and matching, depth information. In order to make the system smarter and more

effective and automating the integrity parameters like universal capability, PC requirement (self-contained), off-the-shelf hardware, and connectivity and I/O control options are the key factors. For justification of the utilization of a machine vision system economic and logistic considerations are also crucial factors. Improvement in safety and reliability of the products, improvement in the quality, and the introduction and possibility of a technology for new productions are key points in the support of the machine vision system.

Qi Huang (2017) reviews the relationship of mechanical engineering and electrical engineering with artificial intelligence. It also summarizes different application of intelligent technologies in the field of mechanical engineering such as fault diagnosis of hot forging press as an example to illustrate the specific application of artificial intelligence in mechanical engineering. Because of the upcoming technologies like hybrid intelligent design, monitoring, control, diagnosis system based on fuzzy logic, neural network, expert system the application of intelligent system in mechanical sector will rise. Theoretical and practical research shows that intelligent technology has been widely used in all aspects of mechanical systems, coupled with the discovery of knowledge and distributed artificial intelligence and other computer technology, which makes artificial intelligence more effective in the mechanical system and other areas

Escobar et al., (2018) reviews different pattern recognition strategy for intelligent supervisory system for detection of quality events. For selecting the feature which contains the most important information about quality of process and classification of task different learning algorithms are used such as l1-regularized logistic regression. In this paper defect detection was formed as binary classification and validated in two experimental datasets from automotive manufacturing systems:

(1) UMW of battery tabs from a battery assembly process.

(2) LSW sub-assembly components from an assembly process. In both cases, the main objective was to detect low-quality welds (bad) from the process.

The proposed strategy was supported by hybrid feature elimination algorithm and optimal classification threshold search algorithm and according to results of experiment 100% defects can be effectively detected.

Vergara et al., (2018) reviews the design and implementation of computer vision system for verification of quality of component. This paper presents detailed explanation of stages involved to create a system which will automatically verify the quality of component by digital image processing and computer vision system. The paper also focuses on discussion based on the problems involved with implementation of computer vision system for quality inspection based on different aspect like hardware and software. A detailed explanation about the design of two study cases to inspect fabric and apple defects, and its correspondent results are presented. As per the result concerned the accuracy of the system is calculated in three different ways and overall accuracy of defect detection system is 93%. Besides, in order to obtain a better performance of the system, the acquisition of the knowledge from the human experts and the techniques to represent it in terms of numerical information is mandatory.

Zajačko et al., (2018) found that implementing deep learning method is vital for detection of defects and pattern recognition. The method was used for technical diagnostics in automotive industry. In the method a camera is proposed with appropriate illumination to capture image of tested product. With the application of deep convolutional neural networks, the system could solve most of the complex tasks related to automated inspection. The system will generate large amount of data in terms of images and neural network system will be used to recognize and extract elements from images and detect presence of defects and errors in the product. DCNN can be used to skip complicated steps for extracting features, instead unprocessed images are used as input.

García-Chamizo et al., (2007) presents use of simulations for design mechanism used in visual inspection systems of crucial surfaces. A collective model is proposed, this model is used or particularized to solve inspection obstacles with the help of simulations. It proposes a flexible and low-cost design, bringing the design model closer to the system implementation by a manufacturing procedure. The research specializes with the problem of complex conditions like intervention of surfaces. It is provided with solution of advances on formal framework which will enable study of domain motive. With this system a low-cost requisite technological system is possible reducing the cost of expensive prototyping. The study includes of the best conditions for performing the inspection of reflectance surfaces to be calculated by evaluation of the used architecture, by considering resolution, angle of light capturing, lighting of surrounding, etc.

Escobar, C. A. et al., (2018) reviews the learning process and image pattern recognition strategy proposed for an intelligent supervisory system. The proposed strategy is guided by a hybrid feature of elimination algorithm and a search algorithm of for optimal classification. This approach resulted in 100% of defects detection effectively. Therefore, the method aims towards zero defect policy, not accepting even rare quality events during the manufacturing. It identifies the most complex features relevant to quality of product. To lower the training time and increase the classifiers prediction ability, the programmed dataset was

processed with two steps, being use of relief algorithm to eliminate unnecessary features and HCR algorithm to eliminate redundant features, which is difficult for most of the filters. The given approach can be used and widely applied for many manufacturing processes to increase the performance of traditional quality methods.

Jing Yang et al., (2020) presents classification of defective products like electronic components, textile components, etc. into certain categories. These categories are reviewed with the characteristics and features described with the help of deep learning methods. This method includes the summarization of core ideas like high precision, positioning, rapid detection, small objects, complex background, and occluded object detection. This paper provides a comprehensive overview of product defect-detection technology in complex industrial processes. It was determined that 3D object detection and detection of occluded objects, etc. are the vital topics of industrial research. It is also stated that embedding sensor equipment is the development trends in the industrial defect detection.

Standard Components

Arduino UNO

The Arduino UNO is a standard board of Arduino. Arduino UNO is based on an ATmega328P microcontroller. The Arduino UNO includes 6 analogue pin inputs, 14 digital pins, a USB connector, a power jack, and an ICSP (In-Circuit Serial Programming) header. It is programmed based on IDE, which stands for Integrated Development Environment. It can run on both online and offline platforms. Subsubsections

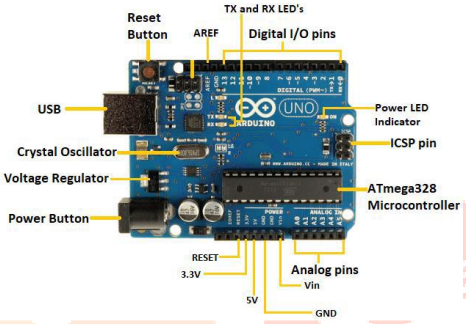


Fig 4.1 Arduino UNO

Camera

A high-resolution camera is used in the project for capturing the images of components that need to be checked.

Fig 4.2 Camera

Servo Motor (SG90)

Micro Servo Motor SG90 is a tiny and lightweight server motor with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller.

Fig 4.3 Servo Motor

Study of Machine Learning Models

Machine learning is a branch of artificial intelligence which focuses on the use of data and algorithm to imitate the way that humans learn, gradually improving its accuracy. There are different algorithms which are used according to type of application and accuracy needed. These algorithms are also called as Machine Learning Models. Some of these algorithms are discussed below.

Linear Regression

Linear Regression is a type of supervised machine learning in which predicted output is in continuous form. It is used to predict the variable data i.e. values in a continuous range e.g. checking the parameters of a product or process having variable data.

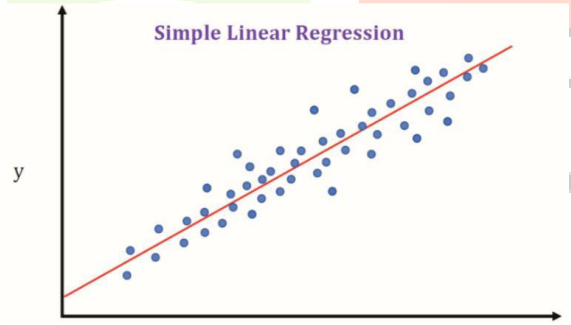


Fig 4.4 Linear Regression

Logistic Regression

Logistic Regression is used to predict the categorical dependent data using a set of independent variables. Instead of giving the exact value i.e. 0 or 1, it gives probabilistic value between 0 and 1. Therefore, it is used to solve the classification problems e.g. in quality inspection checking if a part is defective or not by using some parameters.

Logistic Regression instead of fitting a straight regression line, ‘s’ shaped line is fitted which predicts the results between two values i.e. 0 and 1. It uses a special function called as sigmoid function to compute this results.

$$\textbf{Sigmoid Function, } f(x) = \frac{1}{1+e^{-x}}$$

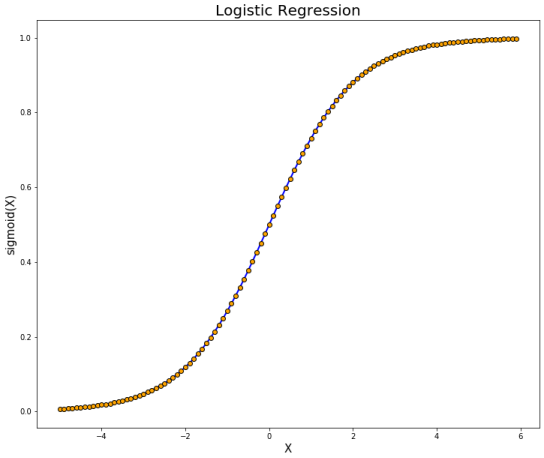


Fig 4.5 Logistic Regression

Gaussian Naive Bayes

Gaussian Naive Bayes is an extension of Naive Bayes Algorithm which is a classification algorithm which is used to solve problems of binary and multi-class classification. In this method, for each hypothesis the calculation of the probabilities are simplified to make their calculation manageable.
Gaussian distribution is the simplest function to work with to estimate the distribution of the data. In this method, the probabilities for the input values for each class are calculated.

Decision Tree Algorithm

Decision Tree Algorithm is a supervised learning algorithm that can be used for regression as well as classification problems, but it is mostly preferred for classification problems. This algorithm uses tree like representation to solve the problem where the leaf node is represented as class label while the attributes are represented as internal nodes. In order to build a tree, CART (Classification and Regression Tree) algorithm is used.

In this algorithm, to predict a class label for an input dataset the algorithm starts from the root of the tree. The values of the input attribute are compared with the root attribute. On the basis of comparison, the algorithm takes the decision and follows the branch corresponding to the input value and jumps to the next node accordingly. The algorithm again compares attribute value with the sub-nodes and moves further according to the decision made at that particular node.

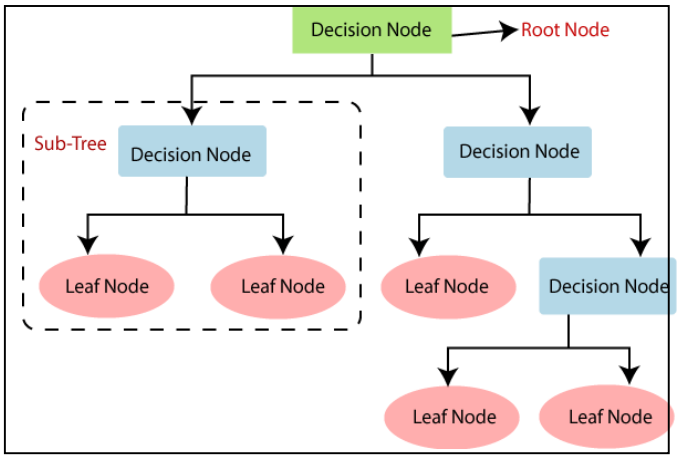


Fig 4.6 Decision Tree

But the most important challenge in the decision tree is to identify the best attribute for the root node and for the sub-nodes. To solve this problem, there is a technique which is known as Attribute Selection Measure or ASM. There are two popular measures for attribute selection:

a. Information Gain

b. Gini Index

a. Information Gain

Information Gain is a statistical measurement of changes in entropy after the segmentation of dataset based on attributes. It measures how much information a given attribute provides us about a class. According the value of information gain, the nodes of a tree are split and according to that the decision tree is built.

b. Gini Index

Gini index is a metric of impurity or purity used while creation of a decision tree in the CART (Classification and Regression Tree) algorithm. The attribute having low Gini index would be preferred as compared attribute having high Gini index.

K-Nearest Neighbors (KNN)

K-Nearest Neighbors is a simple, easy to implement machine learning algorithm which is used for both classification and regression problems but it is mostly used for classification problems.

K-Nearest Neighbors puts the new data into the category that is most similar to the available categories by assuming the similarity between by assuming the new data. It stores all the available data and thus classifies the new data point on the basis of similarity. KNN does not learn from the training dataset immediately, it stores the data and performs an action on the dataset at the time of classification.

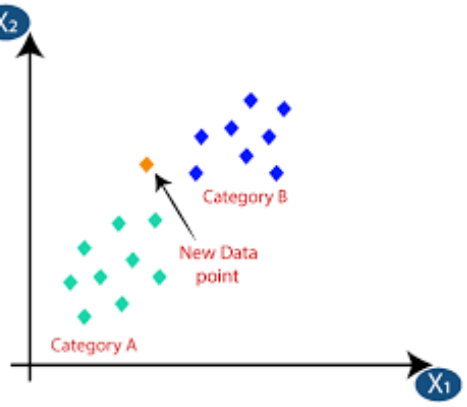


Fig 4.7 K-Nearest Neighbors

Support Vector Machine (SVM)

Support Vector Machine (SVM) is a machine learning model which is useful for classification as well as regression problems, but it is mostly preferred for classification problems.

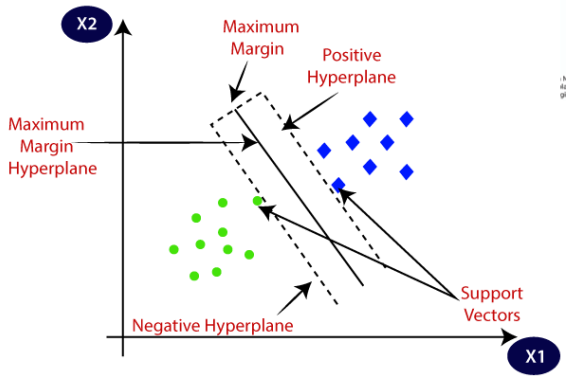


Fig 4.8 Support Vector Machine (SVM)

In SVM, each data item is plotted as a point in n-dimensional space (where n is number of features we have). The value of each feature is the value of a particular coordinate. After that, classification is performed to find the hyper-plane that differentiates the two classes very well. To create the hyperplane SVM chooses the extreme points or vectors that helps in creating the hyperplane. These extreme cases are called as support vectors and hence this algorithm is known as Support Vector Machine (SVM).

Study of Deep Learning and Neural Network

Deep Learning is a subset of machine learning which is nothing but a neural network which attempts to mimic the human brain through a combination of algorithms which use data inputs, weights and bias. These algorithms are called as Deep Learning Models. Some of these neural networks are discussed below.

Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is a biologically inspired subfield of Artificial Intelligence which tries to mimic the biological neural network. Similar to biological neural network, artificial neural network also have neurons that are interconnected to one another in various layers of network.

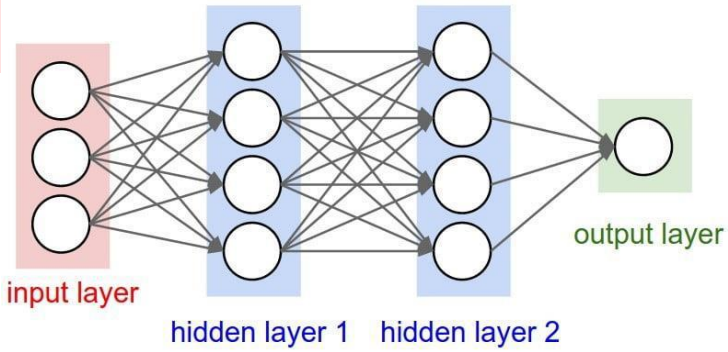


Fig 4.9 Artificial Neural Network Architecture

Input layer is the layer which accepts the pre-processed input data in various formats from the outside.

Hidden layer is the layer which performs the different types of mathematical computation on the input data to find the hidden patterns and features from the data.

Output layer is the layer which conveys the output/ conclusions of the model derived from all the computations performed.

Convolutional Neural Network (CNN)

Convolutional Neural Network (CNN) is a deep learning algorithm which can take an input image, assign importance to the various objects inside the image, differentiates one from the other. The data pre-processing required for the Convolutional Neural Network is very less as compared to other classification algorithms.

The architecture of Convolutional Neural Network is very similar to that of the connectivity pattern of the neurons in the human brain and is inspired by the organization of the visual cortex. That's the reason, CNN is very popular algorithm for the Image Classification and Computer Vision.

An image is nothing but a matrix of pixel values. Thus, for other algorithms image classification becomes a very tedious to detect the features or objects from an image because of the time consuming methods used for feature extraction. CNN makes this task easy, the main role of CNN in image classification is to reduce the images into a form

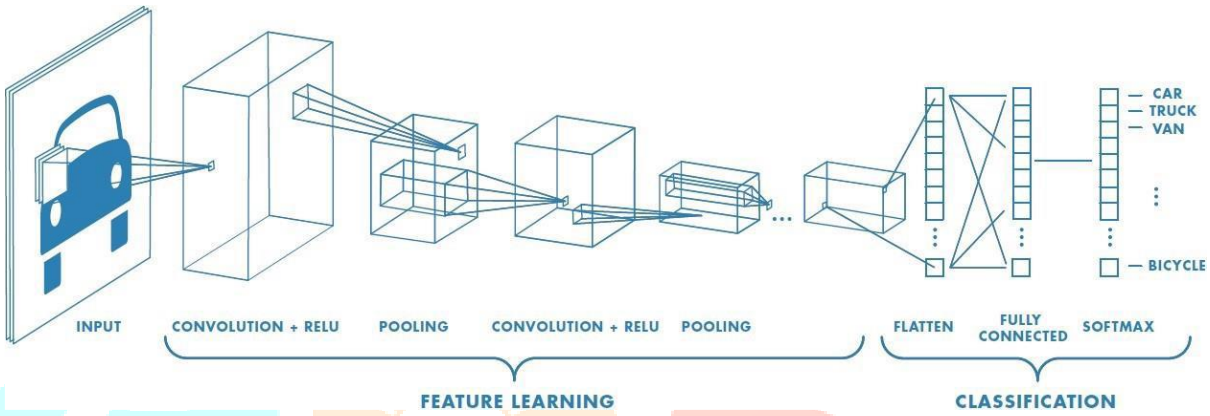


Fig 4.10 Convolutional Neural Network

Convolutional Neural Network architecture consists of three main layers which are discussed below.

a. Convolution Layer

Convolution layer is a very important layer in CNN. Most of the computation of CNN takes place in this layer. This computation requires an input data, a feature map and a feature detector which is also called as kernel or filter. The kernel is an important component which moves across the receptive field of the image, checking if the feature is present. This process is known as Convolution.

The kernel or feature detector may vary in size, but typically it is a 3x3 matrix. When filter is applied to a part of image, a dot product is calculate between the input pixels and the filter. This dot product is then fed to the array, after that the filter moves by a stride, repeating the process until the kernel has swept across the entire image. The final output from the series of dot products from the input and the filter is known as feature map or activation map.

b. Pooling Layer

Pooling Layer is also used to reduce the spatial size of the convolutional feature. This layer conducts the dimensionality reduction by reducing the number of parameters in the input. Similar to convolution process, in pooling process a kernel is moved across the entire input, but the difference is that the kernel does not have weights. Instead, it applies an aggregation function to the values within the respective field, populating the output array.

c. Fully Connected Layer

The pixel values of the input layer are not connected directly to the output layer in the partially connected layers, but in the fully connected layer each node in the output layer connects directly to a node in the previous layer.

The task of classification in this layer is performed based on the features extracted through the previous layers and their different filters.

V. CONSTRUCTION & WORKING

Construction

Automated Product Quality Inspection Using Computer Vision System consists of a frame for supporting the different components, Arduino board for operating the servo motors, servo motors for sorting the components to be inspected, camera is mounted on the top of the frame for capturing the images, PCB for connecting different wires, LED indicators and batteries. Fig. shows all the components as follows.

Working

The main component of automated product quality inspection system is a machine learning or deep learning model. We have studied and selected a deep learning model i.e. CNN earlier in chapter 3. This model is a decision maker of the system and working of the system is completely dependent on this model.

When we place a component on the base plate, the camera continuously captures the images of the component and sends these images to the model. The model is already trained evaluated on the similar data in a very huge quantity. Thus, the model is able to predict the accurate results after getting the images through camera. After predicting the accurate results, the result is sent to the Arduino board through PySerial module. PySerial is a python library which is used to connect the python program to the serial ports of a Arduino board.

After getting the results from the deep learning models to the Arduino, the Arduino script gets executed. According to the results obtained by Arduino, it gives command to one of the servo which then rotates through 90 degrees and pushes the component to a desired place. At the same time, Arduino also gives command to turn on one of the two LEDs. If result obtained is “OK”, then green LED gets turned on and if result obtained is “defective” then red LED gets turned on.

To push the component to a desired place, two arms are used i.e., one per each servo. These arms are moved through 90 degrees by servo, and mechanical advantage is obtained by the system which in turn helps in pushing the component.

Above steps are repeated for each component, this process takes very small time as compared to other conventional inspection processes and also reduces the man power required for this tedious and complicated task.

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