FOOD SCIENCE AND TECHNOLOGY

Lecture 52

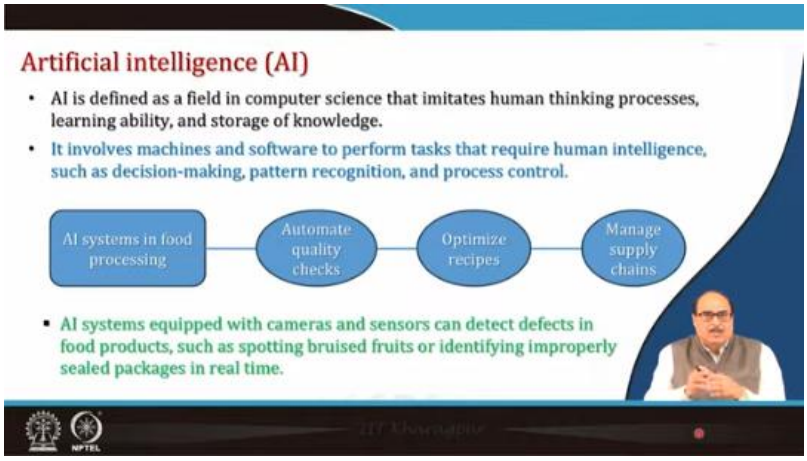
Lecture 52 :AI/ML Applications in Food Processing

Hello everyone, Namaste.

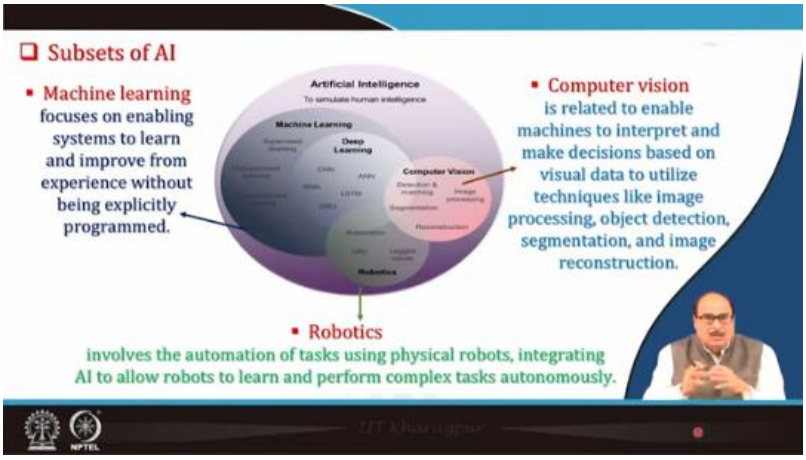
In the class today, we will talk about applications of artificial intelligence and machine learning in food processing.

We will discuss what is artificial intelligence? What is deep learning? and what is computer vision? Then we will also study the applications of artificial intelligence and machine learning in food manufacturing. And in the end, we will take one or two case studies to

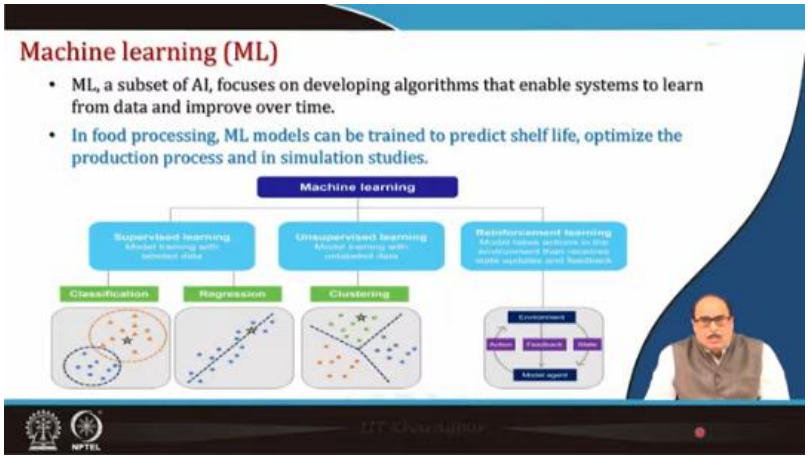
show the productive maintenance and quality control in food processing industry with the help of artificial intelligence and machine learning.



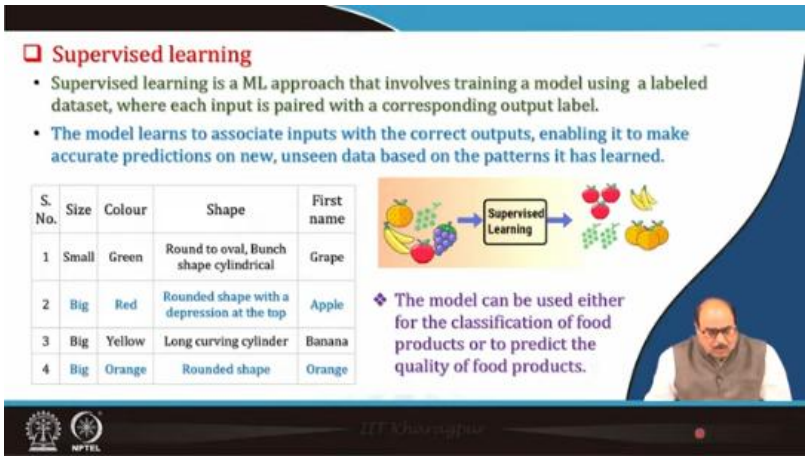
So, let us see what artificial intelligence means. This is the era of artificial intelligence. So, artificial intelligence is defined as a field in computer science that imitates human thinking processes, learning ability and storage of knowledge. It involves machines and software to perform tasks that require human intelligence, such as decision making, pattern recognition and process control. So, everything that we do with the help of a human mind is being done with the help of computers or with the help of suitable software that is artificial intelligence. So, AI systems in food processing can be used to automate quality checks, to optimise recipes, as well as to manage supply chains. AI systems equipped with cameras and sensors can detect defects in food products, such as spotting bruised fruits or identifying improperly sealed packages in real time and online under actual conditions.



So, there are three main subsets of artificial intelligence, and these are machine learning, computer vision, and robotics. Machine learning focuses on enabling systems to learn and improve from experience without being explicitly programmed. Computer vision is related to enabling machines to interpret and make decisions based on visual data to utilise techniques like image processing, object detection, segmentation, and image reconstruction. Robotics involves the automation of tasks using physical robots, integrating artificial intelligence to allow robots to learn and perform complex tasks autonomously.



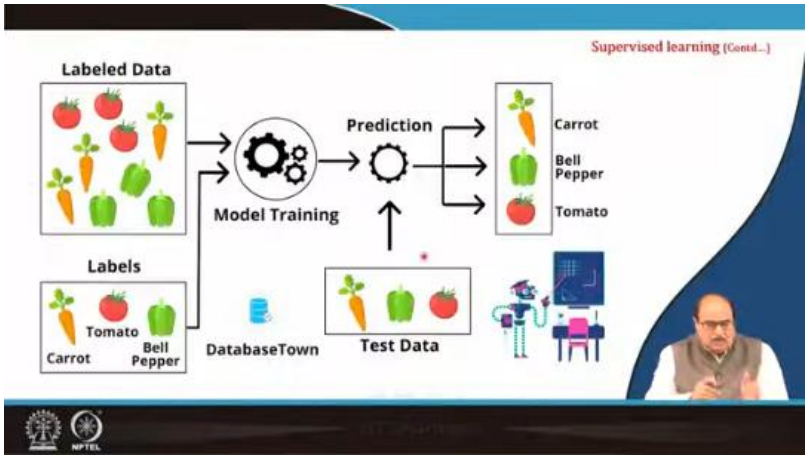
So, in this lecture today, we will discuss a few details of machine learning and computer vision and robotics. We will take a separate class, maybe towards the end of this module. So, what is machine learning? Machine learning, as I told you, is a subset of artificial intelligence. It focuses on developing algorithms that enable systems to learn from data and improve over time. In food processing, machine learning models can be trained to predict shelf life, optimise the production process, and can also be used in simulation studies. So, there are three types of machine learning objects that may be supervised learning, which is models trained with labeled data, then there may be unsupervised learning, that is the model trained with unlabeled data, and there may be reinforcement learning which models take actions in the environment, then receive state updates and feedback. So, supervised learning may use classification and regression, whereas unsupervised learning may be a form that does clustering, etc., and on that basis, it may make decisions and give the output.



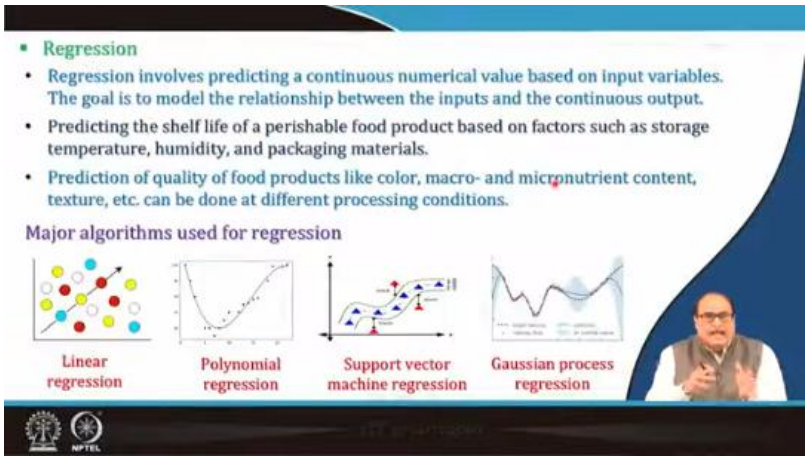
So, let us see in supervised learning that it involves training a model using a labelled dataset where each input is paired with a corresponding output label. The model learns to associate inputs with the correct output. enabling it to make accurate predictions on new, unseen data based on patterns it has learned. So, it basically gives the output on the basis of the labelled data. So, here in the example, it has been shown that there are different fruits, the objects that are fruits. So, like you can say, in the grapes, there are some green-colored grapes and also some purple-colored grapes are given. There are some apples, some bananas, and oranges, etcetera. So, all these are obvious; they are labelled as such, and on the basis of this data, it finally segregates, with the level of data. So, you can see that, like in the grapes, it is given a small green colour, round to oval, bunch shape, cylindrical, etc., and that is a grape. So, it has taken only the green colored shape and it has segregated and identified finally, these are the grapes. There may be like orange for orange the data labelling, which means that it is given as a big in shape, comparatively, it is orange in colour, rounded shape, and then if you find the object like this, it is defined as an orange. So, this way, the model can be used either for the classification of food products to predict the quality of the food products or based on the input data, and on the basis of the unseen data, based on the patterns it has learned, it gives the output.

So, you can see here again a little detail like the labels, as you are telling that is tomato, bell pepper and carrots, etc. So, these are the labels that are as if the algorithm or the software, given that if you find this type of object with these characteristics, etc., it can be a tomato or a carrot, etc. So, that is the way with the help of these label data, there are various fruits and vegetables in the system. So, it will take the labels and then, on the basis of the label data, identify the material, and then it takes the data from the database, stores

the data in the database, trains the model based on the labels and label data and uses the test data for the prediction.

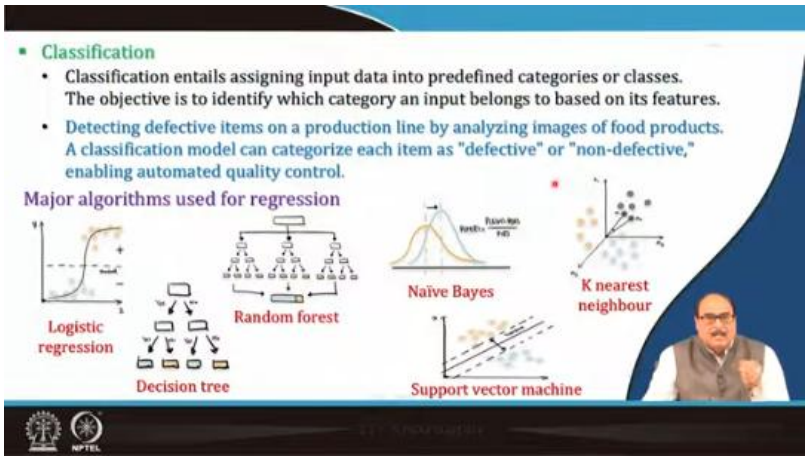


Finally, it recognises from this unknown subject that these are the carrots, these are bell peppers, and these are the tomatoes, etc., that is how this supervised learning system works. Then in the supervised learning, I tell you major algorithms which are used include linear regression, polynomial regression, support vector machine regression or Gaussian process recognition.

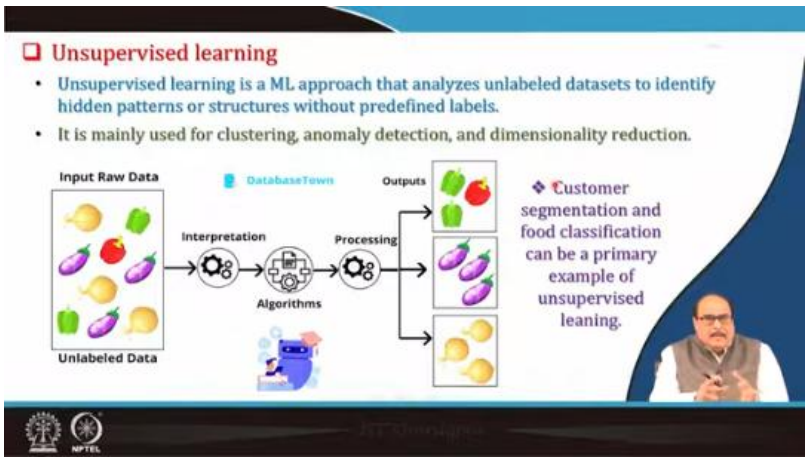


So, the regression in fact involves predicting a continuous numerical value based on the input variables. The goal here is to model the relationship between the input and the continuous output. Predicting the shelf life of a perishable food product based on factors such as storage temperature, humidity or the type of packaging materials, etc., can be analysed using these regression models. Prediction of quality of food products like colour, macronutrients, micronutrients, texture, etc., can be done even at different processing

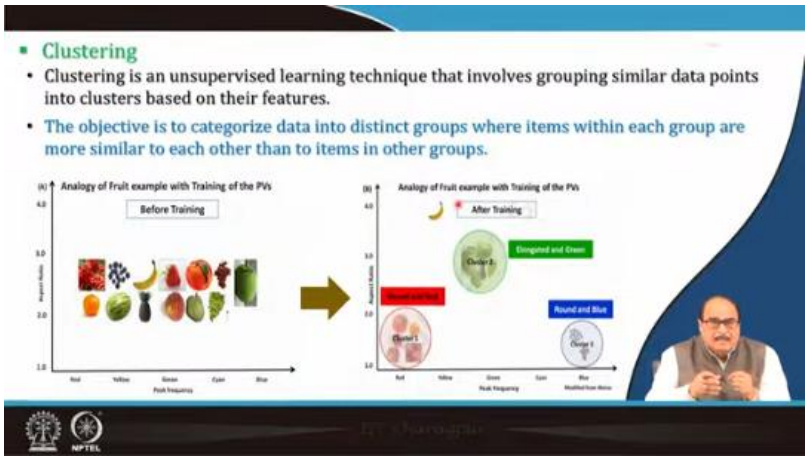
conditions. And that is what many times we do when we take that in our experiments, etcetera. We take the data and we analyze. We say that it is called regression analysis. Another thing linear regression, non-linear regression, polynomial regression, and so on. So, that is basically regression.



Then comes the classification. It entails assigning input data into predefined categories or classes. The objective here is to identify which category an input belongs to base on its features. Detecting, for example, defective items on a production line by analyzing images of the food products. So, here in this case, a classification model can be developed which can categorise each item as either a defective item or a non-defective item. And on particular quality attributes, and therefore, it enables automated quality control. Once you do this, you can automatically control the quality of the products online. So, major algorithms that are used for classification here include logistic regression, decision tree, random forest, naive bias, support vector machines and k-nearest neighbors, etc.

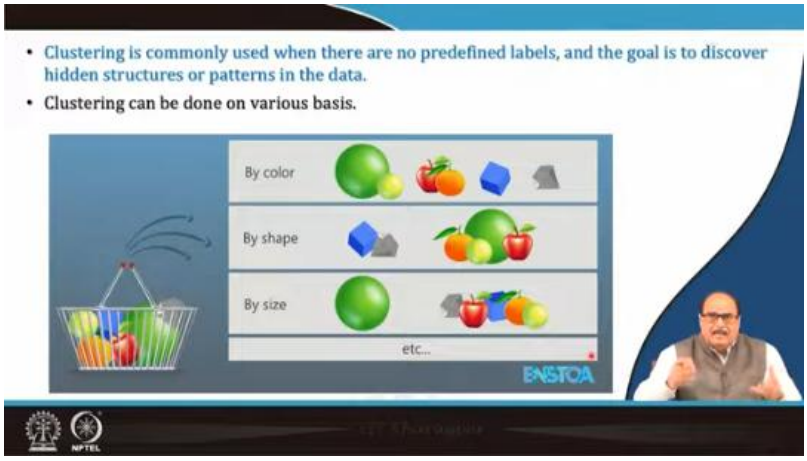


Then let us see unsupervised learning. This is unsupervised learning. analyses an unlabeled dataset to identify hidden patterns or structures without predefined labels. In the case of supervised learning, we have seen that the label was defined, but here the labels are not defined. So, an unlabeled dataset is used and it is basically used for clustering for anomaly detection and for dimensionality reduction, etc. So, here again you can see that there is the input raw data, there is data that is not labelled and various shapes, like vegetables and fruits that are there, but it has not been given what type it will be, a fruit or a vegetable and all those things. Which fruit is it? Is it brinjal or tomato, or another? It is not given, but yes. So, what it will do is that it will take the material, it will identify the characteristics, etc., and it will have its own interpretation, but yes, that if this particular object is like this type or this type. So, on the basis of this interpretation, it goes to the algorithm and it processes the data and then gives the output, and the output may be a similar object, which is put in one place. Like here you can see here it is bell paper, but even the red colour bell paper and green colour bell paper were also are there, but they have been put in one place means it classified is it has classified the material on the basis of their shape etcetera. So, the customer segmentation and food classification can be a primary example of the unsupervised learning that is what different materials we classify, we categorize or we group into the far in on the basis of the various property.

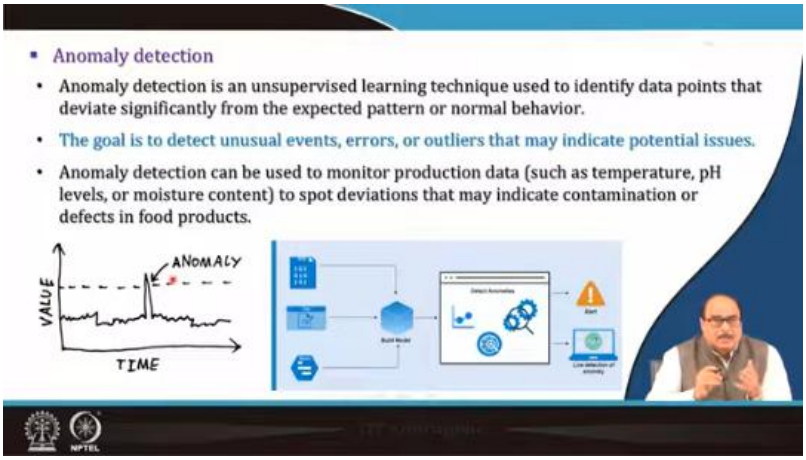


So, the clustering there is another thing that was earlier was the classification there may be another clustering. This clustering is a technique that involves grouping similar data points into clusters based on their features. And the objective is here to categorize data into distinct groups. where items within each group are more similar to each other than each other than to the items in the other group. And then again here you see there are this is a group of fruits or group of vegetables having different color, different size, different shape etcetera.

So, these were in the training, but after this was put into the model, after the model training, they have been grouped into various categories, like even red colour, which is one cluster, which is round and red. So, all the fruits, most of the fruits which were round and red, were put into one class or one cluster. Then, this second cluster, which is yellow in colour, and this is the curved shape, etc., is only one object. So, it is given one object, then in the cluster 2 maybe it is green in colour, it has other characteristics, etc. So, means that it is the elongated and green or even round and blue-colored objects, etc. So, it makes clusters of similar objects.

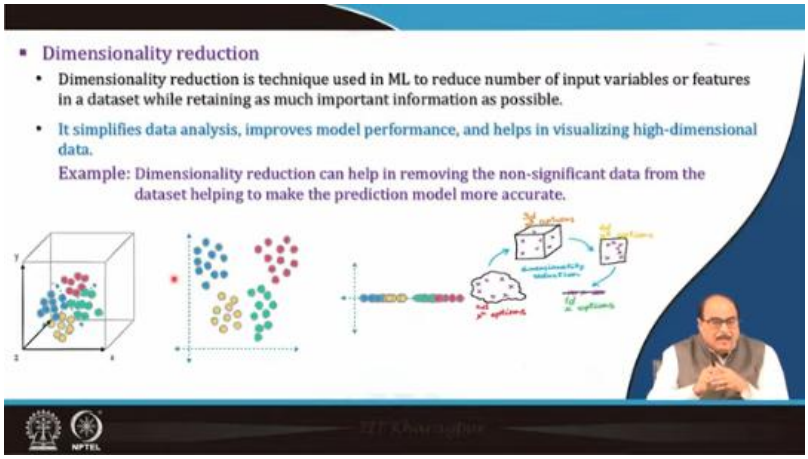


Clustering is commonly used when there are no predefined labels. The goal is to discover hidden structures or patterns in the data. Clustering can be done on various bases, like by colour, by shape, by size or by other attributes of the materials or attributes of the objects.



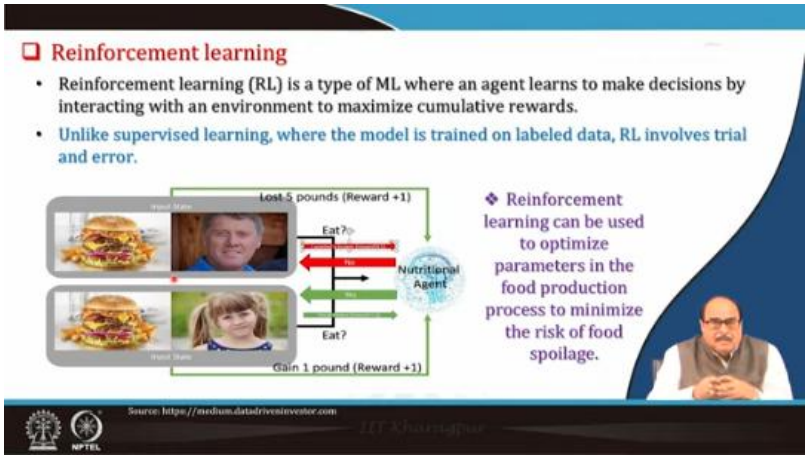
Then here in this case, just as you told, it can be used for anomaly detection or dimension reduction, etc. So, anomaly detection is generally used to identify data points that deviate

significantly from expected patterns or from normal behaviour. And the goal here is to detect unusual events errors or outliers that may indicate potential issues that is when you are conducting the experiment or doing the processing line and then the process may be due to one or the other region there may be some time a sharp that deviations from the expected line like you can see here that value in this case this is a very sharp very high value you have got it. So, you can say it is much above the expected. So, it can be an anomaly. So, anomaly detection can be used to monitor production data such as temperature, pH levels, moisture content, etc., to spot deviations that may indicate contamination or defects in the food products or that may result in quality reduction.

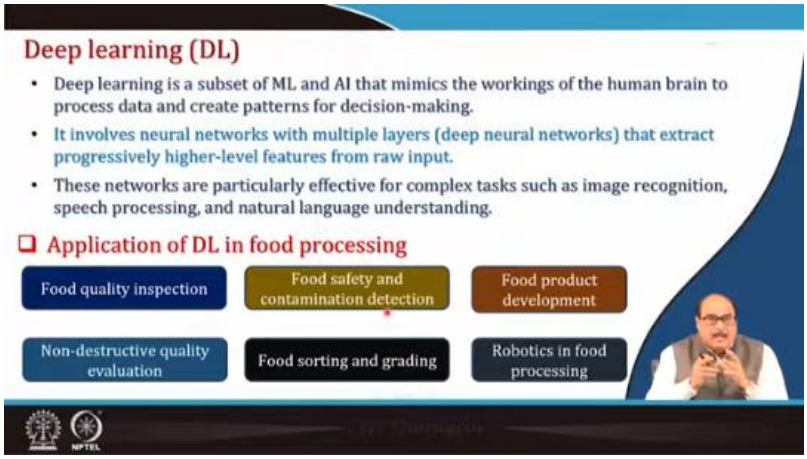


Dimensionality reduction is a technique which is used in machine learning to reduce the number of input variables or features in a dataset while retaining as much important information as possible. And it simplifies data analysis, improves model performance and helps in visualising high-dimensional data. For example, dimensionality reduction can help in removing the non-significant data from the database or data set, helping to make the prediction model more accurate. When you are fitting some model for equations, etc., there may be some data that is non-significant; they do not provide much, but this data. So, you can eliminate this data. So, from the remaining, you will get a better, more accurate model. So, that is what the dimensionality reduction means.

Now let us talk about reinforcement learning. Reinforcement learning is a type of machine learning where an agent learns to make decisions by interacting with an environment to maximize cumulative rewards. Unlike supervised learning, where the model is trained on labelled data, reinforcement learning involves trial and error. You can see here in the example that there are these burgers here, and there are two individuals.

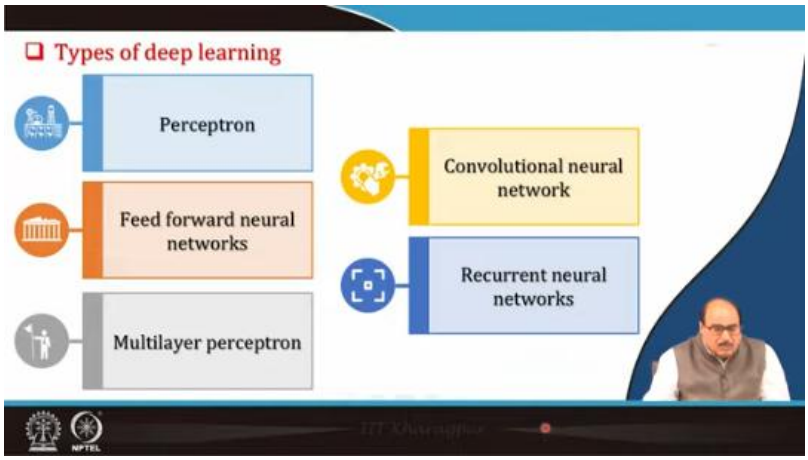


One is that he is a little bit fat and an overweight person, and his main objective is to he should reduce his weight. So, now the decision is that considering this fact, he is thinking whether he should take this burger or not. Whether he should eat this burger or not, because it may give him more nutrients than what is desired, and it may result in further weight gain. So, he decides, no, no, that I will not take it. So, this was a good decision for him, and in the process, he lost some weight and he got some reward points, but on the other hand, this. small girl, alright, because here she has to gain weight; she has to grow up. So, she decides that yes, I will eat this, and again, this is a good decision on her part, and again, she got a reward. So, this reinforcement learning can be used to optimise parameters in the food production processes, minimise the risk of food spoilage and so on. There are several cases where it can be used.

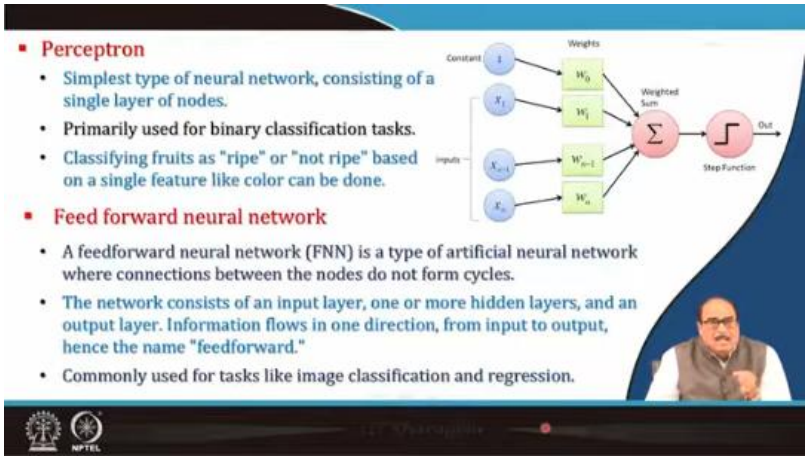


Now, let us talk about deep learning. Deep learning is a subset of machine learning and artificial intelligence that mimics the workings of the human brain to process data and

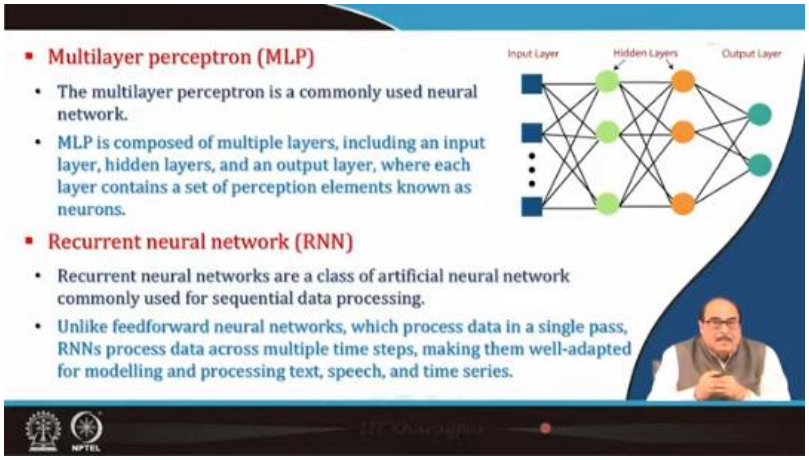
create patterns for decision-making. It involves neural networks with multiple layers that extract progressively higher levels of features from raw input. These networks are particularly effective for complex tasks such as image recognition, speech processing, and natural language understanding. So, deep learning can be used for various purposes in food processing, such as food quality inspection, food safety, and contaminant detection. It can also be used for food product development, non-destructive evaluation of the quality of food materials, sorting and grading of various foods, or even working with robotics. So, various robotics that are trained, and this is the deep learning and development of robotics and its application in food processing.



So, there are different types of deep learning, such as perceptrons. feed forward neural network, multilayer perceptrons, convolutional neural network and recurrent neural networks.

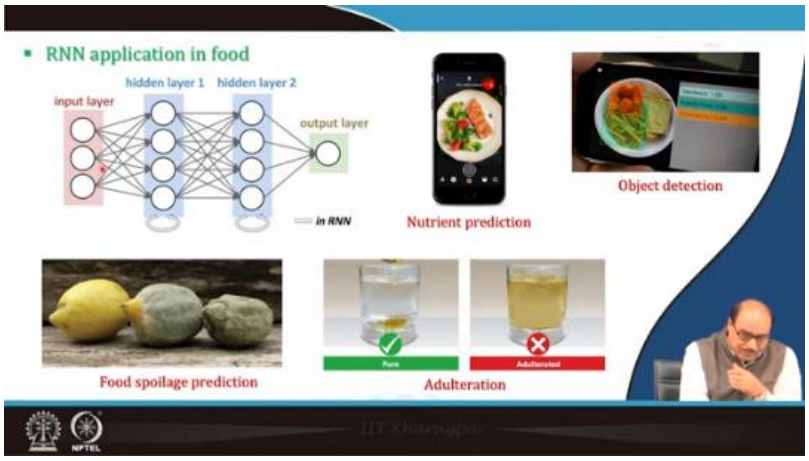


So, let us briefly see about this, like perceptron. It is the simplest type of neural network, consisting of a single layer of nodes, as you can see here in the figure that is given. So, it is primarily used for binary classification tasks, classifying, for example, fruits as ripe or not ripe based on a single feature like colour or any other features; it can determine whether this is good or bad. Then, in the feed-forward neural network, it is a type of artificial neural network where connections between the nodes do not form cycles. The network consists of an input layer, there will be one or more hidden layers, and an output layer. Information flows in one direction from input to output, and hence the name given is feed-forward. It is commonly used for tasks such as image classification and regression.

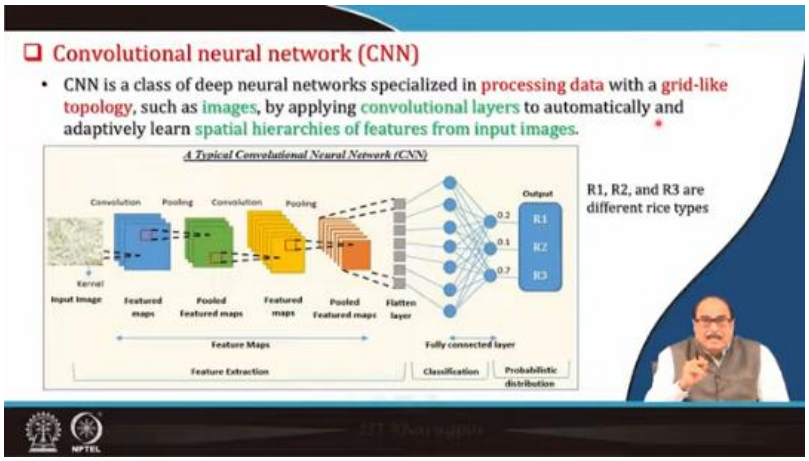


Then, the multi-layer perceptron MLP is a commonly used neural network. It is composed of multiple layers, indicating an input layer, a hidden layer and an output layer, where each layer consists of a set of perceptron elements known as neurons. You can say that these are the input layer, there may be several hidden layers, and it processes the data and finally, gives the output. In the recurrent neural network. It is a class of artificial neural networks which is commonly used for sequential data processing. Unlike feed-forward neural networks, which process data in a single pass, this recurrent neural network processes data across multiple time steps, making it well-adapted for modelling and processing of text, speech, time series, etc.

You can see those applications of RNN reinforced neural network. Input layer there are hidden layers etcetera these takes the input processes the data etcetera and then gives output and it can be used very well for the nutrient prediction that is what is the food in the food, what are the macro nutrient, micro nutrient etcetera even for the object detection for example, here there is a burger, there is some fries, some beans etcetera.

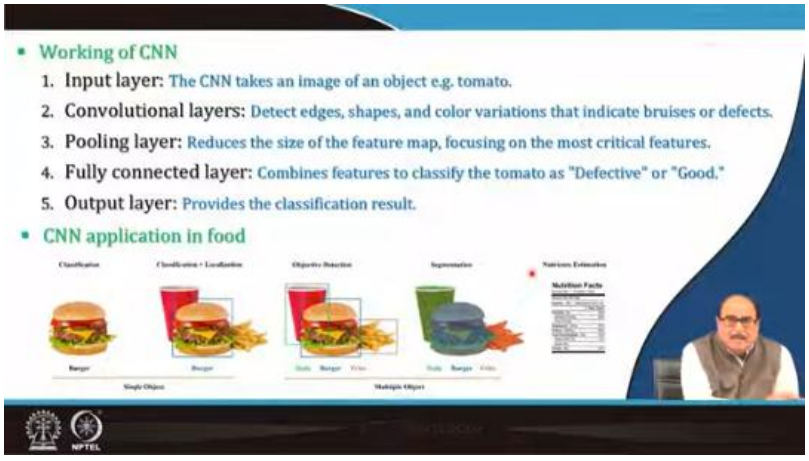


So, these can be identified by using this network in the system, which can be used for food spoilage reduction or even for the detection of adulteration in foods.

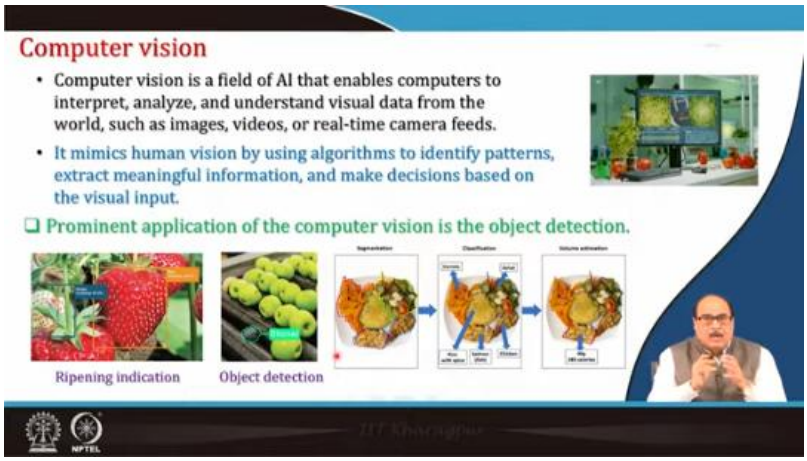


Convolutional neural network is a class of deep learning network that specialises in processing data that is designed for difficult objects, such as data with a grid-like topology. such as images by applying convolutional layers to automatically and adaptively learn a spatial hierarchy of features from the input images. For example, you can say here that there is supposed to be a mixture of different rice. And it may be rice varieties, broken rice, old rice, long rice, or medium rice. So, you can say there are at least three types. So, what we will do then when it comes to kernels and these rices, etc., they will all have very minute differences, might be there in their characteristics, in their features. So, makes it a little difficult task here, but yes, that is the kernel that is the input image. It does the convolution like it features the maps characteristics are taken, and they are pooled. So, this means the

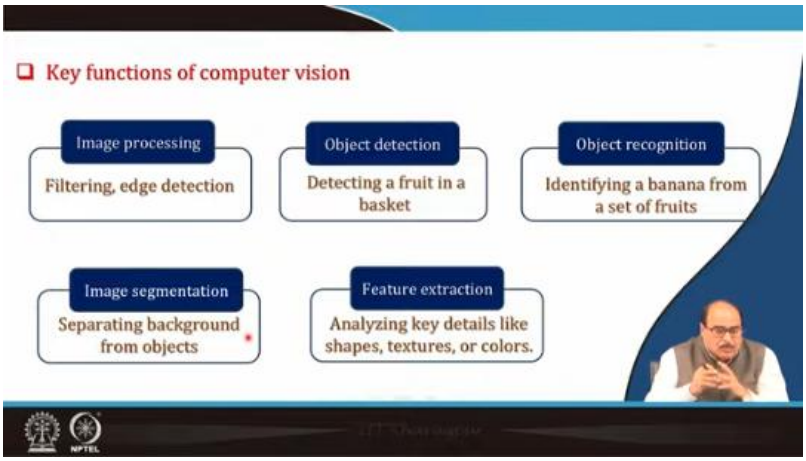
step is the features extraction that is whether it takes that length, width, size, color, chalky grain or even sometimes there are infections on the very fungus infections which cannot be easily seen, but this that object experiment that is instruments etcetera can be used they can measure that and then it goes into the system. Take the extract the feature map the features and finally, it sent to the different patterns where the it is the data is processed and then it is a classifies it and even it gives probabilities distribution that is yes in the whole mixture what are the there are the 3 types of rices R 1, R 2, R 3 and it is 20 percent R 1. 10 percent R 2 and 70 percent R 3 like the similar objects it is gives and then finally, gives the output. So, that is the CNN or convolutional ah neural network.



So, the working of the neural network in this CNN shows that there is an input layer. The CNN takes an image of the object. In the earlier case, it was rice; we can take a tomato as an example now. Then it detects the edges, shapes, and colour variations that indicate even differences in the different tomatoes, such as bruised tomatoes or other defects. The pooling layer reduces the size of the feature maps and focuses on the most critical features. Then, finally, it combines the features to classify the tomato as a good tomato, ripe tomato, unripe tomato, bad tomato, or defective tomato, etc. So, finally, on the basis of that, it provides the classification results and gives. It can even be like an application that classifies. Suppose here is a single object classification. There is a burger as well as some soda water and some other beverages. So, it will identify that now it is the burger. Or it can even detect multiple objects, such as in this system, where there is a fry, a burger, and a soda. So, it will identify all right, then segregate, etc., and it can even give the various nutrients present in the different foods.

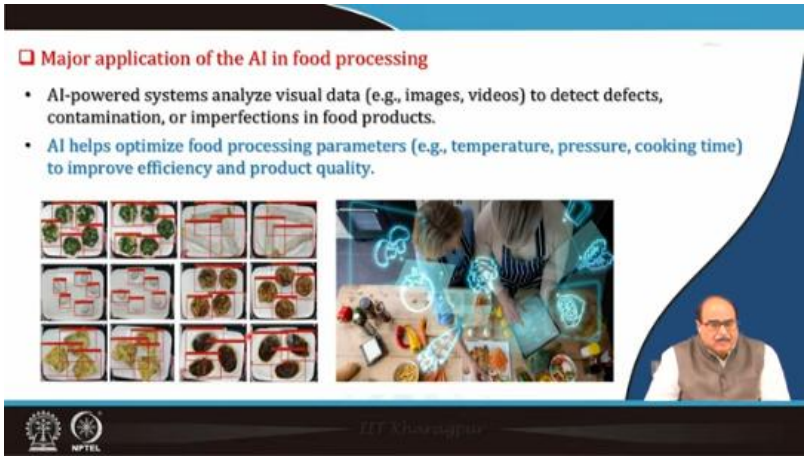


Now, we will talk briefly about computer vision. Computer vision is a field of artificial intelligence that enables computers to interpret, analyze, and understand visual data from the world, such as images, videos, or real-time camera feeds. It mimics human vision by using algorithms to identify patterns, extract meaningful information, and make decisions based on visual inputs. So, prominent applications of computer vision in food processing may be object detection, such as whether there is a ripening indication, which can be used to detect larger objects, like bigger fruits or defective fruits, or even in the fruits, there are stones, etc. So, that can be used for grading for the segregation of other materials and so on.

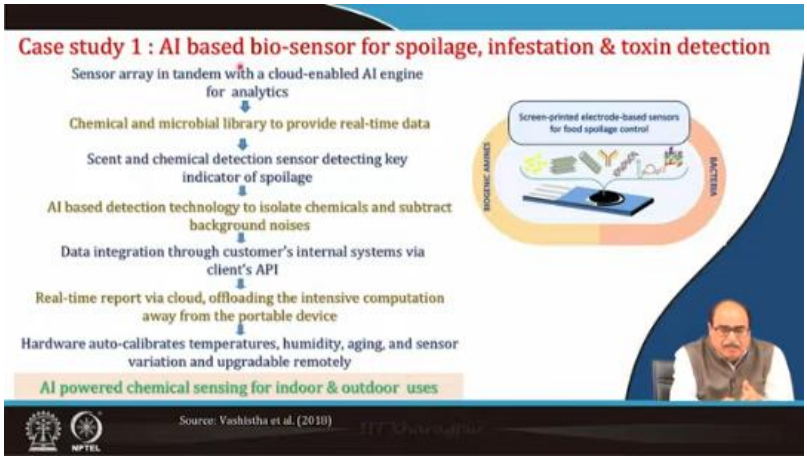


So, the key features of computer vision include image processing, such as filtering, edge detection, etc., or image segmentation, separating background images from the objects. Detecting a fruit in a basket, for example, object detection is what the object is there are in the basket. So, there will be fruit, there will be vegetables, there might be some stones, etc.

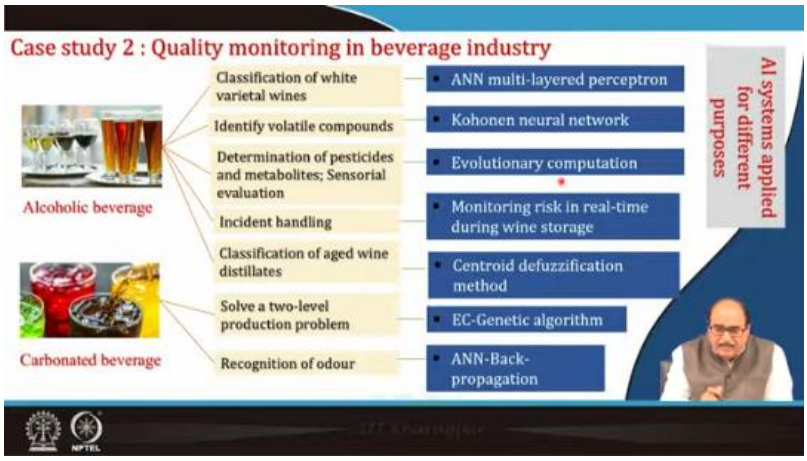
So, it can detect the fruits. Similarly, feature extraction that analyses key details like shape, texture or colour and then on the basis of that, object recognition is identified. For example, a banana from the set of the fruits from the basket, etc. So, all this can be done using computer vision technologies.



So, major applications of artificial intelligence in food processing include artificial intelligence-powered systems that analyse visual data like images, videos, etc., to detect defects. contaminations or imperfections in food processing. Artificial intelligence helps optimise food processing parameters such as temperature, pressure, cooking time, or other processing parameters to improve efficiency as well as the quality of the product during the process, and it can be used online in real-time management of data and management of process variables.



So, let us see a case study, Case Study One, where we are using AI (artificial intelligence) powered chemical sensing for indoor and outdoor uses, such as AI-based biosensors for spoilage, infestation, and toxin detection. So, in the next class, we will discuss sensors and instruments, what the different sensors are, etc. So, here, there is a you can say different sensor array in tandem with a cloud-enabled AI engine for analytics, and accordingly, the sensors can be put into that, it may be a chemical sensor, it may be a microbiological sensor, it may be a physical sensor, or a biological sensor. So, a different set of sensors can be put into the system, and these sensors take the data, particularly the AI-based detection technology, to isolate chemicals and subject them to background noises, etc. Then, it data integration through customers internal system via client API which is followed by real time report by a cloud offloading the intensive computational away from the portable device or then finally, it goes to the hardware, there is a hardware which auto calibrates temperature, humidity, aging and sensor variations and upgrades upgradeable remote. So, all this information is provided to the algorithm. So, this algorithm and the sensors they use and every sensor, can leverage the collective all right for all the sensors. And finally, it this sensor that data which is processed by the sensor is ah processed evaluated and then it material like what we discussed earlier it will give the output that yes that the it is a having a toxin or it is a spoiled or all those things on the basis of the output given by this or input taken by the sensor, the data processor and then finally, the analysis result outputs.

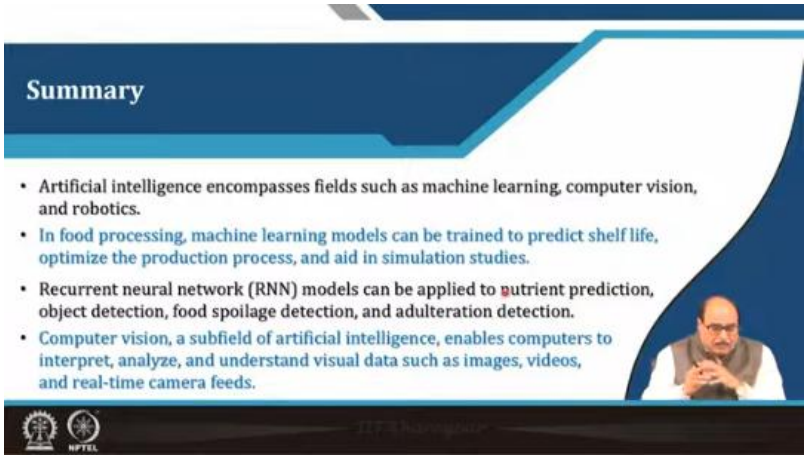


Then, here is another case study we are taking for quality monitoring in the beverage industry. That is where, suppose there is an alcoholic beverage industry or a carbonated beverage industry. So, what are the different AI systems which can be applied for different purposes? For example, in alcoholic beverages, one may want to find the classification, such as the classification of white varietal wine. That is, whether it is white wine, red wine,

or pink wine, and whatever the variety. So, here, a multilayered perceptron can be used to identify volatile compounds in the body. A convolutional neural network can be used for the determination of pesticides and metabolites, if any, which were present in the grapes and might have come into the wine, or for sensory evaluation, and evolutionary computation can be done. For incident handling, monitoring risk in real-time during wine storage, or classification of aged wine distillates or freshly prepared wine, etc., for these purposes, one can use the centroid diffusion method. Then, in the carbonated beverages, to solve a two-label production problem, a genetic algorithm can be used for recognition of odor; an ANN backpropagation model can be used. So, these are the various things which can be used in AI systems for the quality monitoring of the beverage industry.

Major applications of AI in food processing include AI systems analysing real-time data from sensors to detect contamination or deviations in processing conditions. AI-driven robots are considered robots that perform repetitive tasks such as sorting, packaging, portioning with high precision, and even these robots are used in various operations for making and keeping various operations in food processing, like handling, conveying, grading, sorting, or now for transporting materials. So, for various purposes, we will take the robot, especially in the next-to-next lecture.

So, finally, I would like to summarise this lecture by saying that artificial intelligence is a very important area. Now, it is coming, particularly in the case of Industry 4.0 and 5.0, this is the artificial intelligence and machine learning era. It encompasses machine learning, computer vision, robotics, etc., and it can be used in food processing. Machine learning models can be trained to predict shelf life, optimise the production process and aid in simulation studies. The RNN models can be applied to nutrient prediction, object detection, food spoilage detection, and adulteration detection.



Computer vision, a subfield of artificial intelligence, enables computers to interpret, analyze and understand visual data such as images, videos, and real-time camera feeds, meaning that you can say that is whatever a human brain can do a human can think, can make decisions, the same thing with the help of software, with the help of computers, this AI and ML does it.

So, these were the references used in this lecture.

I thank you very much for your patience.