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A Review on AI Based Target Classification Advanced Techniques

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Abstract: **As we know that surveillance in the air has become one of the important defence precautions that we must take. So, for that reason radar plays a very important role as it captures images that can fool a human eye and then converts it into process able data. Then this data can be sorted and classified by our Artificial Intelligence Algorithms. Even here we have a variety of models for this purpose but it is up to us and our data and the output we expect, which Algorithm should be used. Here in this Survey, we have researched on different Radar Systems as well as the different signals that it generates and many AI Algorithms that are currently used in the industry.**

Keywords: **Radars, Artificial Intelligence, sUAV detection techniques, Classification Techniques, CNN.**

1. INTRODUCTION

A radar is device from which we get different images that are converted to different signals and given in the form of input to the AI algorithms. There are different detection techniques for sUAVs which can be a harmful threat to our nation. Illegal use of these sUAVs has been increased in these few years which leads us to finding new variations in our techniques. In this survey we have put forth the different techniques used in the classification of the targets, which are produced by the radars [1].

1.1 RADARS

Radar means Radio Detection and Ranging. It is an electromagnetic device that can detect, track, and find objects of different types at far distances. It works by sending electromagnetic radiation in the direction of what are called targets and then listening for the echoes that come back. The targets may be automobiles, space bodies, ships, planes, boats, spaceships, birds, insects, rain, and even moving cars. Radars can track the presence, position, and velocity of these objects and also their size and shape. Radars have the capacity to identify distant objects in bad weather and precisely calculate their range and distance. Radar is an active sensing technology because it contains a transmitter that it has its own light source to find objects [2-6]. It generally runs between 400MHz and 40GHz as well as in optical and infrared frequencies which are both employed for long-range applications at lower frequencies.

Wireless Radar transmitters can be classed into two types: coherent and incoherent. Coherent transmitters generate a signal with a predetermined phase before sending it. In incoherent transmitters the phase of the signal is unknown prior to the start of the broadcast output. Transmitters also fall into two categories: oscillators and power amplifiers. The invention of magnetron transmitters in the late 1930s led to the creation of radar systems that could operate at microwave frequencies, as described in the radar history section [8-10]. Despite its shortcomings, the magnetron transmitter is used in low-average power applications such as aerial weather-avoidance radar and ship navigation radar. The magnetron is a form of power oscillator since it self-oscillates and generates microwave energy when voltage is applied [11]. Radar receivers use Superheterodyne technology. It removes receiver noise and clutter that hinder detection in order to preserve the required echo signals. It also boosts the weak signals that are received, so that the receiver's outputs are strong enough to activate a display or a computer [12,13].

The Radar antenna sends out radio waves which come back when they hit anything in its path. It returns a very small amount of waves energy back to the transmitter. The Antennas of the radar are differentiated into two categories based on physical structure. Curved Surfaces are used for both signal transmission and reception in Lens Antenna. These are made up of glass and makes use of the lens' converging and diverging characteristics. Its frequency ranges from 1GHz to 3GHz for different applications. Another type is a Parabolic Antenna which has a parabolic cross section. This useful for directing radio waves in narrow beam and also while receiving from a particular direction [14-19].

1.2 ARTIFICIAL INTELLIGENCE

According to Survey of Intelligence [20-23], Artificial intelligence field seeks to automate tasks that need human intelligence. This has been employed over the past 20 years as a development tool in a variety of industries, including forecasting, healthcare, security, and it has also considerably enhanced the performance of both production and service systems Artificial Intelligence is used for a variety of ways for training the soldiers in various military operations. Different armies have already begun launching various sensor simulation programmes [24-26]. Artificial intelligence will provide reasoning with the help of comparable external facts, internal factors, accumulated knowledge from the past and model an algorithm to apply it to our problems. This information can help identify any illegal or suspicious conduct and notify the proper authorities. Target Detection and Classification can be done using AI based Robotics and IoT Enabled techniques. Modern weapons now include AI-enabled technologies. Modern missiles can calculate and analyse the target level for kill zones without the involvement of a human. Cyberspace is now viewed in military circles as the third combat front, behind land, sea, and air. The security of the entire region might be put at risk by a maliciously compromised network. Defence organizations utilise machine learning to anticipate threats and guard against unauthorised breaches. The most common method of detecting intrusions is to label the network as either normal or intrusive. AI-based methods help to increase the categorizations accuracy. One of the most important factors in determining whether or not a military operation is successful is logistics. Military logistic systems incorporate ML and GIS analysis to reduce effort, time, and error [27-28].

2. RADAR SYSTEMS

Radar systems are available in many different sizes ranging from small to very big models with different power usage and frequency availability. The transmitter produces a high-power signal that the antenna radiates. An antenna essentially serves like a Transducer to covert the electromagnetic energy from the transmission line to radiation space and also the other way round. The duplexer allows for simultaneous broadcast and receiving using the same antenna [29-32]. The receiver picks out and amplifies radar echoes such that a human operator may view them on a screen similar to a television or that a computer can interpret them. The Signal Processor gives us the difference between the signals of potential targets and noise. We also have a Radar Equation which gives us the Maximum range of the Radar theoretically and to get to know the factors affecting radar performance. The radar range equation is an important tool for the different aspects for assessing the performance of radar or designing of new radar systems. In the Fig. 1, the basic classification is done as Primary Secondary Radars. The Primary Radar emits high frequency waves towards the target which are reflected and received back to the same radar from which the information is extracted. The Secondary Radars are the exact opposite to primary type of radars, as they need transmitters or receivers fitted inside the aircrafts called as transponders. The Primary type of radars are further divided into Continuous Wave and Pulse depending on its working [33-37]. A Pulse Radar is a type of radar that makes use of pulse signals to identify stationary objects. The antenna will send out a pulse signal each time the clock beats. The time gap between the two clock pulses must be carefully chosen to ensure that the echo signal corresponding to the current clock pulse is received before the next clock pulse. In a radar system like pulsed radar, the electromagnetic waves are emitted from the antenna in short intervals. This means that before the next burst of waves is sent, the waves are temporarily stopped to allow the wave to reach a reflecting object and some of the energy to return to the same antenna. We can find out the accurate distance if time and techniques used are correct. Since the waves travel at a given speed, we can simply translate the time recorded into distance or range values even if these units are measured in time increments [38-42].

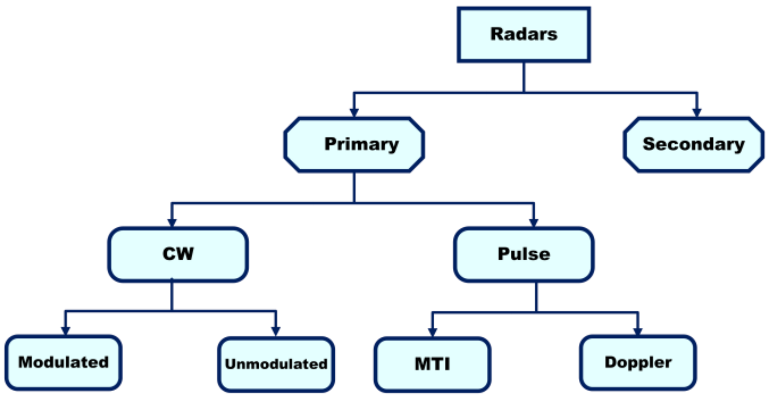

Fig. 1 Classification of radar systems

The instantaneous rate in the change of the target range is measured with CW radar. A direct measurement of the returning signal's Doppler shift is used. The Doppler shift is the electromagnetic wave frequency shift by the movement of target or the radar. Which means while the transmitter is moving the wavelength is shortened by a factor proportional to the rate of movement in the direction of propagation. As the wavelength decreases, the frequency must increase since the speed of propagation remains constant [43]. This phenomenon is known as Doppler shift which causes the transmitted frequency to increase. The frequency received will also rise if the receiver is travelling against the direction of transmission. These effects can be combined together to find the total shift in the frequency. Radar for Moving Target Indication also known as MTI Radar like a Pulse Doppler Radar. Continuous Wave Radars can be classified into the following two types based on its modulation types, Unmodulated Continuous Wave Radar and Modulated Continuous Wave Radar. CW unmodulated radar uses a continuous signal to identify moving objects and is also popularly known as CW Doppler Radar. One of the two antennas' is used for signal transmission and the other antenna is utilized for signal reception [44-48]. The speed of the target is measured instead of its distance. A constant frequency and constant amplitude is emitted by a unmodulated CW Radar. Some of the applications of Unmodulated Continuous Wave Radar are Traffic control radar, Speed gauges, Doppler radar motion sensor, Motion monitoring and many more. Frequency Modulated Continuous Wave Radar employs frequency modulation therefore it gets the name. Considering the target's speed, it also calculates the target distance from the radar by comparing the frequency of the received signal as its reference the distance is calculated [49-53].

There are a lot of possible modulation patterns which are used for several measurement techniques. Sawtooth Modulation is a modulation in which the modulation pattern is used in a relatively large range combined with a tiny influence of Doppler frequency is used in maritime navigation radar [54-55]. Another type is Triangular modulation which allows easy separation of the frequency difference of the Doppler frequencies. Next is Square-wave modulation also known as frequency-shift-keying used for very accurate distance measurement by phase comparison of two signal frequencies. Stepped modulation can be said to represent staircase voltage used for interferometric measurements by expanding the range. Sinusoidal modulations have been used in the past only for the linear part of the sine functions [56-60].

In Synthetic Aperture Radar (SAR), a sensor creates its own energy and then detects the amount of it that is reflected back after coming into contact with things. SAR is an active data collection technique. The generated radar imaging is based on the intensity and time delay of the returned signal, which are mainly determined by the roughness and electrical conductivity of the viewed surface as well as by its separation from the orbiting radar [61-62].

2.1 RADARS SIGNALS

Different deep learning algorithms use different radar signal representations. Representations are used so radar signals may be used as input data to the various number of deep learning algorithms is one of the trickiest parts of utilising radar data with Machine Learning. These consist of radar point clouds, radar occupancy grid maps, range doppler azimuth tensors, microdoppler signatures, etc. Every Signal representation has its own advantages and disadvantages while considering working with a particular algorithm [25],[63-68]. The ability of the high-resolution radar sensors to distinguish between thousands of reflections point every cycle improves their pixel-level identification capabilities. The reflection amplitudes of all detection spots are corrected, normalised, and then translated to the detection probability based on a model of a radar sensor. Based on the movement of the ego vehicle, the a posteriori occupancy probability is computed to produce the occupancy grid map. In the binary grid map produced after the occupancy grid map, the grids in the obstacle regions are classified as occupied [26],[69-73].

Range-Doppler-Azimuth map is like a 3D data cube. Range-velocity is shown by the first two dimensions, while target location is indicated by the third dimension i.e., azimuth angle. The 3 dimensions are represented in FFT are range FFT, velocity FFT, angle FFT, which are used to build the tensor by progressively performing it on the radar to get back samples to produce the whole map. To determine the range of the radar, range FFT is used to the time domain signal. The Range-Doppler spectrum is then produced using velocity FFT over the chirp's frames, and it is then sent to the CFAR detection algorithm to construct a 2D sparse point cloud that can tell actual objects from clutter [74]. A 3D Range-Velocity-Azimuth map is produced by performing an angle FFT on the highest Doppler peak of each range bin also known as detector Doppler. Various deep learning algorithms have frequently used in its spectrums is extracted from automotive radars sensors which are fed as inputs for a variety of tasks right from identification in autonomous driving systems to obstacle detection [25], [75-79].

Micro-Doppler is produced by the periodic movements of any object which produces the side bands near the doppler frequency. For Coherent radars the change in the doppler will be proportional to change in the successive phase values. The data is used to create a range-Doppler plot or a velocity vs time spectrogram to visualise and analyse the characteristics of Micro-Doppler [80]. Toget Doppler information in FMCW radar, the data is transformed using a 2D Fast Fourier Transform. At the beginning every chirp is subjected to FFT which gives us the range profile. The Short Time Fourier Transform which differs from the Fourier Transform in that it gives both time and frequency information. This is accomplished by applying Fourier transform on each segment [27], [81-83].

The concept of radar point clouds is taken from the Li-dar sensors in computer vision applications. Point clouds are unorganized or dispersed 3D representation of information obtained by sensors keep the geometric information already present in the environment. Compared to 2D grid image representations, this type of 3D data representation offers very high-resolution data that is spatially rich and provides depth information. Thus, they are the representations that are most frequently utilised for a variety of scene comprehension tasks, including object segmentation, classification, detection, etc [25], [83-87].

2.2 APPLICATIONS

Some of the major applications of Radars are Satellite Surveillance, Ballistic Missile, Ground Probing, Airborne combat, Over the Horizon Radar, etc [1] This research uses ground penetrating radar (GPR) technology, which incorporates complicated qualitative characteristics and 2-D scattering pictures, for the identification and classification of buried items like explosive ordnance. Illegal Drone detection is another common use show in paper [2]. The classification of UAVs which is the main objective of the paper is done using different techniques such as Convolutional Neural Networks [4,6,10,11], Deep Convolutional Neural Networks [6,9,17,18,19], SVM [12,16], Non-maximum suspension [5], KNN classifiers, ANN, and many more different architectures which change according to its applications [87-91].

3. SUAV DETECTION TECHNIQUES

Many techniques are employed such as video detection, sound detection, radar detection, and Radiofrequency detection for the detection of different sUAVs. These techniques give us outputs which are fed to our algorithm and then the classification takes place. In the Table1 we have enlisted the three different types which are mainly used. We have seen the mechanism behind them and the conditions in which they are favorable to be used and their drawbacks too [92-95].

3.1 CLASSIFICATION TECHNIQUES

Artificial Intelligence can be said to be a program that recognizes, understands, learns and adapts itself. It has a subset called Machine Learning which improves its accuracy of detection as we provide more and more data to it. Deep Learning, in which multi-layered neural networks learn all the smallest features from a large amount of data, is a deeper subset of machine learning.

Classification means sorting the data as per our needs or into sub-sets which is used in ML. Some of the Techniques for radar target classifications are, cluster identification, target classification and target tracking which is mentioned in the paper [1]. All these are used as per our problem and application. Some of the Popular Classification Algorithms are specified in the Table 2. Each one has its own applications which give us greater accuracy [70], [95-98].

Table 1. sUAV detection Techniques

TECHNIQUES	VIDEO DETECTION	SOUND DETECTION	RADIO FREQUENCY DETECTION
MECHANISM	Camera sensors are used.	Microphones are used to detect ambient sounds.	sUAV transmit radio frequency while communicating which can be detected.
ADVANTAGES	Can know the difference between sUAV and birds.	Very minute actions can be detected.	Clutters & interference problems can be avoided.
DISADVANTAGES	Cannot detect in foggy conditions/fast-moving objects/at Night. Detects only in its Line of Sight.	It can detect to a certain Distance.	Radiations can be harmful for some people and the surrounding area can be affected.

3.2 Architectures

As mentioned by a lot of researchers in their papers, Convolutional Neural Networks are a part of Artificial Neural Networks which are used in deep learning and applied for object and picture identification and categorization to find out a particular thing or feature from the picture. Convolutional neural network is used to extract objects from photos using prior knowledge of features. Using CNN to identify solutions for various applications does not need human interaction for the learning process.

Table 2. Classification Techniques

Sr.NO	Classification Techniques	Working	Applications
1	Logistic Regression	Used to find Binary Outcome using the relationship between dependent and independent variables.	[10] Localization & Activity Classification,[43] Educational Research.
2	Bayes Classifier	The data is categorized using the probability functions and Naive Bayes classifier.	Medical Applications for optimizing treatment decisions.
3	Decision Tree	Works like flow charts for separating data points into similar categories.	Bio-informatics.
4	Random Forest	Improved version of Decision tree where multiple trees are used for more precise classification.	[12] Classification of different Drones,[44] Remote sensing.
5	k-NN	Used to find the *k* closest relatives of a data point so that it is situated into a cluster of maximum similarities.	[45] Predicting economic events, Grouping Classes.
6	Support Vector Machine	Hyperplane is used to sperate the classes in the best way possible, where the extreme points are the vectors.	[12] Drone Detection, [10] Activity Classification.
7	Ensemble Methods	Here we combine different classifiers to get better results like Boosting, Bootstrapping, Bagging, etc.	Many applications where we need to improve the accuracy.
8	Neural Networks	Here we connect a number of units called neurons which have weighted edges to form interdependencies.	Financial Analysis in Business and Industry.

After the network training is finished, each image is automatically classified. CNN allows for the reuse of training samples, thus reducing the need for manual labour while creating features [32]. According to [31] we should understand that when data expands into deeper layers, CNN develops conceptual features. CNN circumvents the issue of over-fitting by merely connecting a small percentage of each neuron in a layer to the layer above rather than all of them, as is customary in fully-connected neural networks.

Table 3. CNN Models

MODELS	LAYERS	ADVANTAGES	DISADVANTAGES
AlexNet	8	The training of the model is done by using GPU's result in training of the model increases and also has a Consecutive convolutional layer.	As compared to the newer models it is not as deep such as Google Net, ResNet, etc.
LeNet-5	7	It takes less time for training of model. Recognition of handwritten digits is simpler.	A lot of input data is required to train the model accurately.
VGG-16	16	It can classify large amount of data. It uses transfer learning so that image classification can done very easily.	Takes more time to implement the algorithm, thus training period increases.
VGG-19	19	Due to increase in Convolutional Layers, it can work on more complex functions.	Vanishing Gradient Problem.
GoogLeNet	22	It is a deeper algorithm because it uses 1*1 convolution and global average pooling.	Due to more parameters, overfitting problem can occur.
ResNet	50	Uses identity mapping for solving gradient problem. Training networks with a large number of layers is simple & does not increase the training error percentage.	Less Trainng error percentange.
SqueezeNet	18	As it has fewer parameters its accuracy increases.	It includes a smaller number of parameters.
DenseNet-121	120	Reduced parameters help in destroying gradient problem. It uses feature reuse	Each layers' feature map is merged with the preceding layer and data is repeated numerous times.

Refer Fig. 2 which elaborates on different architectures which are improved versions of their previous ones in detail [99-103].

As have seen in Fig. 2 that CNN has further improved versions like R-CNN, Fast RCNN, Faster RCNN, etc. But we have also different architectures in CNN itself. We can change the number of Convolutional Layers, Max Pooling Layers, Average Pooling Layers, SoftMax Layers, etc. Each variation can give us a different output which generates different accuracies. Some of the CNN Architectures are given in the Table 3.

ImageNet Large Scale Visual Recognition Challenge (ILSVRC) is a competition used for comparing the accuracy of different models for Image recognition and categorization. Every year new advanced and improved models are presented. We can check their accuracy with millions of images given as inputs. In the Fig. 3, we have represented the different architectures with the number of layers and the year that it was released.

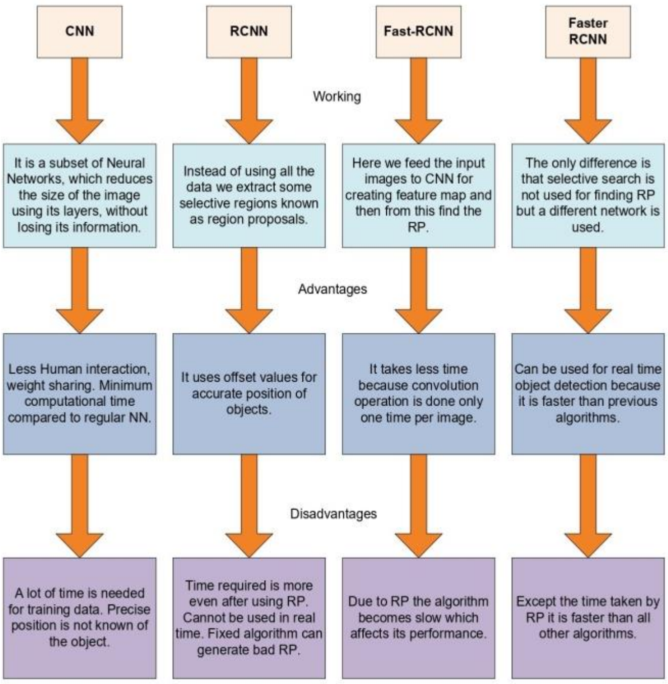

Fig. 2 Comparison between CNN, RCNN, Fast RCNN, Faster RCNN

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4. CONCLUSION

In this Survey, we have seen the various possibilities in which the different radars can produces different outputs which will be used as inputs to different Algorithms which will be of a great use for Target Classifications. We need to make sure that the Algorithms we use are best suited for the results that we are expecting, so we need the knowledge about the features of all the Architectures and its types. We will have to find a better version of the techniques we use because the Technology always keeps on improving and upgrading in all the fields.

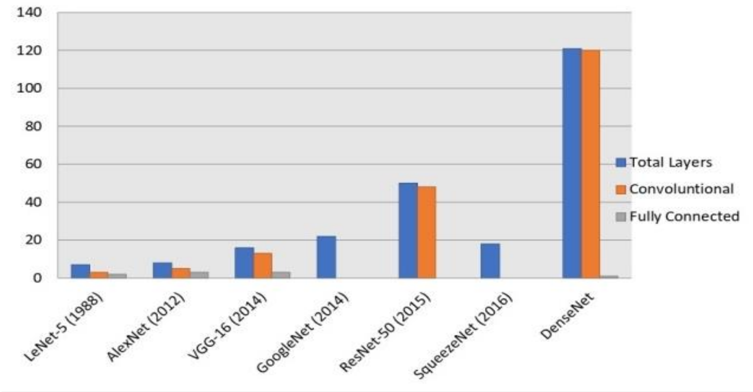

Fig. 3 Evolution of CNN Models.

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