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Machine Learning based implementations of Electronic Warfare System

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ABSTRACT : Electronic warfare is critical in modern defense systems for defending against and diverting enemy attacks. The electronic warfare system detects and extracts information by utilizing electromagnetic energy. Fuzzy logic, machine learning, and artificial intelligence are examples of advanced technologies that could be used in the design and development of electronic warfare systems. This paper examines various countermeasures and algorithms used in the implementation of electronic warfare systems.

KEYWORDS : Electronic warfare system, Machine Learning, ID3, LSTM, Fuzzy logic

I. INTRODUCTION

Electromagnetic pulse is the process whereby generating high energy electromagnetic fields in short bursts or pulses as it is incredibly difficult to generate high energy EMP continuously also pulses are more effective in interfering /destroying electronic microcircuits by inducing fault currents in the victim device's sensitive microcircuits(Integrated circuits) thereby either interfering or destroying the IC. High Altitude EMP (HEMP) weapons have been developed and tested in the field by the U.S army and it has been discovered that HEMP can disrupt the critical infrastructure of a state/country example : civilian communication infrastructure, disabling smart/automated cars, destroying RFID tags, banking cards(credit/debit)[1], [2].

Electromagnetic pulse represents the ability to use the electromagnetic spectrum signals such as radio, infrared or radar to sense, protect and communicate. At the same time, it can be used to deny adversaries The ability to either disrupt on use of these signals electronic warfare can be divided these major area electronic attack, electronic protection, and electronic support. In other words, it is used to attack the enemy, to protect fully force and to provide critical situational awareness. The purposeof electronic warfare is to deny the opponent the advantage of and ensure friendly unimpeded access to electromagnetic spectrum. Electronic warfare can be applied from air, sea, land,and space. In military application it provides the means to committee in all battle phases. Hostile actions that involve the electromagnetic spectrum from beginning to final engagement electronicwarfare exploit the electromagnetic environment by sensing and analogion an advantages application of the spectrum and imposing appropriate continuums to hostile spectrum use[3].

Radar (radio detection and ranging)detection system uses radio means to determine the distances angle, velocity of objects?A radar ape rates by radiating electromagnetic energy and detecting the echo providesinformation about the target[4]. Radar is an active device which carries it own transmitter and doesnot depend on ambient radiation, as do most optical and improved semes. radar can detectrelatively small targets at near and for distance and can measure thing range with precisionmother. Radar was originally developed to satisfy the need of military for purulence and weaponcontrol military applications have funded much of the development of its technology[5]. Radar hasseen

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significant civil application for the safe formed of anklet, ships, and spacecraft, the remotesensing of the environment specially the matches etc.Radar takes more time to lock on an object, it has a under broom mange and short-range Radarcannot track if an object is deselecting at more the impels[6].

Since lasers were invented,the U.S DoD has been actively researching and developing High EnergyLaser(HEL),Space Based Laser(SBL) and Advanced Tactical Laser(ATL) for Electronic Warfarepurposes .SBL and ATl are mainly used for targeting or surveillance purposes for example laser basedInfrared countermeasures(IRCM) and Direct Infrared countermeasures(DIRCM) which are used toredirect or confuse the guidance systems of a targeted IR guided missile these are mainly used fordefensive purposes.For offensive purposes High Energy lasers(HEL) are mainly used and for more destructive or powerfulapplication a cascade of (HEL) are simultaneously fired at a single target. It can be used to target devices which are sensitive to heat and light for example cell towers, sensors oreven single target humans etc.It works best for long range application under the right weather conditions.High Energy Lasers are extremely dependent on the weather conditions as rainy or snowy weather candrastically decrease the total energy/power that is delivered to the target.Also Laser weapons can easily be deflected using mirrors or reflectors.And the colour of the target device also matters a lot as black coloured objects absorb most of the laserbeam's energy, where white colour objects reflect a major part of the beam's energy[7].

Researchers on the machine learning and studies suggest that due to the recent development in the field of Machine Learningand Artificial Intelligence in combination will have a major impact on the capabilities and feasibilities ofelectronic warfare systems[8].Hence, a lot of countries have recently been trying to incorporate machine learning and artificialintelligence into their military capabilities, for example the U.S Air Force has commissioned a projectcalled Kaiju to incorporate machine learning and artificial intelligence algorithms to cognitive warfaresystems to provide a optimal approach and help aircrafts to penetrate air defences i.e finding weakpoints in a country's air defences by using multispectral sensors, missiles and other air force assets[9].Another application of machine learning in electronic warfare, is False Target Generation. This is one ofthe ways of confusing/ distracting enemy radar systems by generating false in the enemy's radar systemwhich will force the enemy to allocate their military resources to the location of the false targets.Thereby, penetrating the enemy's air-space with relative ease[10].

II. ELECTRONIC COUNTER MEASURES

There are several methods to counterattack or detoriate the opponent's utilization of electro magnetic spectrum. The ECM techniques are classified into active ECM and passive ECM.

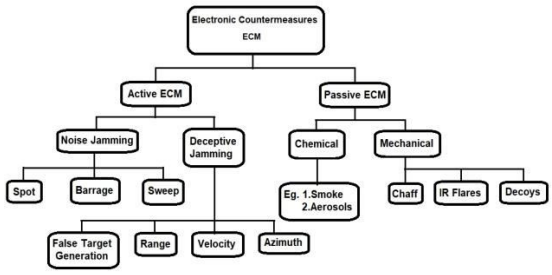

Figure 1 : Electronic Counter Measures

The former one degrades the enemy's attack by generating and transmitting electromagnetic energy. The active ECM includes noise and deceptive jamming to prevent the radar position and to produce false position. The passive ECM does not include electromagnetic energy instead, it confuses the enemy's system by using chemical or mechanical systems[11].

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III. ELECTRONIC WARFARE ALGORITHMS

a. ID3 Decision Tree

The decision tree is used for the classification and prediction task based on the data provided. This algorithm is built upon supervised machine learning technique [8]. This technique is generally used to determine appropriate actions required for any given scenario. The decision tree for the exam results is given below

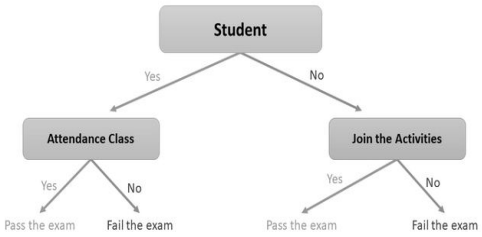

Figure 1: ID3 Decision tree example

This method can be used in the electronic warfare systems by using appropriate attributes. The attributes such as type, distance, signal, speed, etc., The attributes are represented as $attr_1, attr_2, \ldots, attr_{su}$.

Let M be the training set and the entropy of training data may be represented as.

$$\text{Entropy } (attr_{su}) = \sum_{i=0}^{K-1} P(attr_{sui}) \log_2 (p(attr_{sui})) \quad (1)$$

Where p($attr_{sui}$) is the probability that the countermeasure ($attr_{sui}$) is taken and K is the number of countermeasures. Assuming that the data can be split into two groups based on a specific EW. These two groups are referred to as group A and group B. The $attr_{su}$ entropy is each group is calculated by using (1) and the entropy of this split.

Entropy of the split is defined as

$$Entropy_{split} = \frac{n_A}{M} Entropy_A + \frac{n_B}{M} Entropy_B \quad (2)$$

Where $Entropy_A = attr_{su} entropy of group A$

$$Entropy_B = attr_{su} entropy of group B$$

$$n_A = number of datasets in group A$$

$$n_B = number of datasets in group B$$

An ideal split provides a split entropy much smaller than the original entropy. This algorithm splits the data based on the feature that reduces the entropy the most. This process is repeated to separate the data until the entropy reduced

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to be smaller than the predefined threshold, or until the algorithm reaches the predefined threshold. The disadvantages of using this ID3 decision tree algorithm are, the small change in the data may cause large change of the decision tree causing instability[12].

b.Fuzzy Logic

Fuzzy logic works with indefinite/inexplicit data, Fuzzy logic values use numbers in the range pf (0-1).Fuzzy logic combines AND, OR,NOT gates to create operations other than the basic Boolean logic operation, Fuzzy logic can be used in situations where data or information is not perfectly defined and therefore, to make educated guesses with the availability of limited information.In the context of electronic warfare, fuzzy logic can be used to determine the outcome of a military aircraft mission, where the aircraft can only take-in a limited amount of information about the environment and detect only a limited number of threats based on its sensor range.

Therefore, using fuzzy logic and the limited information/data a higher quality decision can be made in a short time period (real time). Present - Time Naval forces have different sensory systems such as Radar, ESM, SIS etc. The fuzzy logic algorithm is used to analyse the data collected from these sensory systems and make optimal decisions and allocate the available sensory systems and weapons etc based on a trained fuzzy logic.

Fuzzy logic should be trained by experts in the particular field (experienced naval battle officer in this case),therefore using fuzzy logic we can incorporate the expertise and experienced decision making of the (naval officers) into an algorithm to make and allocate decision and available resources without much delay(real time) and with limited computer processing power and memory. In context of the current paper, fuzzy logic is used to verify or determine a threat level of the enemy radar transmitter based on its mode of operation and its distance, using this information the Electronic warfare system can determine which enemy radar transmitter(emitter) to engage on first (the fuzzy logic algorithm outputs a numerical value for each of the multiple enemy radar emitters) based on the numerical value the threat level of the emitter is determined/estimated[13]. The distance between enemy radar emitter and us (sensor) can be classified into three basic types as Close, medium and far. The graph for membership function for these classes vs distance is given below. Mostly triangular or trapezoid-shaped curves are used in fuzzy sets and always have a maximum peak value equal to 1 and a decreasing slope or an increasing slope with an overlap between the different classes. They are also defined using sigmoid functions, for example the standard logistic function is defined as

$$S(x) = \frac{1}{1 + e^{-x}}$$

which has the following symmetry property

S(x)+S(-x)=1

From this it follows that

(S(x)+S(-x)). (S(y)+S(-y)). (S(z)+S(-z))=1

Fuzzification converts the input data (crisp sensor data) into fuzzy sets. Rule base: Rule base consists of If-then conditions and a set of rules provided by the expertsto train the decision making system Inference Engine: It defines the degree of matching of the fuzzy input with respect to each rule Defuzzification converts the fuzzy sets back into a crisp value(simple readable value) Advantages of fuzzy logic: Fuzzy logic can work with inexplicit or noisy input data/information. The mathematical concepts of set theory used in fuzzy logic are relatively simple. It provides an effective solution to complex-problems on the field in real time Disadvantages As fuzzy logic works on mostly imprecise data, therefore most of the time accuracy is compromised In the case of fuzzy logic we mostly do not get

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its proof of characteristics i.e after the fuzzy logic is trained by experts we do not get a exact mathematical description of the approach.

C. Long short-term memory neural network.

LSTM is an artificial recurrent neural network architecture which is used in fields of deep learning . It considers previous information through the integration of LSTM'S cells than old feed-forward networks which works on same set of information. It processes data passing information as it propagates forward. The output of network depends on current input, state memory and carry over memory. LSTM at a particular point in time is dependent on three things:- The current long –term memory of network (Cell state). The output at the previous point in time (Hidden state). The input data at the current time step[14], [15].

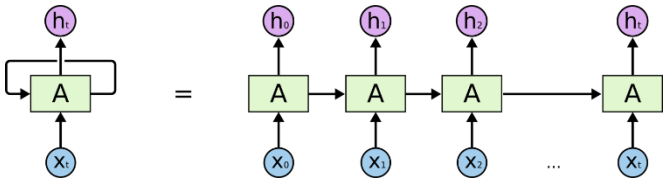

Figure 2: LSTM Technique

LSTM's uses series of 'gates' it's controls the information coming in and stored and leaving the network. The three gates are forgot gate, input gate and output gate. These gate can be of filters and they have their own neural network. The cell members valves over arbitrary time intervals and three gates regulate and flow the information in and out of the cell.

LSTM is used in electronic warfare is to predetermine the multifunction radar's of next operating signals based on previously set data or information. Advantage:- 1)The constant error back propagation within memory cells results in LSTM's ability to bridge very long time lags in some cases. 2)The LSTM algorithm's update complexity per weight and time step is essentially that of BPTT. This is excellent in comparison to other approaches such as RTRL. Unlike full BPTT, however is local in both space and time. Disadvantages:- 1)It is quite inefficient as it needs lots of resources and time to get trained as they need high memory bandwidth because of linear layers present in each cell which the system usually fails to provide. 2)LSTMs get affected by different random weight initialization and hence behave quite similar to that of a feed-forward neural net. They prefer small weight initialization instead.

The comparison of ID3, Fuzzy logic and LSTM techniques are provided in table 1.

Table 1 : Comparison of ID3, Fuzzy logic and LSTM techniques

Machine Learning Technique	ID3	Fuzzy Logic	LSTM
Applications	Decision making protocol	Countermeasure and allocating resources for electronic attack	To predict a multifunction radar's next operating signal set based on previously recorded data
			Jamming Prediction
			To extract timing features of the pulse signal data
			To identify the modulated signal with a recognition rate of nearly 90%.
			Recognizing different types of radar signals
			Processing sequential data

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IV. CONCLUSION

Electronic warfare is a modern technology used by defence forces across the world to give counter attack to the enemies. The modern technologies enables such systems to be rigid and adaptable to any situations in the battle field. The technologies like machine learning, artificial intelligences and neural networks are greatly employed to design sophisticated electronic warfare systems. This paper reviews the fundamentals of EW design and development and various modern technologies. The LSTM techniques is most preferred for various implementations due to the coverage of broad parameters and noise handling abilities.

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