On an attempt to explore challenges for Artificial Intelligence and Machine Learning in Indian Military and Defence Sector and Studying the Possible Inter-relationship amongst them using ISM Methodology

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ABSTRACT
Recent developments in Artificial Intelligence (AI) have resulted in breakthroughs in applications such as computer vision, natural language processing, robotics, and data mining. These breakthroughs have been optimally utilized in various military applications such as surveillance, reconnaissance , threat evaluation, underwater mine warfare, cyber security, intelligence analysis, command and control as well as military education and training . However, it is not easy to achieve these breakthroughs . They are subject to the package of challenges of being prone to high risks ; robustness and reliability crunch or absence of the required training to name a few. Present research work tries to explore such challenges and further attempts to study the possible inter-relationships using ISM methodology.

Keywords
Interpretive Structural Modeling Methodology , MIC -Mac Analysis , Military and Defence sector , Artificial Intelligence and Machine learning

1. INTRODUCTION
Artificial intelligence (AI) is termed as the intelligent behavior displayed by machines. It is sometimes referred to as sub-field of machine learning (ML) and deep learning (DL). The high speed development in AI from being mere a traditional machine translation , quality assurance and speech recognition have moved beyond to the remarkable AI-applications such as image captioning [13] , Voice imitation [9] ; Video synthesis

[11] and continuous control [1] etc. This suggest that now machines are becoming capable of improving efficiency with respect to development costs of both software and hardware ; performing specific tasks at superhuman level and providing creative solutions to problems not previously considered by humans and also provide objective and fair decisions where humans are known for being subjective, biased, unfair, corrupt, etc. AI and ML applications have also created new opportunities to perform higher-level tasks that provide more meaningful employment for humans. AI and ML track records show that performance over time is truly unmatched.

1.1 AI and ML in context of Military domain
The potential for AI is present in all domains (*i.e.* land, sea, air, space and information) and all levels of warfare (*i.e.* political, strategic, operational and tactical). In military , artificial intelligence could be used at different levels ranging from combat level to tactical and operational levels. This development has led to decision support systems being used at the battalion and brigade levels. Quite recently , AI have been found to be useful in command and control systems. Also, artificial intelligence have been used at different levels to perform different functions. For example, at operational level , it can be used to perform threat analysis to predict enemy actions. Similarly , at political and strategic levels , it can be used to destabilize an opponent by producing and publishing massive quantities of fake information. At the tactical level, AI can improve partly autonomous control in unmanned systems so that human operators can operate unmanned systems more efficiently , to ultimately increase battlefield impact.

By expanding servicemembers' access to AI and ML technologies for experimentation, Department of Defense can take an important step toward harnessing these technologies, developing future applications that marshal the collective knowledge of the entire force, and stand postured for the difficult road that lies ahead.

Army to test artificial intelligence and machine learning to detect hidden targets in 2020 wargames[1] . Potential applications includes shooting down drones , aiming tank guns, coordinating resupplies, planning artillery barrages and blending sensor feeds . The most high profile example of AI on the battlefield till date is the controversial project ***Maven*** used machine learning algorithms to sift hours of full motion video looking for suspected terrorists and insurgents .

Apart from benefits that it provides to the military sector , it suffers from a packet of challenges which need to be resolved so as to utilize its benefits to maximum . The purpose of this paper is to explore the major challenges for AI in military applications . Section 2 provides a brief introduction to the literature review of these challenges. Section 3 provides the ISM methodology and Section 4 the case application . Section 5 describes the various observations, applications of AI and the managerial implications .

2. LITERATURE REVIEW : KEY CHALLENGES BEFORE AI IN CONTEXT OF MILITARY AND DEFENCE

Early AI and ML applications in technologies such as self-driving cars, search results, and stock-trading algorithms have demonstrated significant failings. However, many self-driving cars have driven millions of accident-free miles, a feat that few human drivers could ever claim. Potential breaches of personally identifiable information also raise concerns. There are several key challenges that could potentially slow down or otherwise limit the use of modern AI in military applications . They are as follows:

1. **Insufficient transparency (IT):** Many applications require, in addition to high performance, high transparency, high safety, and user trust or understanding. Such requirements are typical in safety critical systems [4], surveillance systems [13], autonomous agents [6], medicine [3], and other similar applications.

2. **Vulnerabilities (Vu)**: Models developed using Machine Learning are known to be vulnerable to adversarial attacks . As an example, unmanned aerial vehicles (UAVs) using state-of-the-art object detection can potentially be deceived by a carefully designed camouflage pattern on the ground.

3. **Deficiency of high quality and sufficiently large data sets (DDS):** Developing machine learning based applications in a military context is challenging because the data collection procedures in military organizations, training facilities, platforms, sensor networks, weapons, etc. were initially not designed for machine learning purposes.

4. Limited training data (LTD): The main ingredient in any machine learning application is data from which the machines can learn and, ultimately, provide insight into. Military organizations are often good at collecting data for debriefing or reconstruction purposes.

5. **Challenge of cyber security (CCS):** Intrusion detection is an important part of cyber security to detect malicious network activity before it compromises information availability, integrity, or confidentiality. Intrusion detection is performed using an intrusion detection system (IDS) that classifies the network traffic as normal or intrusive. While signature-based IDSs are often good at detecting known attack patterns, they cannot detect previously unseen attacks.

6**. Insufficient funds (IF)** : Development of signature-based detection is often slow and expensive since it requires significant expertise. This hampers the systems adaptability to rapidly evolving cyber threats.

7. Large variability in network traffic (LVNT): Intrusion detection presents specific challenges such as lack of training data, large variability in network traffic, high cost of errors, and difficulty of performing relevant evaluations [9, 55]. Although large volumes of network traffic can be collected, the information is often sensitive and can only partially be anonymized. Using simulated data is another alternative, but it is often not sufficiently realistic.

8. Difficulty in labelling data (DLD): The data must then be labelled for supervised learning in terms of whether the patterns are normal or an intrusion, or for anomaly detection assured to attack-free, which is often difficult to do.

9. Lack of appropriate training (LAT)/ trained personnel : Military and defense department suffers lack of qualified personnel for giving hands on training to the new comers. Now days , modelling and simulation has been used extensively by the military for training, decision support, studies, etc.

10. Difficult interpretability of ML-models(DI): Models generated using alternative ML-algorithms where the model can be graphically visualized, such as parser trees or decision trees, are hard if not impossible to interpret even when applied to toy-problems [5].

3. ISM METHODOLOGY

Interpretive structural modelling methodology or ISM [14] is a known technique to map the relationships amongst the relevant elements as per decision maker's problems in a hierarchical manner. Starting with the identification of elements , it proceeds with establishing the contextual relationships between elements (by examining them in pairs) and move on towards developing the structural self-interaction (SSIM) matrix using VAXO [14] and then initial reachability matrix and final reachability matrix and rearranging the elements in topological order using the level partition matrices . A *Mic-Mac* analysis is performed afterwards which categorize the variables as per the driving and dependence power in to autonomous, dependent, driver and linkage category. Finally, a diagraph can be obtained.

4. CASE EXAMPLE

10 challenges described in the above section are being further studied for the possible inter-relationships amongst them. These are : Insufficient transparency (IT); Vulnerabilities (Vu) ; Deficiency of high quality and sufficiently large data sets (DDS) ; Limited training data (LTD); Challenge of cyber security (CCS); Insufficient funds (IF) ; Large variability in network traffic (LVNT); Difficulty in labelling data (DLD); Lack of appropriate training (LAT)/ trained personnel; Difficult interpretability of ML-models (DI).

4.1 Construction of Structural Self - Interaction Matrix (SSIM)

This matrix gives the pair-wise relationship between two variables i.e. i and j based on VAXO. SSIM has been presented below in Table 1.

4.2 Construction of Initial Reachability Matrix and final reachability matrix

The SSIM has been converted in to a binary matrix called the initial reachability matrix shown in fig. 2 by substituting V, A, X, O by 1 or 0 as per the case. After incorporating the transitivity, the final reachability matrix is shown below in the Fig 3.

Fig 1: SSIM matrix for pair wise relationship amongst barriers

S. No.	Barriers	1	2	3	4	5	6	7	8	9	10
		IT	Vu	DDS	LTD	CCS	IF	LVNT	DLD	LAT	DI
1	IT		X	A	A	V	A	A	A	A	O
2	Vu			V	V	V	A	V	O	A	A
3	DDS				X	V	A	A	O	A	V
4	LTD					V	A	A	O	A	V
5	CCS						A	A	O	A	X
6	IF							V	V	A	V
7	LVNT								A	A	V
8	DLD									A	X
9	LAT										V
10	DI										

Fig 2: Initial reachability matrix

S. No.	Barriers	1	2	3	4	5	6	7	8	9	10
		IT	Vu	DDS	LTD	CCS	IF	LVNT	DLD	LAT	DI
1	IT	1	1	0	0	1	0	0	0	0	0
2	Vu	1	1	1	1	1	0	1	0	0	0
3	DDS	1	0	1	1	1	0	0	0	0	1
4	LTD	1	0	1	1	1	0	0	0	0	1
5	CCS	0	0	0	0	1	0	0	0	0	1
6	IF	1	1	1	1	1	1	1	1	0	1
7	LVNT	1	0	1	1	1	0	1	0	0	1
8	DLD	1	0	0	0	0	0	1	1	0	1
9	LAT	1	1	1	1	1	1	1	1	1	1
10	DI	0	1	0	0	1	0	0	1	0	1

Fig 3 : Final reachability matrix

S. No.	Barriers	1	2	3	4	5	6	7	8	9	10	D.P
		IT	Vu	DDS	LTD	CCS	IF	LVNT	DLD	LAT	DI	
1	IT	1	1	1	1	1	0	1	0	0	1	7
2	Vu	1	1	1	1	1	0	1	0	0	1	7
3	DDS	1	1	1	1	1	0	0	1	0	1	7
4	LTD	1	0	1	1	1	0	0	0	0	1	5
5	CCS	0	0	0	0	1	0	0	0	0	1	2
6	IF	1	1	1	1	1	1	1	1	0	1	9
7	LVNT	1	1	1	1	1	0	1	1	0	1	8
8	DLD	1	1	1	1	1	0	1	1	0	1	7
9	LAT	1	1	1	1	1	1	1	1	1	1	10
10	DI	1	1	1	1	1	0	1	1	0	1	8
	De.P	9	8	9	9	10	2	7	6	1	10	

D.P : Driving power ; De.P : dependence power

4.3 Level Partition

From the final reachability matrix, reachability and final antecedent set for each factor are found . The element for which the reachability and intersection sets are same are the top-level element in the ISM hierarchy. After the identification of top level element, it is separated out from the other elements and the process continues for next level of elements. Iterations have been shown from table 1 – table 6 below .

Table 1 Iteration I

S.No.	Reachability set	Antecedent set	Intersection set	Level
1.	**5,10**	1,2,3,4,5, 6,7,8,9,10	**5 ,10**	**I**
2.	1,3,4,5, 10	1,2,3,4,6,7 ,8,9,10	1,3,4,10	
3.	1,2,3,4,5, 10	1,2,3,6,7, 8,9,10	1,2,3,10	
4.	1,2,3,4,5, 7,10	6,7,9,10	3,7,10	
5.	1,2,3,4,5,7, 8,10	6,7,8,9,10	7,8,10	
6.	1,2,3,4,5,6, 7,8,10	6,9	6	
7.	1,2,3,4,5,6, 7,8,9, 10	9	9	

Table 2 Iteration II

S. No.	Reachability set	Antecedent set	Intersection set	Level
2.	**1,3,4**	1,2,3,4,6,7,8,9	**1,3,4**	**II**
3.	1,2,3,4	1,2,3,6,7,8,9	1,3	
4.	1,2,3,4,7	6,7,9	3,7	
5.	1,2,3,4,7,8	6,7,8,9	7,8	
6.	1,2,3,4,6,7,8	6,9	6	
7.	1,2,3,4,6,7,8, 9	9	9	

Table 3 Iteration III

S. No.	Reachability set	Antecedent set	Intersection set	Level
3.	**2**	2,6,7,8,9	**2**	**III**
4.	2,7	6,7,9	3,7	
5.	2,7,8	6,7,8,9	7,8	
6.	2,6,7,8	6,9	6	
7.	2,6,7,8,9	9	9	

Table 4 Iteration IV

S. No.	Reachability set	Antecedent set	Intersection set	Level
4.	**7**	**6,7,9**	**3,7**	**IV**
5.	**7,8**	6,7,8,9	7,8	
6.	6,7,8	6,9	6	
7.	6,7,8,9	9	9	

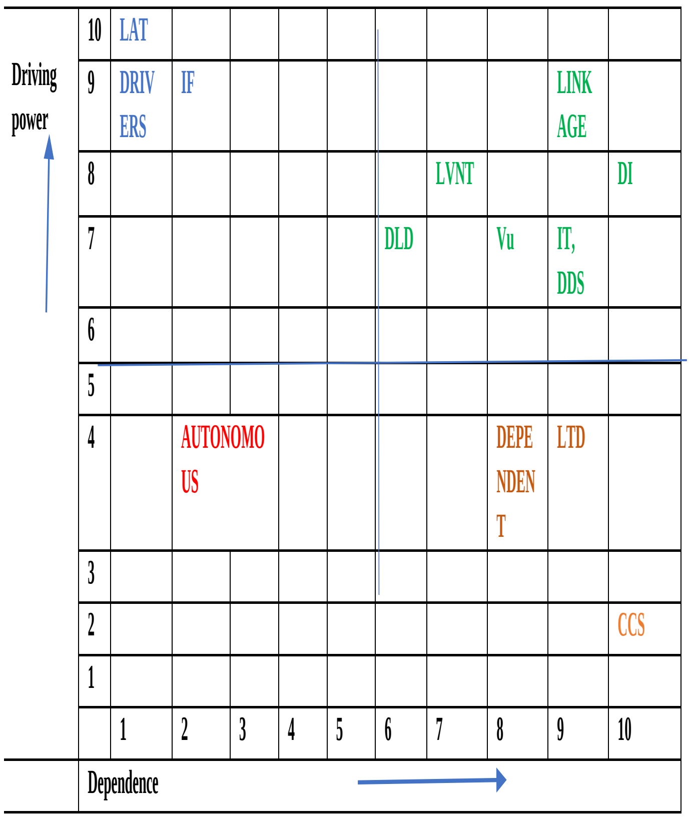
Table 5 Iteration V

S. No.	Reachability set	Antecedent set	Intersection set	Level
6.	**6**	**6,9**	**6**	**V**
7.	6,9	9	9	

Table 6 Iteration VI

S. No	Reachability set	Antecedent set	Intersection set	Level
7.	**9**	9	9	**VI**

4.4 Driving power and Dominance diagram



4.5 ISM Diagraph

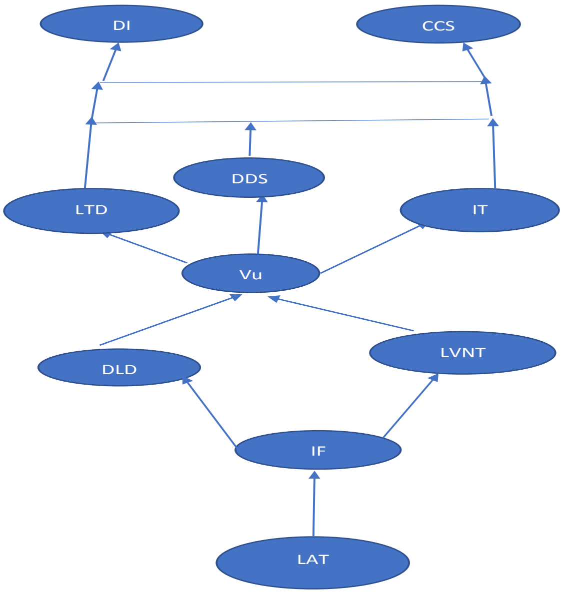


Figure 1 : ISM Diagraph

5. RESEARCH IMPLICATIONS: NLP AND ITS USE IN MILITARY AND DEFENCE

Natural-Language Processing (NLP) is a way for computers to analyze, understand and derive meaning from human language in a smart and useful way. By utilizing NLP , developers can organize and structure knowledge to perform tasks such as automatic summarization , translation, named entity recognition , relationship extraction , sentiment analysis, speech recognition and topic segmentation. Apart from the common word processor operations that treat text like a mere sequence of symbols , NLP considers hierarchical structure of language. Several words make a phrase , several phrases make a sentence and ultimately sentences conveys ideas . NLP is used to analyze text, allowing machines to understand how humans speak . DARPA [15] , (Ministry of Defence , India) created the Deep Exploration and Filtering of Text (DEFT) program to harness the power of NLP.

6. AI AND MACHINE LEARNING APPLICATIONS IN MILITARY & DEFENCE

This section presents a few examples where AI can be applied to enhance military capability.

6.1 Surveillance

Maritime surveillance is performed using fixed radar stations, patrol aircrafts, ships, and in recent years electronic tracking for maritime vessels using the automatic identification system (AIS). An early approach to maritime anomaly detection use the Fuzzy ARTMAP neural network architecture to model normal vessel speed based on port location [7]. Another approach use associative learning of motion patterns to predict vessel movement based on its current location and direction of travel [8].

6.2 Underwater mine warfare

Underwater mines pose a significant threat to marine vessels and are used to channel movement or deny passage through restricted waters. Mine searches are increasingly performed with an autonomous underwater vehicle (AUV) that is equipped with synthetic aperture sonar (SAS), which provides centimeter-resolution acoustic imagery of the seafloor.

6.3 Training and decision making studies : Modelling and Simulation

Modelling and simulation has been used extensively by the military for training, decision support, studies, etc. As a result, there are lots of already validated models that have been developed over long periods of time that could also potentially be used to generate synthetic data for ML-applications.

6.4 Aid to Automated target Recognition Problems

Artificial intelligence and machine learning can optimize Automatic Target Recognition (ATR) problems using UASs where the optimal number of drones, payloads, along with path planning can be prescribed using multi-objective evolutionary algorithms [16].

6.5 Automated vehicle technologies

Automated vehicle technologies utilize artificial intelligence for rapid decision making to provide assistance to motor vehicle drivers [17]. Some of the examples includes the vehicles used by the Defense Advanced Research Projects Agency's (DARPA)[15] Urban Challenge and current self-driving cars and aircraft.

7. LITERARY OBSERVATIONS

- The recent breakthrough of AI is gradually reaching a point where it can be used in military applications.
- Future studies should also include how to utilize the rich set of visualization techniques that are developed in the visual analytics research area.
- Finally, transfer learning makes it possible to adapt pre-trained models to military applications where there is both limited training data and computational resources.
- Google has already made its flagship ML technology, TensorFlow, open source. Amazon Web Services offers AI and ML stacks for developing insights into an organization's data. Massive open online courses also offer free instruction on AI and ML technologies, making them available to anybody.

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