Artificial Intelligence (AI) and Human–Machine Teaming

G. Praveen*

> *"Extensive opportunities in AI and Data Analytics call for the Indian Armed Forces to prepare a perspective plan to embrace these technologies and place greater thrust on training its personnel to learn these technologies and also reskill service and civilian personnel with advanced training and learning management systems."*
>
> *General MM Naravane*
>
> *"Advantage will not automatically lie with the force that has the newest or most expensive algorithm, but more likely with the most effective human-machine team."*
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> *Joint Concept Note (JCN)* 1/18, United Kingdom[1]

Introduction

The battlefields of the future will be dynamic, chaotic, unpredictable, and uncertain. In such interlinked battlefields in multiple theatres and domains, commanders and staff would be sifting through multitude of data for information, decision, and feedback. In a time-constrained operational environment obscured by Clausewitzian fog of war, effective and unbiased

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decision-making by leaders and cohesive, cogent actions by teams of humans and machines/systems will be enablers for succinct victory. The pace and complexity of decision-making is expected to reach a level beyond human cognition. Capabilities offered by latest and emerging technology will aid the decision-makers and troops in various domains even as there will be parallel battles to contest those domains by state and non-state actors. The famous OODA loop will have technology-assisted inputs at each stage of Observe, Orient, Decide and Act. Faster processing capabilities of Big Data and inferential analytics and seamless integration of inputs by algorithm-driven machines would simplify the complexities associated with the five Vs of Big Data, i.e., Volume, Velocity, Veracity, Value and Variety.

Artificial Intelligence or AI is a branch of computer science that brings together multiple disciplines, with the aim of creating smart machines—devices and systems capable of performing complex tasks such as those performed by human intelligence, but in a manner that equals or exceeds the capabilities of humans. Essentially, the aim is to make intelligent[2] machines which can replicate human behaviour and intelligence in every sense. As we are aware, amongst the three types of AI (Artificial Narrow Intelligence, Artificial General Intelligence and Artificial Super Intelligence)[3], present capability is 'Artificial Narrow AI' or 'Weak AI', where a machine or a system like Alexa or Siri can perform a series of predetermined and defined range of activities repeatedly. In day-to-day life, our interaction is with one of the sets or subsets associated with AI, like Big Data, Machine Learning, and so on, even though all are loosely termed as AI. Even as ethical debates of AI gaining too much freedom rage on, with AI singularity[4] predicted in two decades, topics like Chat GPT, swarm drones, iron men, driverless automatic cars are on the reading list for the AI Illiterate.

Countries like USA, China and Russia have made rapid progress in the realm of AI in various domains including that of military capability. Trials or events like simulated aerial combat of an ace F16 pilot with an AI system Falcon {US Defence Advanced Research Projects Agency's (DARPA's) Air Combat Evolution (ACE) programme} of August 2020 have received more attention than 'Deep Blue' beating Kasparov in 1997 or Deepmind's AlphaGo beating Lee Se-dol in 2016.[5] India has undertaken a series of steps to develop and exploit the capabilities of AI, which include setting up a national-level structure and Centres of Excellence at various institutes. The National Strategy for Artificial Intelligence #AIForAll was published by NITI Aayog in 2018, which was followed by setting up a National AI portal in 2020 in addition to various other initiatives. Defence AI Council and Defence AI

Project Agency have been established and efforts are underway to identify and develop projects under various domains.[6] Ten Centres of Excellence and two dedicated laboratories of the DRDO are focused on identifying and developing key technologies and applications while the Indian Army has set up the AI Centre of Excellence at MCTE, Mhow and added AI oriented curriculum at various training institutes. In addition to various seminars, the Indian Army has recently announced its plans to procure weapons such as jetpacks, robot mules, drone systems, and jammers with an eye on increasing its advantage in combat.[7]

In the Armed Forces, AI and related capabilities can be used to exponentially improve performance in the fields of Training, Surveillance, Intelligence collation, Logistics including Supply Chain Management, Cyber Security, Arms & Ammunition, etc. A Manekshaw Paper on 'Leveraging AI for the Military' mentions the domains of situational awareness, lethality, Human Resources (HR), training, survivability, cyber, Information & Electronic Warfare (EW) and mobility on which AI can focus on.[8] It can be surmised that the aim of incorporating AI systems and sub-systems, including unmanned and remote systems and robots, will be to[9]:

- **Strengthen information superiority** (example: provide aerial photos of an adversary's position; integrate inputs from both structured and unstructured data).
- **Reduce cognitive load** (example: identify new targets in a fire-fight and recommend targeting options).
- **Take on physical loads** (example: carry heavy battle gear or assist humans in the form of exoskeletons).
- **Handle dangerous tasks** (example: deliver supplies or conduct medical evacuation in a danger zone).

As the Armed Forces incorporate and exploit various facets of AI, a visible manifestation will be in the domain of Combat or Battle Effectiveness. Defined as the readiness of a military unit to engage in combat based on behavioural, operational, and leadership considerations,[10] Combat Effectiveness is a combination of tangible and intangible factors like force (numerical strength), equipment availability, morale, leadership, training standards, etc. In other words, it is the capacity of a military force to succeed in its mission, or task.

The present thinking is however silent on two important and inter-related aspects that can affect combat effectiveness while incorporating the various facets of AI, that is, 'Trust' and 'Bias'. Even as technological advancements

are made and levels of intelligence change from 'Assisted' to 'Augmented' to 'Autonomous',[11] what would remain constant is the 'human factor' or 'human in the loop'. Aspects like organisational culture, age, gender, and such, will influence the way new technological advancements will be accepted by the human component in various organisations.[12] The three pillars of people, process and technology must be seamlessly integrated with active feedback mechanisms to ensure that any form of bias, either passive or active, doesn't manifest and thereby impact trust and thereon effectiveness.

Trust

Human–Machine teaming is a relationship, one made up of at least three equally important elements: the human, the machine, and the interactions and interdependencies between them. Building trustworthy AI that is transparent, interpretable, reliable, and exhibits other characteristics and capabilities that enable trust is an essential part of creating effective human–machine teams.[13] A complex dynamic of man–machine interaction is the future, which would command increased trust on a machine, in a similar manner as that between two soldiers in the same team. In any fighting unit or sub-unit or what could be called as a Team, each team member having trained together, is aware of the strengths and weaknesses of the other. Camaraderie and *espirit de corps*, amongst the team members, finally make the team a combat effective cohesive unit. Much more than anything else, a key factor amongst the team members is 'trust' which is a must while operating under enemy fire wherein the life of one is dependent on the covering or supporting fire from the other.

As the level of complexity and interactions increase, there will be an increased demand on interpersonal (human–machine and human–system) trust which in a human–human context depends on character and competence of the involved parties and their mutual awareness of the same. Even though 'trust' is a difficult aspect to factor in while developing systems, what can be done is to have transparency, reliability and explainability which will engender trust in human–machine teaming. Introduction of a machine, a faceless, emotionless member into such a cohesive unit impinges on the trust factor. Human beings traditionally resort to anthropomorphism, which is a habit of ascribing human emotions to other beings which is commonly seen at homes with pets. A machine that exhibits human-like features, habits and emotions has a greater chance of winning over trust in a team.

One study on human–machine teaming identified three factors—coordination, communication and adaptation as key competencies for team

members of successful teams.[14] Two-way **communication** is an important aspect and therefore reduced transparency of complex systems using deep neural networks are being addressed by explainable AI or xAI.[15] Effective communication also builds trust. **Coordination** is more to do with recognition of knowledge, skills and behaviours of team members to achieve a common goal. Presently a major weakness in this competency is **implicit coordination**, where a team member can predict what another is likely to do based on his/her behavioural patterns which is beyond the scope of a machine with clear frameworks and rules. Maybe, with 'theory of mind AI', such a requirement will also be fulfilled. For **adaptation**, each member of a human–machine team must adapt as per the known knowledge and behaviour of teammates as well as the anticipated patterns. This is another facet, which will mandate the present 1st generation (knowledge-based) and 2nd generation (statistical) AI systems to 3rd generation (causal and contextual) models. Availability of large-scale datasets and enmeshed systems with shared situational awareness and experience will aid the systems with faster adaptation.

Another study on factors affecting trust in human–robot interaction identified 33 factors under three heads of human, robot and environment (see Table 1). The study revealed that of all the factors, robot performance contributed most towards building trust while the environment also played a considerable role.[16] Just as how trust develops in a human-only team, it will be the belief that an AI-assisted robot or system will deliver **unbiased** quality outputs or performance that will build trust in a human–machine team.

Table 1 Factors affecting trust in human–robot interaction

HUMAN-RELATED	ROBOT-RELATED	ENVIRONMENTAL
Ability-based	**Performance-based**	**Team Collaboration**
Attention/ Capacity/ Engagement	Behaviour	In Group Membership
Expertise (Amount of Training)	Dependability	Culture
Competency	Reliability of Robot	Communication
Operator Workload	Predictability	Shared Mental Models
Prior Experiences	Level of Automation	
Situation Awareness	Failure Rate	**Tasking**
	False Alarms	Task Type
Characteristics	Transparency	Task Complexity
Demographics		Multi-Tasking Requirement

Personality Traits	**Attribute-based**	Physical Environment
Attitudes towards Robots	Proximity/ Co-location	
Comfort with Robot	Robot Personality	
Self-Confidence	Adaptability	
Propensity to Trust	Robot Type	
	Anthropomorphism	

Source: Extracted from Peter A. Hancock, Deborah R. Billings, Kristin E. Schaefer, Jessie Y. C. Chen, Ewart J. de Visser and Raja Parasuraman, 'A Meta-Analysis of Factors Affecting Trust in Human-Robot Interaction', *Human Factors: The Journal of the Human Factors and Ergonomics Society,* Vol. 53, No. 5, 2011, pp. 517–27.

Bias

"If you want the bias out, get the algorithms in."

Andrew McAfee, MIT

"Unfortunately, we have biases that live in our data, and if we don't acknowledge that and if we don't take specific actions to address it then we're just going to continue to perpetuate them or even make them worse."

Kathy Baxter, Salesforce[17]

Cognitive biases in human decision-making and judgement is well documented. Daniel Kahneman in "Thinking Fast and Slow" spoke of System 1 and 2 types of brain, wherein the fast and intuitive System 1 attempts to hijack the slow analytical System 2 brain thereby leading to increased propensity of mental shortcuts or heuristics and thereby biases.[18] Though there are ways and means for removing and mitigating biases (debiasing), the awareness of a bias does not always result in removal of bias from the decision loop. What is more damaging is the lack of knowledge of implicit biases which normally occur when brain adopts one of those shortcuts (heuristics) in a limited time window under conditions of uncertainty and risk.

In addition to having policies and processes at various levels in the organisation for systematic debiasing and having feedback mechanisms, there is a need to adopt "Evidence based Decision Making".[19] This would entail common data-sharing platforms like a data cloud, and standard algorithms which can decipher inputs and analyse both structured and unstructured data to offer insights to a leader or decision-maker, at various stages of the decision-making process. Human biases can be mitigated in

the 'Observe' phase of the OODA loop by having machines synthesise large volumes and varieties of inputs to offer a collated intelligence picture. In the 'Orient' phase when a decision-maker is going through the 'sense making' paradigm of the decision loop, a collated and synthesised set of analytic inputs will help in framing and orienting in a faster timeframe. The 'Decide' phase duly supported by a machine-learning based Decision Support System can supplement the experience and intuition of a leader to arrive at a better decision in a faster manner, which is essential in a futuristic multi-domain battlefield with no clear boundaries even in the cognitive and physical domain.

On the other hand, increased dependence on AI-enabled systems could further amplify inbuilt biases in the algorithm or existential biases in the training datasets. Even though there are checks and balances to systematically review algorithms for bias and to prevent implicit biases from occurring due to training on incomplete datasets, the probability and likelihood of human cognitive biases getting incorporated at design stage cannot be ruled out. Though not comprehensive, a list of data model biases, as identified in a Deloitte study on bias and trust is given in Table 2.[20]

Table 2 Data model biases

Passive Bias	**Active Bias**
Selection bias (Over-inclusiveness or under-inclusiveness of a group; insufficient data; poor labelling)	Adversarial bias (data poisoning by the adversary)
Circumstantial bias (Training data staleness; changing circumstances)	Judgement bias (Incorrect application of AI system suggestions by the user, due to his/ her bias)
Association bias (AI models trained on terms or factors associated with legacies of bias based on race, gender, and other grounds, even though unintentionally)	

Though some argue that a biased algorithm trained on a larger historical dataset will still suggest a more balanced 'Course of Action' than a biased human decision-maker,[21] the aspect of 'debiasing (bias removal/ mitigation)' deserves far greater attention than what is being given today. It can be stated that both humans and machines need to undergo a 'mutually beneficial debiasing strategy' to improve quality

of decision-making to explore and understand those biases which are unethical, not robust and unlawful.[22]

Recommendations

AI and its associated tools and capabilities can be introduced at various levels and stages to both enhance and measure skills and standards, while being amenable to further modifications as per demands of an ever-evolving battlefield and operational spectrum. Mental and physical immersion though Virtual and Augmented Reality combined with haptic technology[23] can add realism and dynamism to training while simulations and war-gaming models can reduce costs, improve adaptability, and improve inter-operability. Virtual Reality (VR) can be used in the domains of education, medical and in combat training. The COVID-19 pandemic saw large-scale increase in online teaching platforms with many educational institutions using the available technology to make the learning more immersive. Complex concepts could be explained with 3D online models while multiple levels of education and skill development mandated for a soldier can be progressively achieved using VR systems. Healthcare aspects including combat medical care can be better learnt and practised by all soldiers. Using the capabilities of Natural Language Processing, conversational AI systems can be set up which can engage a soldier on various issues ranging from basic documentation, aspects of field craft and tactics, basic medical clarifications, tenets of Professional Military Education (PME), and such. Unmanned sensors, load carrying, robots for repetitive tasks, multimodal intelligence analysis, edge computing using a cloud architecture for faster decisions and shorter OODA loops, are some of the fields in which AI assisted systems would manifest at a battalion/regiment level.

The moot point is about what will change at Battalion or Regiment level? Will it change the way we work and operate presently? There will indeed be paradigm changes in the way we work and operate in terms of efficiency and transparency. There will also be concomitant demand on change management and technological skill enhancement. Starting from Services Selection Board (for Officers) and Recruitment Centres (for Junior Commissioned Officers and Other Ranks), AI-assisted software can help in identifying individuals with the right aptitude and uptake to work in such human–machine interface teams. These teams can thereon work in synergy to identify actionable sections or domains at each level and thereon collaborate with various Centres of Excellence to produce need-based machines or systems. In the present context

of Agniveer schemes, AI-enabled systems can provide valuable inputs about the retainability of such soldiers at the end of their four-year deployment.

For a Battalion or a Regiment or a Ship to be truly combat effective, it must have minimum basic awareness of the other combatants including tri-service elements. Basic awareness would include awareness of their operational style as well as situation awareness to have a Common Operating Picture (COP). Presently, the three Services and Coast Guard have limited numbers of joint exercises, primarily due to planning and space constraints. The type of assets, cost, serviceability, and aspects of wear-and-tear results in scaled down participation of various components in joint exercises. At a point wherein the Services are debating and implementing Theatre Commands and exploring more joint avenues to operate together, the AI-assisted technologies of Augmented and Virtual Reality offer the participants a more integrated chance to train together. The scenarios and settings can be dynamically changed as per evolving strategies and weapon profiles of the adversaries while own processes can be systematically addressed through such joint simulations and AI-assisted war-games. The same is the case of Unmanned Aerial and other Systems which can be a joint asset for better operational efficacy.

The capabilities of AI and the role of all associated systems of AI needs to be introduced as part of Professional Military Education (PME) at the tri-services level. An integrated multi-domain fighting force, which is the demand of future battlefields, cannot have commanders or staff who are unaware of the capabilities that these emerging technologies can offer. PME needs to address these requirements at the level of Officers, JCOs and troops. Even as agencies like DIPR devise psychological measures to embrace machines and systems, there is a need to revamp present training methodology at unit/sub-unit level, which focuses on Mission Essential Tasks (MET) and Mission Essential Task Lists (METLs). There is a need to set up Human–Machine Interface Teams (HMiT) at each level, which will facilitate this transition. The HMiT can identify various stages where technology can enhance and augment success in operations or for various tasks. After all, success in a task is one of the prime determinants of Combat Effectiveness.

Diminishing numbers of Field Firing Ranges (FFR), ever expanding urban landscapes encroaching into traditional training areas, cost-cutting measures, and other such factors can be summarily overcome by adopting AI-assisted Joint War-gaming and Simulation methodology[24] which will bring in much-needed awareness, dynamism and joint (purple) mindset at various levels of leadership. AI-enabled systems and HR analytics can also assist in HR management by identifying key personnel to operate specific platforms,

right from recruitment and training stage which will at some stage obviate the biases or prejudices that are found in identifying a right man/woman for the job.

While the capabilities of AI and related technologies are tremendous, the pitfalls of faulty implementation strategy can cause long-term damages. As new technologies are adopted, ethical and moral concerns including concerns of privacy need to be duly factored. The subsets of Machine Learning and Deep Learning require huge datasets for establishing a referential framework. In the present set-up, with differing levels of confidentiality and limited sharing and recording of events, having a viable training dataset and an algorithm which can cater for multiple contingencies becomes a challenge. The famous 'Death Algorithm'[25] concept wherein an algorithm for a self-driving car should save the occupants or a pedestrian in case of likely occurrence of a crash gives an insight into the challenges in devising AI systems.

Conclusion

Even as AI in its present form transforms from 'Weak AI' to a stronger variant with deep learning, neural networks, etc., concepts like Artificial Intuition and Quantum Cognition will gain more traction. A future-ready force preparing for multi-planar, multi-domain operations must be truly integrated at the human–machine, human–system level and this can become a reality through systematic, sustainable, incremental yet parallel, nudges at various levels of the organisation. Trust amongst the members of a team has to transcend to human–machine trust with adequate safeguards against systemic and implicit biases.

Notes

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