DECISION SUPERIORITY OPTIMIZATION THROUGH ARTIFICIAL INTELLIGENCE, MACHINE LEARNING & COGNITIVE AGILITY

"Information, information processing, and communications networks are at the core of every military activity."

Joint Vision 2020. America's Military – Preparing for Tomorrow[1]

INTRODUCTION

1. Within modern military organisations the human operator is the core capability and its most important asset. As military campaigns increasingly concentrate on the human aspects of warfare and often operating on the very edge of philosophical, legal and policy mandate boundaries, soldiers, sailors and airmen must continuously assimilate diverse information sources, quickly interpret and analyse these, then devise and execute judicious actions to achieve Decision Superiority. This fundamental process is at the core of every modern military action.

2. This paper will examine opportunities to optimize information superiority for military practitioners utilising both "Push" (maximize efficiency of relevant, accurate and current information provided) and "Pull" (tailor information provision based on human capacity to absorb) mechanisms. To achieve this, a combination of Artificial Intelligence (AI), Machine Learning, and persistent Biomarker Monitoring technologies is proposed that will be outlined later in this paper.

3. **Purpose.** To **outline** advanced Push/Pull methods of information delivery to human military operators harnessing AI, Machine Learning and Cognitive Monitoring in order to enable optimized Decision Superiority in the complex multi-domain battlespace.

BACKGROUND

4. In 1992 a total of 100GB of data was generated globally per day. In 2018, it is estimated approximately 50,000GB of data will be generated globally *per second* (4320 Petabytes per day)

[1] Joint Vision 2020. America's Military – Preparing for Tomorrow (2000). National Defense University, Institute for National Strategic Studies, Fort Lesley J. McNair, Washington, DC, 20319.

with no signs of this trend abating.[2] As such, the challenge lies in identifying the relevant knowledge needle amongst the information haystack within the parameters of the specific mission requirements. Concurrent to this is the ever-increasing complexity and diversity of military operations requiring rapid, accurate and continuous knowledge to enable Decision Superiority against an evolving, agile, amorphous and often asymmetric threat. Fusing these two premises results in a future complex battlespace that demands high levels of rapid intelligence support drawn from a colossal and growing global reservoir. To deliver tactical advantage to human operators however, this information must be translated into knowledge. Unfiltered, voluminous information provided *en masse* to tactical elements will quickly result in incorrect interpretation, disorientation, information overload, unsound tactical actions, and/or decision paralysis. Humans alone are unable to process the vast quantity of information generated, whilst conventional processing machines, whilst faster, have limited utility in analysing intuitive linkages between data points and comprehending trends and patterns. This dynamic is referred to as the "Push" component of Information Superiority in this paper.

5. Multiple peer-reviewed research articles have validated the inherent limitations of humans to absorb and process multiple concurrent information sources simultaneously.[3] The resulting condition is known as "cognitive overload" and typically occurs when more than three information sources are provided simultaneously. At this point individuals are unable to process information effectively, and when matched with high levels of stress (as tactical combat elements are likely to experience), results in a "fight or flight" reaction through triggering of the Sympathetic Nervous System (SNS).[4] When this occurs, judgement, cognitive function and decision making are all significantly diminished. An instinctive reaction with limited cognitive appreciation is most likely[5] – an outcome which is inimical to tactical best practice. Tailoring the priority, quantity, method and time of delivery of information to the human practitioner based on maintaining their optimal cognitive function is referred to as the "Pull" component of this paper.

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[2] http://www.vcloudnews.com/every-day-big-data-statistics-2-5-quintillion-bytes-of-data-created-daily/

[3] Lavie, Nilli, Hirst, Aleksandra, de Fockert, Jan W., Viding, Essi (2004), Load Theory of Selective Attention and Cognitive Control. Journal of Experimental Psychology: General, Vol 133(3), Sep 2004, pp. 339-354.

[4] Murphy, R.L, Ross, D,L (2009). Virtual Training Systems and Survival Humanistic Factors. Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) 2009 submission paper No. 9116. Suwanee, Georgia.

[5] McGrath, J.E. (1970). Major methodological issues. In J.E. McGrath (Ed.), Social and Psychological Factors in Stress. New York: Holt, Rhinehart, and Winston.

This cognitive function would utilize a combination of persistent biomarker monitoring technologies augmented by manual voice activated cues from the human operators themselves. To optimize outcomes, the "Push" and "Pull" elements of Decision Superiority must be managed as complementary and co-dependent effects using a variety of technologies.

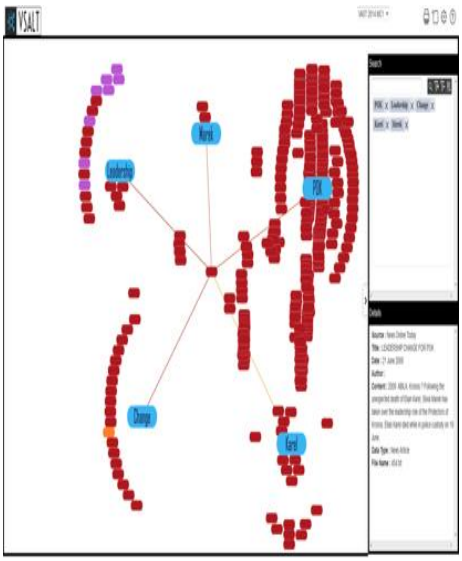
6. The rapid evolution of communications technology in the last century from primitive First World War means (telephone cables and carrier pigeons) to modern persistent social media platforms, ubiquitous civil infrastructure, mesh networks, satellite communications, software designated radios and sophisticated encryption has progressed almost without consideration of the human in the loop to manage or incorporate this increased data volume and methods of access. Modern communications whether civil or military are typified by immediate information, continuously provided, with little to no tailoring of the quality or relevance of information prior to arriving at the recipient. The proliferation of such practices, technologies and trends across a global population has resulted in broader and faster networking with increasing time compression between communication iterations, but also a deterioration in analysis, comprehension and understanding. Should this societal trend continue with permeation into the military domain, the natural conclusion is a diluting of the quality of actionable knowledge supporting military actions due to the inability of human or machine processing protocols to effectively achieve filtering, analysis and distribution optimization. Noting that Decision Superiority based on quality intelligence is at the core of almost every tactical military action, this has widespread and ubiquitous consequences if not addressed.

"PUSH" TECHNOLOGY OPPORTUNITIES – AI / MACHINE LEARNING

7. Artificial Intelligence (AI) and Machine Learning is at the forefront of technological evolution. With significant financial and intellectual investment, the next decade is ripe with possibility for the judicious employment of AI and Machine Learning to real world problems, both civil and military. As an enabler to the information superiority challenge outlined in this paper, AI and Machine Learning has the potential to mitigate the exponential growth of data generation through advanced automated analysis, filtration methods, simulated artificial neural pathways and game theory to narrow in on those information kernels of genuine relevance to deployed military forces, in a timeframe many orders of magnitude faster than human operators. Showing particular promise are Reinforcement Learning techniques and Generative Adversarial

Neural Networks which can essentially improve their own performance as they are used over time.

8. To illustrate the potential "game changing" effect AI and Machine learning can have, a recent initiative by Google Deepmind was the development of the "AlphaGo" program. Employing cutting-edge AI mimicking human neural networks, AlphaGo successfully focused it's AI engine on a 3000 year old game that has more possible combinations than there are atoms in the universe – 5.63×10^{170}.[6] An insight into the sophistication of modern AI is the fact that in 2017 AlphaGo defeated the top 20 Go players worldwide by a margin of 60-0, including 3-0 against the current world champion. Whilst validated through a tactical game, this nevertheless represents a comparable testbed covering diverse and complex decision branch trees, weighted evidence deliberation, simulated neural pathways, and predictive outcomes analysis. It is proposed to build upon this new baseline of AI and Machine Learning within a context of information filtering and customised mission intelligence support to enable the human military practitioner to receive accurate, relevant and current knowledge in direct support of their specific mission requirements.



9. Recently developed to TRL 3 for the UK Centre for Defence Enterprise (CDE), SimCentric Technologies has built a concept demonstrator of the Visual Search and Linkage Tool (VSALT). Whilst the user interface has been generated with the Intelligence Analyst community in mind, it is the underpinning AI/Machine Learning technology utilised in this application that we would propose as meeting the requirements of big data management within a military intelligence support function. VSALT uses multiple machine learning filters employing a multi-layer Neural Networks to intelligently filter out data which is unrelated to the knowledge requirements of that search iteration. It has been successfully validated using a bounded dataset of approximately 1.5 million records, with significantly larger database testing scheduled throughout 2017.

[6] https://www.youtube.com/watch?v=g-dKXOlsf98

10. The future roadmap for VSALT includes numerous functions of relevance to Information Superiority as defined in this paper including intelligent imagery processing using convolutional Neural Networks; a series of unsupervised learning to support outlier detection, sub-community identification and network analysis within data sets; and a deep Recurrent Neural Network to anticipate queries for data based on recent and current events. SimCentric also intends to develop a pair of Generative Adversarial Neural Networks which will allow the system to teach itself new strategies to balance the breadth vs depth of information presented to the human based on how they are using the system. It is estimated that such techniques and methods will become critical to mitigate the continued expansion in data generation that whilst useful in generating knowledge, simultaneously masks it by pure quantity and speed of creation.

"PULL" TECHNOLOGY OPPORTUNITIES – COGNITIVE AGILITY

11. Military practitioners on front line duties are required to concurrently process multiple information sources rapidly whilst fatigued and typically in physical danger. However, numerous studies have confirmed that excessive information stimuli causes cognitive overload which remains an inherent and enduring human characteristic.[7] As such, the human operator must only receive succinct knowledge that is pertinent to that mission, at a time and in a method whereby they can process the information judiciously whilst remaining combat effective.

12. The wearable technology sector has experienced exponential growth in the past decade with a multitude of devices available to monitor dozens of human biomarkers across various form, fit and function options. It is proposed to harness the existing (and continuing) investment in this field to understand the relationship between individual biomarkers and the cognitive functioning of the individual. From a human context, this enables the real-time monitoring of each individual to comprehend when they are cognitively effective in terms of decision making and information processing, and when they are cognitively overloaded and thereby ineffective.

13. SimCentric is currently partnering with the Academic Research Sector BioMedical Sciences community to conduct further studies on the collection of individual biomarkers and their relationship to both stress and cognitive functioning. It should be mentioned that this niche research initiative is based on solid foundations of existing global research and published studies.

[7] Salas, H. and J. Driskell (1996). Stress and human performance. Mahwah, NJ. L. Eribaum Associates.

14. One intent from this study would be to establish, then refine, the "Pull" component of this proposition. By analysing the tactical military operators in real-time based on their biomarkers (and supported by manual verbal cues), information flow could be adjusted in quantity and priority based on their cognitive state and tactical circumstances. For example, if the force element was out of physical danger, a larger quantity of "slow time" deliberate planning information could be provided to the tactical commander including augmented reality (AR) map overlays and route fly-throughs, intelligence summaries, geographical information and AI analysis of terrain, adversary, and tactical planning. Alternatively, if a force element was in immediate physical danger, such as a contact, with higher stress and lower cognitive functioning, then the quantity of information would be immediately reduced, whilst being tailored around those components with immediate tactical consequence such as AR weapon effect overlays, manoeuvre and withdrawal routes, and available supporting close air support platforms with summarized predictive effects. Through a combination of biomarker monitoring to determine cognitive function, supported by manual voice cues, the filtered and prioritised knowledge generated in the "Push" component of Decision Superiority is delivered to the operator in a form, time and method supportive of their requirements.

15. Two additional research areas are proposed from this initiative. First is the testing of whether it is possible to train military members (and humans in general) to improve their cognitive flexibility and, therefore, be able to cope with a higher volume of concurrent information sources under stress. Enhancement of neuroplasticity amongst military members would be of ubiquitous benefit across all mission profiles. The second study area surrounds the validation and optimisation of the plethora of emerging enabling technologies that are now provided to the tactical member. Prototype technologies such as Augmented Reality Glasses and data network features could be quantified in terms of overall benefit in enhancing the combat effectiveness of the individual and small tactical collective unit. In other words, are such capabilities a true combat enabler, or do they cause detriment to the cognitive functioning and thereby the combat effectiveness of the individual?

SUMMARY

16. Successful military operations require accurate, relevant and current knowledge on a continuous basis, however the global trend of exponential data generation continues to limit the ability to decipher knowledge from information, tailored to tactical mission requirements. Human analysts are unable to process the vast quantity of data, whilst conventional processing machines lack the intuition to identify pertinent patterns and trends. It is proposed in this paper that the employment of ground-breaking AI and Machine Learning technologies including the replication of human-like neural pathways, can aide in mitigating this challenge to achieving Information Superiority. When matched with the capacity to tailor priority information requirements to the recipient based on their verified cognitive functioning and circumstances, this ensures that Information Superiority, enabling Decision Superiority is optimized.

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