ACADEMIA MILITAR

AI-powered military decision-making: an assessment of the current capabilities and applications

Aspirante de Infantaria Luis Filipe dos Santos Ribeiro

Trabalho de Investigação Aplicada

Mestrado Integrado em Ciências Militares na Especialidade de Infantaria

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EPIGRAPH

“The rise of powerful AI will be either the best, or the worst thing, ever to happen to humanity.”

- Prof. Stephen Hawking

DEDICATORY

To my father, whose unwavering strength and support were the driving forces behind this achievement. To my mother, whose boundless love and affection nurtured me throughout this journey. And to my sister, whose lucid guidance and wise counsel illuminated my path when I needed it most. This work is a testament to the profound impact you have had on my life.

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A big thank you to my Infantry comrades with whom I spent the most difficult moments of my life. The impact they had on my life was crucial in completing this stage and I couldn't have asked for better comrades on my side.

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Thank you to my advisor, José Borges, for taking on this challenge and helping me so readily.

Your support was not in vain.

ABSTRACT

Artificial intelligence has been present lately in almost every place, mainly applied in the civilian world. In the military world, the application of artificial intelligence can be a challenge since a small decision can cause severe collateral damage. This work entitled "AI-powered military decision making: An Assessment of Current Capabilities and Applications" has the central purpose of analysing the possibilities and the application of artificial intelligence in supporting military decision-making. The research objectives include performing a systematic review of artificial intelligence research evolution, understanding how Artificial Intelligence can leverage faster and smarter decisions and identifying the role of artificial intelligence in military decision-making. It starts by giving a theoretical framework of the various concepts of AI present, their applications, and small notions of the importance of transparency in decisions between humans and machines.

This work used a methodology mainly based on a systematic literature review and interviews. This research found that AI significantly impacts the military spectrum and that its applications are not limited to just one area of the military context. AI can leverage military decision-making through a huge speed of data analysis, allowing faster, more efficient, and better decision-making.

KEYWORDS: Artificial Intelligence; Decision-Making; Command and Control; Defence applications;

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LIST OF ABBREVIATIONS AND ACRONYMS

Artificial General Intelligence – AGI

Artificial Intelligence – AI

C4ISR-OTM – Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance On-The-Move

C5ISR – Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance, and Reconnaissance

Computer Vision – CV

Decision Support Systems – DSS

Deep Learning – DL

Deep Reinforcement Learning – DRL

ES – Expert Systems

Exclusion Criteria – EC

Explainable Artificial Intelligence – XAI

Explainable Intrusion Detection Systems – X-IDS

Federated Learning – LF

Human Machine Teaming – HMT

Inclusion Criteria – IC

Intelligent Decision Support Systems – IDSSs

Knowledge-Based Systems – KBS

Machine Learning – ML

MAHPG – Multi-Agent Hierarchical Policy Gradient

Military Decision-Making Process Engine – MDMP

Natural Language Processing – NLP

Partial Observable Markov Decision Processes – POMDPs

Quality Criteria – QC

Recognition Primed Decision-Making – RPDM

Research Question – RQ

Sub-Questions – SQ

Systematic Literature Review – SLR

INTRODUCTION

Since the 1950s, Artificial Intelligence (AI) has evolved from concepts and mathematics to reality, driving multiple facets of modern society - a once sci-fi creative idea now intrusively interwoven into our daily lives. A disruptive force promising to revolutionise industries and domains, integrating AI into military operations and defence strategies leverages the immense potential for significantly augmenting decision-making processes, strategic planning, and warfare capabilities. Initially, this research aims to correlate AI's many definitions, current real-world applications, cutting-edge techniques, ethical considerations, and its role in enhancing military decision-making. It commences by scrutinising the diverse viewpoints and meanings attributed to AI's intricate, multifaceted concept - outlining the primary goals of replicating, enhancing, and ultimately surpassing human intelligence and cognition through advanced Machine Learning (ML) algorithms, deep neural networks, and computational techniques at the forefront. We explore the complexities in defining intelligence broadly, highlighting challenges in establishing a universal definition as perceptions of AI range from viewing it as merely an algorithm to replicating human intelligence. The focus is directed towards AI systems emulating "intelligent behaviour" by pursuing specific goals while emphasising current narrow AI's specialised task design versus replicating the full scope of human cognition that Artificial General Intelligence (AGI) aims for. The work shifts from theory to modern practice, delving into AI's rapidly proliferating applications across spheres like finance, healthcare, education, customer service, and more - a transformative effect spanning sectors. With the consumer-focused segment addressed, this work focuses on military operations and national defence strategies - examining the integration of AI techniques and their transformative effects by accurately depicting the current AI landscape. Leveraging AI to heighten situational awareness and operational flexibility and enable rapid responses is investigated through use cases like processing vast intelligence data to construct predictive analytics and autonomous decision-making systems. We review primary AI functions across domains, including knowledge representation via ontologies and expert systems, autonomous unmanned system control, signal intelligence analysis, cyber defence, logistics optimisation, and more. Moreover, we assess AI's potential as a strategic asset in today's multi-domain operational environment, providing commanders with crucial planning, simulation and course of action evaluation capabilities. A central issue also tackled is machine ethics' complex, evolving theme. As AI systems grow increasingly self-reliant in high-stakes decision-making like defence operations, scrutinising their actions' ethical and societal repercussions becomes imperative. Approaches to introducing ethical frameworks into AI - both implicit models restricting unethical acts through software constraints and explicit models transparently integrating ethical principles into decision-making - are investigated. The ethical aspects and burgeoning field of eXplainable AI (XAI) are also focal points for addressing the machine ethics quandary. With increasingly complex ML models, interpreting their decision-making rationale, especially in legally regulated areas, becomes necessary - traced to the need for XAI to bridge the divide between opaque "black box" models and human-interpretable systems fostering trust. New research pathways for creating explainable ML models are highlighted - purposely structural, statistical, and perceptually-oriented models generating interpretable outputs via feature visualisation, example-based explanations, natural language rationalisation, and more. XAI's various explanation types (raw feature attributions, model summaries, cognitive strategy presentation) undergo examination. Among the most crucial topics, trustworthy AI analysed links to XAI principles - evaluating fundamental tenets for developing trust and confidence: safety via rule creation, legal/ethical compliance, human-centric values like privacy and fairness, transparency and accountability. Combining XAI with robust model governance is vital for realising trustworthy AI ecosystems that are deployable across critical domains like defence. We then refine the research to present the Methodology, Results, and Conclusions. Integrating insights from the Systematic Literature Review, this phase develops into the analyses of the findings from interviews with experts, explains the methodology used and draws conclusions from this research.

We defined the research question for this work as: "What are the possibilities and applications of artificial intelligence in supporting military decision-making?". Therefore, we set the thesis objective as "Analyse the possibilities and the application of artificial intelligence in supporting military decision-making". We refine the thesis objective into detailed research objectives:

- SO1: Perform a systematic review of artificial intelligence research evolution;
- SO2: Understand how AI can leverage faster and smarter decisions;
- SO3: Identify the role of artificial intelligence in military decision-making.

PART I – LITERATURE REVIEW

CHAPTER 1 – ARTIFICIAL INTELLIGENCE

1.1. Relevant Concepts in Artificial Intelligence

As a field of mathematics and computer science, AI has become a nearly omnipresent topic. Aggarwal & Kumar (2020) state that AI is the branch of computer science which deals with creating artificially intelligent systems that are more intelligent than human beings. It works through multiple processes, which include rule matching, qualitative attribute description, logical and computational association, and predictive modelling for the unfolding events, making it the core of the automation process, which enables a relevant boost to the productivity and performance of job holders. Sheikh et al. (2023) argue that the definition of intelligence becomes more complex because we lack a standard definition. Different authors provide different definitions for AI, some more focused on its algorithmic nature, others on its ability to emulate human intelligence using computers. We adopt the definition provided by the High-Level Expert Group on Artificial Intelligence (2019) as *"systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals"*. Xu et al. (2021) suggested that AI is similar to human intelligence imitati, stressing that AI aims to put the human intellect into machines, enabling them to have "human" abilities of perception, reasoning, learning, predicting, and planning. The authors emphasise the difference between human intelligence and animal intelligence and how AI aims to mirror the cognitive functions that humans own exclusively. In their work, they also mention Alan Turing's test, indicating the threshold of an intelligent machine, which is indistinguishable from human intelligence and thereby qualifies as artificial intelligence. Valavanidis (2023) presents AI as a discipline of science leading to the creation of intelligent machines that can do tasks that were exclusively a preserve of humans. ML and Deep Learning (DL) combined with interdisciplinary science have changed several sectors. From technology to business, the impact of AI is undeniable as it can digest massive data with effective algorithms that allow machines to learn from data patterns or input feature sets independently. Valavanidis (2023) also points out that AI can create or improve human capabilities that increase productivity, efficiency, and organisational decision-making in different industries. AI covers a wide range of definitions and interpretations, reflecting the complexity of it and the fact that it is a multidisciplinary concept. From the potential to outperform human intelligence in some tasks to mimic human thinking and emotion, AI can potentially lead to social and industrial transformations that could impact human decision-making.

According to Hagos and Rawat (2022), DL possesses relevant features that enable it to solve complex problems in multi-dimensional spaces with high accuracy. Valavanidis (2023) also explains the importance of DL and ML's critical roles in AI. ML represents the computer's ability to discern hidden patterns and make accurate predictions without programmatically teaching it utilising using algorithms and statistical models to identify complex patterns and automate analytical tasks, rendering valuable insights from large datasets. What is more, he also highlights significant aspects of DL. It builds on ML, extending these algorithms using complex neural networks with several processing units and layers. DL algorithms can discover patterns in large datasets based on the progress in computing strength and training methods. They are especially suited for computer vision and natural language processing problems.

Leveraging the biological analogy of Neural Networks, inspired by the human brain's structure, the neurons' networks comprise interconnected units and layers. Their design supports image and speech recognition tasks because they can identify intricate patterns in data. Inversely, Hagos & Rawat (2022) examine the necessity of considering the data privacy constraints of the customary ML and DL methods as a contributing factor to the advent of Federated Learning (FL). Such a decentralised framework promotes cooperative model training and protects user's personal data from home. It is also used for cases where data privacy is of prime importance, for instance, in sensitive and confidential data cases.

Moreover, Valavanidis (2023) emphasises the capability of Natural Language Processing (NLP), allowing computers to comprehend, read, and generate human language. Natural language processing makes the communication process between humans and machines more human-like, providing such services as sentiment analysis, text summarisation, and chatbot communicativeness. By studying language data to arrive at the meaning behind a message and its context, NLP algorithms provide devices with the ability to understand and generate appropriate responses in human languages. The work of Valavanidis (2023), for example, sheds light on Computer Vision (CV), a relevant application of AI in a way that consists of training algorithms to interpret and understand visual data related to images or videos. Through pattern recognition and DL technologies, computer vision systems can detect objects, scenes and gestures in real-time. This allows the use of AI in autonomous vehicles, surveillance machines and image analysis in the medical field. These significant technological advancements enhance human decision-making.

While Simo's (1972) work on bounded rationality, as presented by Bosch and Bronkhorst (2018), throws light on our cognitive limits in decision-making, it is important to note that decision-making, as a process, should consider the facts and the intuition of the decision maker. The idea of "bounded reality" exemplifies the nature of human beings very well, standing for the tendency of human beings to encounter the point where the solutions to problems they face are good enough, or they can only keep going. It is in this area that Decision Support Systems (DSS) demonstrate their tremendous worth. They are the systems that formally gather and impart this knowledge to decision-makers, helping them solve structured and unstructured problems (Kaklauskas, 2015; Susnea, 2012). Intelligent Decision Support Systems (IDSS) provide tools to mimic cognitive engines. These functions may extend capabilities, enhance reasoning, extract/detect details which may not be visible to the human eye, perform analysis and propose solutions in varied domains such as military tactics and business analytics (Kaklauskas, 2015; Moisescu et al., 2010).

1.2. Explainable AI

Machine ethics, a newly created field in AI research, deals with the complex ethical problems caused by the increasing independence of AI algorithms in their decision-making processes. Due to the fast growth of AI systems in both the educational and industrial sectors, ethical problems, social issues, and the management of these systems are sometimes neglected, resulting in an urgent call for us to thoroughly explore the safety and ethical aspects of autonomous technologies to understand the possible implications. The primary objective of machine ethics is to design robots capable of rational thinking with a moral and ethical compass, which is essential in their interactions with people and other autonomous systems. It requires the development of control systems for intelligent machines to make decisions that comply with the established ethical principles. According to Hagos and Rawat (2022), two fundamental approaches emerge within this domain: implicit and explicit ethics systems. Implicit ethical machines act by limiting the activity of intelligent systems towards unethical situations, mostly done through the internalisation of software functions that promote ethical conduct. Explicit ethical machines utilise explicit representations of ethical principles for making decisions, which allows the implementation of transparent, ethical judgments, even in novel situations. Recent developments in ML opened doors to different methodologies of ethical decision-making within AI, including the classification of ethical judgements using neural network models and case-based moral reasoning while also unlocking some alternative methods, including action-based approaches and the application of deontic logic, introducing particular ethical principles into the decision-making formula of autonomous systems. The assessment of these approaches, especially in correspondence with the categorical imperative, an important ethical principle by Immanuel Kant, highlights the multifaceted nature of machine ethics research and its possibility to inform the creation of ethically right AI systems. As we enter the area of Explainable AI (XAI), ensuring the ethical foundations of autonomous systems is crucial, enabling transparency, accountability, and public trust to be achieved and earning the most needed visibility in recent years due to the increase in the need for explainable and interpretable AI Systems that Hagos and Rawat (2022) have noticed. Nowadays, ML systems are becoming more developed, so the expectations also increase, making systems cool and human-understandable. This is vital in certain domains where the defining factors are ethics, law and society. Regulatory activities in recent years have highlighted the necessity of explainability, which has led to a wave of concrete research initiatives to create explainable ML methods. XAI has bridged the gap in which users can clearly understand what AI systems decide; thus, it enables the users to learn new things, which boosts confidence and trust Hagos & Rawat (2022). On the other hand, ML and AI systems have inbuilt opacity, and their interworking is not yet known completely to humans. This poses challenges that Li et al. (2020) explore. Despite efforts to explain the open-source tools that are trying to be faithful to human expectations, we still have a large area to improve to be trustworthy Hagos & Rawat (2022). Trustworthy AI is a major factor in ML systems development, and it revolves around safety standards, laws, goodness, and principles of ethics as building a trusting relationship between humans and devices becomes necessary, especially for the military and national intelligence government areas. The framework of trustworthy AI comprises several elements, including security, data privacy, transparency, and fairness, intending to achieve complete AI utilisation. Applicating XAI effectively and addressing basic issues and concerns helps trusted AI, making it more transparent and consequently making humans understand and trust ML systems (Hagos & Rawat, 2022). The generation modes of modelling also need attention (Li et al., 2020). The introduced approaches are purposefully structural, statistical, and perceptually human communication modes, as shown in Figure 1. The structural mode stimulates the process of basic interpretation and visualisation at the perceptual level, which originates from simple diagrams and symbolic classification. The statistical mode uses feature extraction and example-based explanations to improve explainability. In contrast, the human perception mode focuses on examples, comparisons, and natural language explanations to aid user understanding. Li et al. (2020) organise ML explanations into raw, summative and cognitive explanations or thinking processes. Raw explanation highlights the feature that most contributed to the decision-making process, explaining it in raw, unbiased information. Summative explanation is realised with the help of design-explainable models and surrogate models. These models and models are used to provide particular insight whose statistical processing comes from data of black box models (Li et al., 2020). Integrative cognition links biological mechanisms, the purposeful processes of human understanding, and compliant language development. XAI is a dynamic and never-ending field resting on the foundations of the 1970s, where the principles were laid out for the first time by Van Lent et al. (2004). It hopes to serve in the medical field, finance, defence, transport, justice, security, and many more areas (DARPA, 2016). However, the fuzzy boundaries between the far-reaching notion of "interpretability" and "explainability" in the discussion of this topic impose obstacles, accentuating the demand for the precision and standardisation of definitions and measurement criteria for interpretability (Neupane et al., 2022).

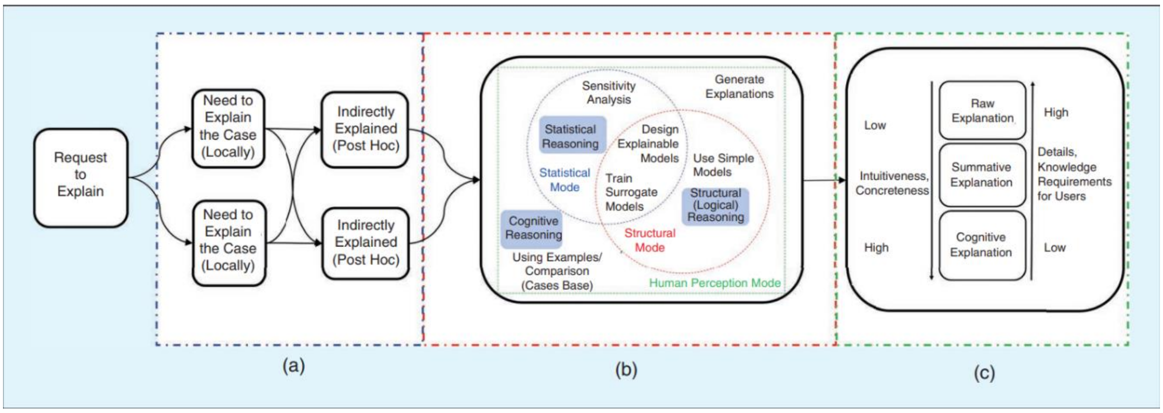

Figure 1 - The mapping between XAI and trust: demonstration of (a) directions, (b) modes (analysis and generation), (c) methods (demonstration), and their relationships.

Source - (Li et al., 2020)

1.4. AI applications

Several applications of AI include practical applications in daily life cases, as stated by Sheikh et al. (2023). The authors explore how AI can impact daily life and tasks and how it went from theoretical developments into practical applications. Current applications include different fields, ranging from image and speech recognition to autonomous vehicles and healthcare and ML plays a pivotal role in predictive analysis as it can help predict future events/trends. They also stress the way AI helps regarding recommendation systems. AI provides tools to analyse users' behaviour and preferences and deliver the most suitable content. They also mention AI's significant impact on financial services, namely in tasks such as credit rating and fraud detection, since its AI-driven algorithms improve the accuracy and efficiency of cybersecurity, enabling more efficient protection of financial institutions and their consumers. Valavanidis also mentions how AI is involved in computer vision, highlighting how it can help to automatically process visual data, underlining the usage of facial recognition technology in optimising security systems and, for example, giving self-driving cars better navigation. Besides, he also goes into detail about how AI has the potential to be the leading customer support through advanced NLP and speech recognition technologies, which in turn will make the interaction between users and AI-driven systems smoother and more effective. In online shopping, Sheikh et al. (2023) present information on how AI boosts customer satisfaction through the personalisation of recommendations and the real-time assistance of chatbots. They also support AI's changing role in the educational field, where students receive personalised learning experiences and automated administrative tasks, enabling teachers to dedicate more time to the individual student's needs, thus vastly improving the traditional teaching methods. Besides, Sheikh et al. (2023) and Valavanidis (2023) both focus on the positive effects of Artificial intelligence on email security, financial services, and personalised experiences across different digital platforms. The collective knowledge of the experts shows how AI is still flexible and touches upon the changes of AI in modern life with the gradual improvement of individual performance and the user experience in various fields. Yadav and Pandey (2020) use the above ideas to expand on the views of other scholars in the fields of artificial intelligence, spatial research, and robotics. They explore the way AI helps disabled people to communicate through the new assistive technologies, ensuring accessibility and life quality improvement. They point out the significance of AI in space research: the analysis of the universe's data and the discovery of new secrets, thus studying how it is used in them. Yadav & Pandey (2020) can present how AI impacts robotics, making machines go beyond mechanical operations and efficiently improving how ideas surge different industries. The research of Sheikh et al. (2023), Valavanidis (2023) and Yadav and Pandey (2020) is a combined contribution to the study of AI's transformative power in various sectors. Thus, innovations and improvements will be the outcomes in modern society.

1.5. AI Applications in Defence

AI is now one of the critical technologies in contemporary defence operations, thus transforming how military forces carry out their operations and consequently improving the armed forces' capabilities on the battlefield. Sinchana et al. (2020) emphasise AI's multifaceted role, highlighting that it can be applied in various fields of defence, from knowledge representation to autonomous decision-making. They also believe that Ontology, a data modelling approach, is critical in representing elements like operations, intelligence, logistics and tactics within military contexts, highlighting that Ontology is a framework that allows the information to be arranged and understood properly to make decision-making easier, give situational awareness, and improve the coordination of the military units referring also to the knowledge-based systems (KBS) backed by AI algorithms, which can gather all the data. Thus, they can be used in different military activities. Hence, for example, in the Air Force, KBS can assist technicians in consulting with specialists, enabling them to solve problems and maintain the systems correctly and accurately. This was also noted by Nalbant and Bozkurt (2022) as they continued the discussion by emphasising the advantages of AI in making quick real-time decisions and the capability to improve target-oriented operations. The AI's ability to process large amounts of data in real-time is pivotal to military commanders, enabling them to evaluate complicated situations instantly and improving agility and responsiveness on the battlefield. The capability to do this is crucial for the agility and quick reactions of the military forces in the war, ensuring the time of the battles on land, the air, and the sea is shortened. Iqbal et al. (2023) were the next to stress AI's involvement in the defence sector, especially in logistics optimisation, equipment maintenance, and long-term strategy planning, to discuss how AI enhances military abilities through the execution of predictive analysis and decision support systems, consequently making the decisions more and more accurate and effective, also mentioning how AI is a key component in cybersecurity as it protects military networks from cyber-attacks and is involved in forming geopolitical situations, empowering numerous military sectors, such as intelligence analysis, autonomous systems, situational awareness, and logistics optimisation, as mentioned by Szabadföldi (2021) also. However, Bartneck et al. (2021) are against using AI in defence, mainly because of the ethical issues related to AI-based weapons campaigns. He believes, on the one hand, that using AI would decrease the number of civilian casualties and, hence, follow the rules of engagement, but still, on the other hand, there are concerns that an arms race would be created and that life and death decisions would be assigned to the algorithms that deprive humans of the human control aspects. Bistron and Piotrowski (2021) additionally show that AI has many applications, including object detection, cybersecurity, robotics and logistics management and in their work, they argue that the social significance of AI integration is highlighted by transparency, trust, human-machine interaction, and ethical oversight, which are the essential aspects emphasising the importance of accountability and responsibility in the process of overcoming ethical and operational troubles. To sum up, aside from AI being vital for international military power, ethical, societal, and operational issues should be considered, as integrating technology will raise morality problems, and it is our job to ensure that AI will help us instead of hindering us.

CHAPTER 2 – DECISION MAKING

2.1. Decision-Making Modules

In contemporary military operations, integrating Artificial Intelligence (AI) offers a transformative potential, particularly in enhancing decision-making processes by developing Intelligent Decision Support Systems (IDSSs). These kinds of systems have been using advanced AI tools such as DL and reasoning, which guarantees the efficient management of massive data flows from different sources (Bosch & Bronkhorst, 2018). Nevertheless, military decision-making is a multifaceted landscape full of complicated cognitive processes, as Harari (2016) notes. The human brain functions via the amalgamation of sensations, feelings, memory, emotions, and thinking, which are further segregated into Type 1 and Type 2 cognitive processes, as Evans (2008) mentioned. Type 1 thinking is primarily based on automatic and intuitive decision-making processes, often instant and unconscious (Gladwell, 2007; Kahneman, 2011). Although faster and easier, intuitive decisions are vulnerable to biases and mistakes, mainly when the context refers to a high-stakes military decision (Dane et al., 2012). Williams (2010) points out that using heuristics can be risky as mental shortcuts may deceive military leaders. Heuristic availability, detailed by Slovic et al. (1980), makes human judgment mainly influenced by the memorability of past experiences, giving a distorted perception of the event and its related probability, leading to military failure.

Furthermore, uncertainty is omnipresent in decision-making at the military level, especially during wars where the situation is in constant change Reed (2008). Dealing with ambiguity with imperfect information obligates commanders to come to conclusions using assumptions and inferences. On the other hand, an overabundance of assumptions can overload human cognitive capacities, causing difficulties in uncertainty management of military operations. In addition, Moffat and Medhurst (2009) and Moffat (2002), who came up with the Deliberate Planner and the Rapid Planner models, make the point that each has its own theoretical background and practical implications regarding decision games. The Deliberate Planner is used to decide on the deployment of forces, and the headquarters do long-term campaign planning.

Meanwhile, the Rapid Planner upholds the Recognition Primed Decision-Making (RPDM) model by Klein and Sullivan (2001), which gives more space to decision-making under pressure employing recognition rather than analysis using reason. The RPDM model argues that decision-makers analyse several possible alternative action plans by comparing the current situation with similar scenarios they have stored in their memories, providing a quick, intuitive decision basis and also diverging from standard rational decision-making, where the utilities of multiple options weighed up to elect the most effective response. One practical example is decision games, where they mirror real-life situations, aligning precisely with the RPDM model as players follow the data provided to predict patterns. Data from Moffat & Medhurst (2009) indicate that game-making processes align with the RPDM model by 60–80%. Additionally, players often mirror their behaviour in real-world circumstances in these games. As the psychological model is in line with the decision games, interest is turned to the Rapid Planner, which assesses the available options, taking into account the current situation, such as values of parameters and uncertainty, to identify the most probable option and to choose it. The nexus of AI technologies with cognitive elements of strategic decision-making could positively affect military outcomes. Although AI-enabled IDSSs claim to increase the speed and efficiency in managing complex data streams, fully understanding human cognition, biases, and pervasive uncertainty is essential.

2.2. Human-Machine Teaming

Human Machine Teaming (HMT) is the cutting edge of AI, which represents the cooperation between humans and intelligent machines that contribute towards dealing with complicated problems by exchanging functions. This collaboration, initiated by the exponentially increasing speed of AI technologies, envisages taking advantage of individual human and machine expertise to attain common ends. On the other hand, harmony between humans and artificial intelligence is not taken for granted; it is a mighty obstacle that emphasises the undeniable need for transparency and confidence on the part of humans and AI systems in the future age. Trust, in this context, is the key element since it determines how people perceive decision-dependent AI, which determines the HMT success rate. Co-functionality among disciplines is fundamental to improving transparency and creating an AI ecosystem that could be fully used to exploit the full potential of AI in the future to solve big societal problems. Explainability, as mentioned in this work, becomes a crux that lets humans get a grip on AI rationality and better understand the decisions made by AI. Through their explanations and interpretations, AI systems become an extension of the functionalities of humans, making them use the predictive capabilities of AI systems effectively. This aspect gets particular importance in domains like security, healthcare, and production, where self-governed systems work so closely with people. Promoting human-machine-technology aims to boost overall performance metrics, including productivity, reliability, operation, and accident prevention. Ad-hoc human-machine teaming, in turn, features a particular aspect: "collaboration without prior coordination".

Consequently, here, robust cooperation mechanisms are implemented in the context of the intelligent agents operating with heterogeneous teammates in the rapidly changing surroundings. However, this is a difficult hurdle to overcome with necessary unconventional methods, such as online algorithms explicitly designed for ad hoc groups (Hagos & Rawat, 2022). The military decision-making resulting from the composition of AI capabilities and the human interface symbolises collaborative innovation brought about by the same capability degree in different domains and organisational levels Kerbusch (2018). Decision-makers navigate multifaceted scenarios from land to cyberspace, necessitating robust analytical tools. Artificial intelligence technologies have become multifaceted tools for data analysis, predictive modelling, and scenario evaluation. They are used to gain valuable knowledge about adversary behaviour and the operational environment. The principal question is the role of expert system support in human-AI collaborations, where AI acts as an efficient, knowledgeable assistant, ready to make suggestions and give optimisation ideas. Such synergy enables the leaders to formulate data-driven conclusions, employing AI to do the modelling and simulations.

On the other hand, AI technologies become virtual team members in decision-making processes, contributing actively and, therefore, comprehending the strategic picture. Thus, AI development containing human-robotic pairing may shift the field of science to the next level, gradually bringing together different domains for joint creative and intensive work. Technology automation through AI utilizes a powerful tool for the symbiotic union of man and machine that amplifies the decision-making processes and operations efficiency levels. Diagrams that show how AI improves human involvement in predictive maintenance, recommendation systems or supply chain optimisation depict AI as a supporting tool that offers personalized input and drives efficiency in complex operational structures. Human-machine teaming represents a flow-based change in how Artificial Intelligence (AI) helps. Working directly together, humans and AI instruments can develop as quickly as possible to deal with complex challenges in rapidly changing circumstances and reach common goals in an ever-changing technological environment.

2.3. AI Applications in Decision-Making

Military command and control is a systematic decision-making process composed of planning, directing, coordination and control. It aids commanders and their staff execute assigned tasks in mission analysis, planning, decision-making, and execution. This instance of the methodology embodies the idea that the treatment of the systematic approach enhances thoroughness, clarity, and success, ensuring we sustain logical thought and effective military judgment (Liao, 2000). As computed to date, decision support has not been used for complex operations, focusing mostly on simple data manipulation like storage, retrieval, data consistency checking, and small calculations to predict any value accurately. Notwithstanding, the discourse on how learning or training affects how decisions are made requires improvement. As a key point, the human psychological dimension, reasoning, and decision-making process are significant because they determine an individual's decision behaviours, skills, and traits (Liao, 2000). Today, military operations, particularly in the context of different domains and levels of organisations, call forth the significance of command and control that acts as a catalyst or the linchpin for success (Kerbusch, 2018). Artificial intelligence (AI) technologies present themselves as the enabling factor which increases the capability of both the staff and commanders to manage conflicts effectively at all echelons of the military command. Strategically, the deployed AI tools enable commanders to handle comprehensive analyses, predictions, and simulations, assisting them to accomplish their objectives to the highest degree. On the next level of operations, the AI will support the commander's attempt to organize means, monitor operational effectiveness and adjust to the enemy's progress so that fast decisions and accurate placement of power are provided on time to reach objectives. AI has become a big weapon on the tactical front in real-time intelligent, predictive analytics and efficient decision-making with the help of various tools, thus retaining the superior party. It is detrimental to expect AI to be endowed with the best ML to mirror human decision-making processes fully, enhancing military operations and effectiveness (Goztepe et al., 2015). The AI serving the Military Decision-Making Process Engine (MDMP) responds to the diverse nature of security threats, with commanders being part of the process with intelligent systems as partners. ML is known to be capable of going through immense data records at a much greater speed than humans do to allow faster and broader task perspectives and, thus, better decision-making (Goztepe et al., 2015). Advances in AI provide decision support systems with real-time data and recommendations as well, which, in a way, augment the abilities of military personnel. At the same time, they are freed up to pay attention to the tasks of higher-level decision-making (Goztepe et al., 2015). This is supported by Carey (1990 and Storey Hooper et al. (1998), which reflect the great interest that the military is showing in expert systems and their application across different functions. Such jobs are related to military intelligence, command option-making, instruction, and database management. Besides that, larger-sized systems have been invented, like the introduction of the slating method, which is employed to complete the fellows' selections to the Senior Service College. The crucial role of artificial intelligence (AI) and expert systems (ES) in carrying out military operations has been widely documented (Carey, 1990; Storey Hooper et al., 1998). Recent studies have suggested making sensible integration of planning and deep reinforcement learning (DRL) to allow the development of superior decision-making systems in autonomous environments, as portrayed in an autonomy study on driving scenarios (Hagos & Rawat, 2022) as this approach demonstrates the benefits of combining two methodologies, DRL and planning, to face a dynamic and unforeseeable environment that faces challenges such as uncertainty or adversarial rows. Although partial observable Markov decision processes (POMDPs) present a formal approach for the mathematical modelling of decision-making under uncertainty, formulating tactical decision-making tasks with uncertainty awareness in the setting of POMDPs still constitutes a significant challenge (Hagos & Rawat, 2022; Kitchenham & Charters, 2007). Military command and control are essential to victory in any armed mission based on proper planning, coordination, execution, and all-important control routines. In the modern world, with the development of advanced technologies with artificial intelligence (AI), there are unprecedented opportunities for amplifying decision-making and improving task performance. The modern age of war has adopted AI-informed decision support systems, which give military generals a glance into the future, help them foresee hazards before they happen and make informed and immediate responses. Incorporating AI into military decision-making processes provides several vital and consequential opportunities. Initially, AI technology can be applied to process a large amount of data at speeds that go beyond what's humanly possible. These skills enable me to conduct comprehensive and quick analyses of multifaceted problems. Thus, it helps in the realisation of good choices. Using predictive modelling, robotic technology will be capable of far-forecasting possible results and estimating the effect of specific behaviour, which will help the commanders decrease risks in earlier stages. AI-powered decision support systems also develop synchronous data streams and accelerate real-time recommendations and decisions among soldiers. In these systems, machines learn from multiple information resources, such as sensors, satellites, and intelligence, which translates to action-oriented intelligence. Through AI specialisation in routine associated activities, workers busy themselves with essential, relatively high-level decision-making, simplification, and eliminating the cognitive burden. Besides, AI systems have adaptive and self-improvement learning functionality, allowing them to improve themselves continuously. The requirement for adaptability is vital in dynamic and unpredictable environments where instantaneous decisions are of cardinal importance for the endeavour's success. Through advanced data analysis with pattern recognition, AI aids in risk assessment and management to identify the situation and identify security weak spots pre-emptively. While AI provides many benefits, it is not aimed at removing human decision-makers from their work; instead, it is considered a companion of human judgment, providing a manager with timely and relevant data to facilitate the manager's decision-making process. AI integration into the military decision-making system notes a paradigm shift in how modern military forces are carried out. Through AI applications, military organisations can increase their capability to deal with challenges by offering situational awareness, agility, and effectiveness, which can advance the success of the missions in a complex security net. AI's ethical, legal, and technical challenges at integration should be considered to realise the prospective while pulling off the risks simultaneously. While AI keeps developing, its function in military decision-making will probably rise, and it will define the future of the war. Today's growing capabilities in AI are bringing new opportunities for successful strategies and the modernisation of military processes. By implementing AI-based decision-making systems, commanders can overcome the complexity of modern warfare with an umbrella of trust and accuracy, ultimately leading to the safety of the military personnel and the mission's success.

CHAPTER 3 – METHODOLOGY

In this chapter, we will explain the methodology used to achieve this work, try to answer the most important questions and factors and stress why this was crucial to the present research.

3.1. Research Questions and Research Aim

This research explores and assesses how artificial intelligence can leverage smarter and better decisions and its current possibilities and applications in military decision-making.

For this purpose, the main research question (RQ) is defined as:

- RQ1: What are the possibilities and applications of artificial intelligence in supporting military decision-making?

Three sub-questions (SQ) were defined to focus the research and help derive the answer to the main research question:

- SQ1: What is the current state-of-the-art application of artificial intelligence in the military scope?
- SQ2: How can we use artificial intelligence to make better decisions?
- SQ3: Which artificial intelligence applications serve us the most in the military?

Although this research primarily centres on military decision-making, the conclusions regarding artificial intelligence are expected to have broader relevance to other contexts involving complex decision-making processes.

Regarding this research's general aim, we defined our primary research goal as:

- Analyse the possibilities and the application of artificial intelligence in supporting military decision-making;

From this research aim, we set more specific research objectives:

- RO1: Perform a systematic review of artificial intelligence research evolution;
- RO2: Understand how AI can leverage faster and smarter decisions;
- RO3: Identify the role of artificial intelligence in military decision-making.

3.2. Systematic Literature Review

A systematic literature review (SLR) endeavours to meticulously identify, evaluate, and consolidate all existing evidence about a particular research inquiry. It adheres to a systematic, rigorous, and transparent process, following predetermined steps to uphold the integrity and credibility of the findings. According to Kitchenham and Charters (2007), a systematic review protocol must follow a predetermined sequence of steps to uphold the quality and reproducibility of outcomes. These steps encompass defining the research question, locating pertinent studies, applying predefined inclusion and exclusion criteria for study selection, extracting and amalgamating data from chosen studies, and assessing the evidence's quality. This work outlines the process of conducting a systematic literature review (SLR) based on Kitchenham and Charters (2007) protocol, detailing how studies were chosen, analysed, and synthesised.

3.2.1. Databases for Literature Searching and Research Strategy

A manual search on the SCOPUS database was performed for this SLR. As this research aims to assess how Artificial Intelligence can support better and smarter decisions in military decision-making, the keywords "artificial intelligence", "decision support", and "defence" were used on the queries on the search. The OR Boolean operator, used with "defense" and "defence", ensured the research was as thorough as possible. These three keywords were combined using the AND Boolean operator. The following queries were used on the selected database:

- SCOPUS: (TITLE-ABS-KEY(artificial AND intelligence) AND TITLE-ABS-KEY(decision AND support) AND TITLE-ABS-KEY(defence) OR TITLE-ABS-KEY(defense))

After examining the SCOPUS database query results, it became apparent that the "ALL" field yielded considerable material beyond the scope of the SLR. This occurrence was attributed to matches found within document references rather than the documents themselves, as the "ALL" field also encompasses queries within references. Consequently, the database queries on the SCOPUS database were limited to the "TITLE-ABS-KEY" field, which incorporates abstracts, keywords, and document titles.

3.2.2. Definition of the Inclusion & Exclusion Criteria

The Inclusion Criteria (IC) outline the specific attributes an academic work must possess to qualify for the SLR. In contrast, the Exclusion Criteria (EC) delineate the factors deemed irrelevant to the research. Establishing the IC and EC served to mitigate bias and enhance the review's validity by ensuring the inclusion of only studies pertinent to the research question while also managing the review's scope in terms of the number of studies to be analysed.

This research considers the following IC and EC:

- IC1: Following the queries identified in "3.2. Databases for Literature Searching & Research Strategy" on the SCOPUS database;
- EC1: Language – Documents not written in English;
- EC2: Date- Documents published between 1986-2024;
- EC3: Credibility and Reliability – Documents published in journals rated below Q1 on the SCIMAGO database.
- EC4: Expertise – Journals publishing less than two articles in the research area under study.
- EC5: Scope – Documents considered "off-topic";
- EC6: Availability – Documents without the full text available;

3.2.3. Definition of the Study Criteria

Implementing Quality Criteria (QC) was instrumental in guaranteeing the inclusion of pertinent studies in this review. Such studies are inherently more inclined to yield precise and dependable outcomes, thereby bolstering the validity and credibility of the evaluation. Moreover, the QC facilitated the identification of any shortcomings or deficiencies within the included studies, thereby aiding in the contextual interpretation of the review's findings. Additionally, this assessment played a crucial role in the data synthesis phase by enabling the evaluation of evidence and the formulation of judgments regarding the overall quality and robustness of the evidence base. This research considers a weighted QC, as showcased in Table 1.

Table 1: Quality Criteria Matrix

ID	Definitions	Weight
QC1	Does the document employ Artificial Intelligence techniques to provide decision support in Military Decision Making processes?	2
QC2	Are the AI techniques utilized in the research clearly specified, and are they appropriate for assessing military decision-making capabilities?	2
QC3	Is the research methodology adequately documented?	2
QC4	Is the dataset used for analysis clearly identified, and is there a justification for its selection in evaluating AI capabilities in military decision-making?	2
QC5	Is the purpose of the document clear?	1
QC6	Does the document present the applied methodologies and their effectiveness?	1
QC7	Was the document cited in the last years (2022, 2023)?	1

3.2.4. Data Extraction

The objective of the Data Extraction process was to systematically gather and structure pertinent data from the included studies, ensuring consistency and facilitating thorough comparisons. It aimed to address the central research question and sub-questions effectively. The most relevant metadata for answering the primary research question (RQ1) and research sub-questions (SQ1 to SQ3) was identified and integrated into a data extraction form template. This template was designed to streamline the organisation of extracted data, enabling easy reference and comparison among studies. Table 2 provides a detailed overview of the developed data extraction form template.

Table 2: Data Extraction form template

Field Name	Definition
Internal Reference Number	The document tracking number as it pertains to this research
DOI	Document DOI number
Publication Year	Document publication year
Document Title	Document title
Publication Title	Where the research was published

Authors	Document authors
Abstract	Document abstract
AI Techniques Used	Which Artificial Intelligence techniques are used in the research?
Type of Decision Problem	Which decision problem does the document address? Decision Support, Military Decision Making, or Both?
Decision Support Methodology	What methodology is used for decision support?
Military Decision-Making Method	What methodology is used for Military Decision Making?
Features or Factors Considered	What features or factors are considered in the decision-making process?
Training Methodology	What is the training methodology for AI models?
Evaluation Metrics	Which evaluation metrics are used to assess the performance of the AI models?
Dataset Used	Which dataset(s) are used for training and evaluation?
Implementation Platform	What technology or platform is used for implementing AI models?
Best Results	What are the best-performing AI models or methodologies?
Is Code Available?	Is the implementation code available?
Challenges and Proposed Solutions	What challenges are identified, and what solutions do the document's authors propose?
Notes	Any additional remarks or notes taken during document analysis.

3.2.5. Study Selection Procedure

A seven-step methodology was employed in this research to meticulously filter documents of the highest quality through a phased selection process governed by rigorous criteria. Additionally, the research protocol delineates the approach for resolving disagreements between the first and second authors to mitigate bias during document selection. The study selection procedure, illustrated in Table 3, visually represents the comprehensive process.

Table 3: Systematic Literature Review Methodology Overview

Step 1	Initial search of the databases and applications of the Inclusion Criteria (IC1) and Exclusion Criteria (EC1, EC2).
Step 2	Documents were filtered to include only those from Q1-rated journals in the SCIMAGO database.
Step 3	Journals publishing less than two articles in the research area under study were excluded.
Step 4	Analysis of the Title and Keywords to discard records considered off-topic as defined in the EC5.
Step 5	Records matching EC6 are discarded.
Step 6	Full-text analysis and quality criteria validation.
Step 7	Data Extraction on the relevant records.

In the first step, the initial search was conducted according to the criteria outlined in the inclusion criteria IC1 while simultaneously applying the exclusion criteria EC1 and EC2 to filter the query output.

Moving to step two, documents were refined to include only those published by journals rated Q1 on the SCIMAGO database. This criterion aimed to ensure the selection of documents from high-impact journals, thereby enhancing the credibility and reliability of the research findings.

In step three, documents from journals publishing fewer than two articles in the research area under study were excluded from consideration. This criterion aimed to prioritise sources with deeper expertise in the subject matter.

Subsequently, in step four, the titles and keywords were scrutinised to determine whether each document fell into categories of off-topic, possibly off-topic, or on-topic, as per the definition in EC5. Documents categorised as off-topic were excluded at this stage.

In step five, the author gathered the relevant documents for the research. EC6 was applied to academic works that were inaccessible to either author due to limitations on database access.

Moving to step six, a thorough analysis of the complete texts was conducted, with only documents meeting the quality criteria outlined in "3.4. Definition of the Study Quality Criteria" considered for the final phase.

Finally, in step seven, pertinent information for addressing the research question and its five subquestions was extracted, as outlined in "3.5. Data Extraction."

3.3. Interviews

According to Mathers et al. (2000), interviewing is crucial for researchers to gather data through verbal exchanges with subjects. It finds widespread use in survey studies and exploratory/descriptive research designs. Interviewing techniques span a broad spectrum - from an entirely unstructured approach where the subject freely discusses the topic of their choice to rigidly structured interviews constraining responses strictly to the questions asked. In this research, we did semi-structured interviews by using open-ended questions that ensured an opportunity for the interviewee to discuss the topic at hand in more detail. The interview script aimed to answer our Research Question and Sub-questions while also maintaining a relevant contribution to our research.

3.3.1. Interviewee Characterisation and Identifications

With these interviews, we aimed to maximise diversity to get the most significant number of perspectives about AI in the different sectors. According to Mathers et al. (2000, the number of people interviewed is relatively unimportant; what truly matters is that each interviewee contributes valuable insights to the researcher's understanding of the setting. The goal is to uncover the broadest spectrum of meanings participants in the setting hold. To achieve this, our interviewee worked with AI in different sectors, as shown in Table 3.

Table 4: Interviewee Characterisation and Identifications

Interviewee	Rank / Function	Workplace	Area of Expertise	Level of Education	Nationality
Interviewee 1 (I1)	Section Head	GMV	Artificial Intelligence	MSc	Portuguese
Interviewee 2 (I2)	Associate Professor	Hellenic Army Academy	Information Technology with Military Applications	PhD	Greek
Interviewee 3 (I3)	Associate Professor	Hellenic Army Academy	Information Technology with Military Applications	PhD	Greek

3.3.2. Instruments Used

- Interview Guide

According to Mathers et al. (2000), an interview guide is a great tool to use that aids the interviewer to ensure they cover essential areas as interviewing can be stressful and will readily assist any interviewer in recalling any critical areas that the interviewee hasn't yet covered. This work's interviews were conducted personally or telematically, if the interviewee couldn't do it face to face, and followed the Interview Guide[1].

[1] Appendix A – Interview Guide

3.3.3. Formal and Ethical Procedures

The data collection process for the interviews happened between 31MAY24 and 04JUN24. They were conducted mainly on Microsoft Teams platforms. We followed every interview's ethics and privacy rules and kept the interviewee's anonymity. Before each interview, we followed a specific protocol that enabled us to get an Informed Consent form explaining everything about the current research to the interviewee, mentioning the research goals and questions and asking their consent to record every interview. This ensured that the interviewee was fully aware of their relevance and importance in this research and their data security.

3.3.4. Data Processing

According to Griffee (2005), interview data extend beyond the literal words spoken by respondents, encompassing evaluator assumptions, biases, and questions as an interview is a co-creation between the evaluator and the respondent and the author has the task of analysis, which is to concretise the meaning of the interview, a process known as interpretation. The words spoken during an interview serve as raw data, similar to how numbers function as raw data in a test. However, raw data alone do not reveal their meaning; they must be interpreted. Hitchcock and Hughes (2002) outline two primary strategies for analysing interview data. The first strategy involves becoming deeply familiar with the data, and the second involves creating meaning through analytical categories. In this first strategy, the author immerses themselves in the data by rereading everything over and over and coming to a conclusion about Theme A, Theme B and Theme C. By reading everything over and over again and by joining every interviewee response, we come to the realisation that the respondents are talking about a theme X. This method ensures that every information we have its actually "grounded" in the data, meaning that they emerge organically from the data and reflect it. In the second strategy, the author creates categories before the interview, helping them "group" the same responses and answer some relevant factors. In this research, we used the first method, which consisted of analysing the interviews and their responses and then connecting every interviewee's answer to get the best result and conclusion.

CHAPTER 4 – RESULTS

4.1. SLR Results

The methodology's first step, conducted in early January 2023, followed the documented procedure outlined in Table 2, which summarises the inputs and outputs for each step.

Table 5: Systematic Literature Review methodology applied to this research.

Step 1	Initial search of the databases and applications of the Inclusion Criteria (IC1) and Exclusion Criteria (EC1, EC2).	**Input: N/A** **Output: 317**
Step 2	Documents were filtered to include only those from Q1-rated journals in the SCIMAGO database.	**Input: 317** **Output: 81**
Step 3	Journals publishing less than two articles in the research area under study were excluded.	**Input: 81** **Output: 47**
Step 4	Analysis of the Title and Keywords to discard records considered off-topic as defined in the EC4.	**Input: 47** **Output: 12**
Step 5	Records matching EC6 are discarded.	**Input: 12** **Output: 10**
Step 6	Full-text analysis and quality criteria validation.	**Input: 10** **Output: 6**
Step 7	Data Extraction on the relevant records.	**Input: 6** **Output: N/A**

The application of EC1, EC2 and the initial search on the SCOPUS database resulted in 317 documents, which were selected on the pass criteria of the outlined query in the chapter "3.2. Databases for Literature Searching & Research Strategy", leading to step two in the process of review. As a part of this step, refinement is made using EC3 to select Q1 papers that rank among the ones tracked by the SCIMAGO database, obtaining 81 documents. During stage three, the journals that are not prominent in the selected field of research and the journals that have published only two or fewer articles in the same area of research have been neglected. This resulted in narrowing the pool of eligible documents down to 47. In another part of the work, the author read the titles, keywords and abstracts of 47 remaining articles. Eventually, the author classified 12 of these documents as relevant or maybe relevant, matching the research. Through step 5, EC6 was applied, and those academic works whose full text was unavailable to the author were removed, resulting in 11 documents. Moving to the last step, all documents are subjected to analysis and the quality criteria outlined in "3.4.1. Definition of the Study Quality Criteria". Those who received a score of 5 and above were eligible for step seven, resulting in 6 records. In Table 6, we provide the list of studies cut in our selection criteria and highlight them in order, starting from the oldest publication year.

Table 6: List of studies analysed on step 6 ordered by publishing year ascending

Authors	Document Title	Publication Year
Rebecca Storey Hooper, Thomas P. Galvin, Robert A. Kilmer and Jay Liebowitz	Use of an expert system in a personnel selection process	1998
Shu-hsien Liao	Case-based decision support system: Architecture for simulating military command and control	2000
James Moffat and John Medhurst	Modelling of human decision-making in simulation models of conflict using experimental gaming	2009
Chen Li, Weisi Guo, Schyler Chengyao Sun, Saba Al-Rubaye and Antonios Tsourdos	Trustworthy Deep Learning in 6G-Enabled Mass Autonomy: From Concept to Quality-of-Trust Key Performance Indicators	2020
Zhixiao Sun, Haiyin Piao, Zhen Yang, Yiyang Zhao, Guang Zhan, Deyun Zhou, Guanglei Meng, Hechang Chen, Xing Chen and Bohao Qu	Multi-agent hierarchical policy gradient for Air Combat Tactics emergence via self-play	2021
Desta Haileselassie Hagos and Danda B. Rawat	Recent Advances in Artificial Intelligence and Tactical Autonomy:	2022

	Current Status, Challenges, and Perspectives	

In the sixth step, six documents were analysed, and then the author extracted significant information using constituting items from the form template in Table 2. The utilisation of the integrated studies charts contributed to the fast identification of similar studies. It gave a strong base for composite responses to the main research question RQ1 and its sub-questions SQ1 to SQ3.

4.2. Analysis of the Interviews

Question 1 – "What are the most significant advancements or developments in AI technology that have impacted military decision-making?"

(I1) mentioned, *"Data fusion and mass data analysis level"*. In other words, "*things like analysing sensor data and merging this information so we can have global situation awareness with all this information."*

(I2) said, *"High data availability due to the increased availability of sensor networks and portable sensors, the expansion of C4ISR-OTM*[2] *system usage, and cloud and edge storage infrastructure."*

(I3) answered, *"Cyber security and Information warfare, C5ISR systems, IoT and the development of mobile devices, Big Data storage and analysis, Cloud technologies, powerful computing systems and artificial intelligence regarding neural networks, machine learning and deep learning."* He also mentioned, *"Artificial Intelligence based on Machine Learning & Deep Learning for big data analysis applications and real-time pattern recognition makes a decisive contribution to decision-making, crisis management and early warning systems."*.

Question 2 – Could you provide examples of specific AI applications currently used in military decision-making?

When questioned about the applications of AI in military decision-making (I1) said that they were able to create a system of pipelines, defining this system as basically,*" us being able to associate a source of information (...). That source of information is RAW data, raw data, without processing, for example, a video from a drone"* and most of the times it is not only a drone, but a handful of them, and that originates a *"series of screens giving us*

[2] Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance On-The-Move, definition by O'Brien et al. (2006).

data that is becoming difficult to process” and then *“instead of having all the screens present, in these pipelines, we allow different artificial intelligence applications to be coupled”* enabling us to *“analyse the video and do pattern detection or specific object detection. (...)* while *“At the other end of the pipeline, what comes out is the RAW video”* and some useful*” objects that can be put into a GIS, into Situation Awareness, where all the information is merged and much easier to interpret and, from there, make decisions about what you're seeing.”*

(I2) mentioned a few valuable applications of AI in military decision-making, such as *“Tactical decision making, logistics decision making, robotics and smart devices, cyber security, surveillance of military installations, border surveillance, soldier health monitoring, risk models, crisis management, robotics and equipment control, natural language processing, target tracking”* and *“routing in difficult terrains.”*.

(I3) answered that Artificial Intelligence technologies based on ML and DL create a *“key advantage in finding solutions to highly factorial problems facing military decision-making”* and *“with the modern technologies of Artificial Intelligence in applications of Cybersecurity and data analysis, the information superiority that is necessary for modern doctrines of defence and security is ensured”*.

Question 3 – How does AI contribute to making faster and smarter decisions in military operations?

When asked whether we could use AI to leverage smarter and better decisions, (I1) said we have an enormous amount of information coming from drones, sensors, etc., and *“All this information is useful for making better decisions, but it's becoming increasingly complicated to assimilate all the information needed to make that decision”.* What AI enables us to do is *“with machine learning and reinforcement learning techniques, gives us an abstraction of the level of complexity that we have due to the number of sources of information, the amount of information, and even the complexity of interpreting that information.”* making it more manageable for us to process all that information at once. Finally, we have to take into account and try to *“understand what the algorithms are doing so that they don't make blind decisions.”*

(I2) mentioned the *“Creation of data digests offline, with trained models for on-demand use; Real-time tracking of the evolution of the data and hence real-time situational awareness”* and a *“wide range of applications, from strategic and tactical decision support to low-level equipment control.”*

(I3) mentions that military operations have multi-factorial problems and require a long computational time to find the optimal solution. He also mentions that, since the data is so massive, traditional ways of analysing the information won't solve these optimised real-life problems. A way to solve this, according to the Interviewee, is through decision systems linked to C5ISR systems that, through interoperability and cross-industry, receive critical data in real-time and then *"Artificial Intelligence based on neural networks, machine learning and deep learning processes the knowledge it has received and renders in near real-time the optimal solution to the problem as the existing knowledge has been used to train the model"*.

Question 4 – Are there specific areas within military decision-making where AI has shown particular promise or effectiveness?

When interrogated about what areas of decision-making AI had shown promise (I1) highlighted the *"automation of small tasks"*. He then gave an example where they had an intelligence system used to prepare for a mission. In that case, they had a three-person team to analyse all the intelligence gathered for the mission. What AI enabled them to do was automatically check content with "Natural Language Process techniques" They also implemented things like "*GNI and LLMs with Large Language Modules to make the removed information even richer and easier to search."* concluding that "*we've gone from having three people allocated for a certain amount of time, doing a job that would then be lost, to something that's done automatically and where searching for information is much easier and much faster"*.

(I2) said, *"All these applications are highly promising and worth pursuing. So far, I have not seen any indication that some areas should be abandoned due to limited effectiveness."*

(I3) answered, *"Today, there are many cutting-edge sectors and applications where Artificial Intelligence provides effective solutions, such as self-guided drones, real-time cyber attack detection, and crisis management optimisation."*

Question 5 – What are some significant challenges and obstacles in integrating AI into military decision-making frameworks?

When delving into the challenges and obstacles in integrating AI, (I1) said, *"It always has to be the human user who makes the final decision, and it has to be informed"* stressing that the human operators should at least understand how and why they are getting those results *"and we know that even if it's a decision made on RAW data, an error can be associated with interpreting that data."* emphasising that *"If we let an artificial intelligence* *system on top of that information and don't understand its internal mechanism, this error can be propagated and amplified.”* (I1) also delves into the ethical problem of integrating AI, highlighting that one of the problems is its utilisation as “*The use of these algorithms can be misleading. And we've already started to see some cases, especially of algorithms that use indices and things like that, in which they're trained to understand how to interpret this data.”*. He also mentions that *“Malicious forces contaminate this data, so the algorithm isn't trained properly”* leading into ethical problems. He then concludes saying that the real main issue is *“knowing the limit to which we can use these types of algorithms”*.

(I2) stressed some challenges in integrating AI into the military, for example, *“ethical considerations concerning letting machines make decisions; limitations of the processing power available to mobile units”* and *“concerns about information security while using wireless equipment in the field.”*

(I3) answered, *“The significant challenge is to enable science to integrate artificial intelligence into smart mobile devices with limited computing resources connected to military operations with IoT networks so that the user can find the optimal solution”*, mentioning that *“smart mobile phones do not have adequate computing resources and for this, they are looking for solutions using cloud technologies”*.

Question 6 – How do you address ethical concerns related to the use of AI in military operations and decision-making?

When probed about the ethical part of AI and who is to be accounted for and responsible for AI actions, (I1) said, *“The decision-maker is always to blame”*, mentioning also that this has been happening *“since autonomous cars, automatic pilots, etc.”* He also noted that if we let the machine decide for itself, we will have this problem since we can't make a machine accountable or responsible. He then says, *“In the military case, it's about getting to the root of this problem”* since we always assume that *“the partner makes decisions on machine-generated results when we know exactly what mechanism the machine used to arrive at the results.”* Finally, he stresses that ethical problems are a hot topic for discussion, and there’s no standard opinion on this.

(I2) said, *“The most acceptable approach is to use AI as decision-support tools at various levels”* and that *“in decisions that raise ethical concerns,”* we should *“involve human operators in the final stage of the decision-making.”*

(I3) answered, "*Today's ethical concerns are very large related to artificial intelligence as there is very limited research on these ethical issues”*. He then mentions military operations where *"defence and security are carried out. These issues are addressed for the public good, but at least legal issues that have recognised the protection of sensitive personal data and war crimes are always considered"*.

Question 7 – Based on your experience, what recommendations would you offer for optimising the use of AI in military decision-making processes?

At the end of the interview, (I1) recommended *"Training with reliable data. Then, when we get to the point where we have well-trained data or well-trained algorithms, we can create and carry out parallel missions, in other words, for example, exercises carried out in the army."* Then he suggested first, *"Having a parallel using only the traditional mode, only with humans.* Then, the AI algorithms will be introduced to decision-making. That way, *"we can have metrics and make comparisons",* comparing how it went only with humans and how it went with humans with help from AI algorithms. "*From that moment on, and with all the explainability, (...) we'll start to realise in which areas the impact is positive while having a very low negative impact."* This approach will bring us a lot of added value as it "*reduces the time it takes to analyse and merge data, which can easily be done by artificial intelligence much more quickly",* and if we manage to make AI bring error to a minimal "*we'll eventually start putting some of these algorithms into production to accompany us on real missions".*

When asked about future recommendations, (I2) recommended *"including mathematical analysis and mathematical safeguards in algorithms to ensure convergence"* and *"extensive analysis of the behaviour of the systems in the place of outliers or high variability of data"*.

(I3) answered, *"Decision-making processes in military operations have been based for many years on some of the methodologies of Artificial Intelligence, e.g. models with Neural networks, optimisation with genetic algorithms and real-time controls with fuzzy logic and neuro fuzzy technology."* He then adds up *"today the development of machine learning and deep learning gives more options based on big data and statistical methods. Developing and corresponding technologies combining the above and cloud technologies will optimise military decision-making processes".*

4.3. Discussion of Results

This chapter offers an opportunity to evaluate, synthesise, and critically interpret the review findings and explore their implications for the research question and sub-questions derived from the extracted data.

SQ1: What is the current state-of-the-art application of artificial intelligence in the military scope?

Regarding the current state-of-the-art AI in the military field, Liao (2000) mentions that efforts are being made to develop methods for data fusion, situation assessment, decision planning, and response monitoring in military command and control systems. He gives examples of blackboard architectures and expert systems since he does not believe they have been used to improve decision-making processes. To corroborate this information, we have Interviewee 1, who says that, as far as he has seen, the current application of AI in the military has been chiefly data fusion and massive data analysis. He gives an example of a system made up of pipelines in which the input was RAW data coming from, for example, a large number of drones, and what the artificial intelligence allowed them to do was to introduce the RAW data at the beginning of the pipeline and the other end, through the coupling of artificial intelligence, analyse and detect patterns and specific objects. Then, with this final product, they would put it into a GIS or Situation Awareness and merge the information, making it more interpretable and improving the quality of the decisions.

AI can also improve decision-making by applying artificial intelligence to develop conflict simulation models that incorporate human decision-making processes, as mentioned by Moffat and Medhurst (2009). They refer to the Rapid Planning process, which is based primarily on the psychological construct of naturalistic decision-making. In this case, artificial intelligence captures the effects of command decision-making in military simulations.

Storey Hooper et al. (1998) add that artificial intelligence, specifically expert systems, is used in the military for various purposes, namely command decision-making, instruction, and database management. His document mentions a BOARDEX[3] programme that aims to help manage human resources.

Li et al. (2020) discussed using artificial intelligence in subnets. They mentioned its use in critical mass multimodal autonomy in terms of security in localised subnet

[3] A basic rule-based expert system, Board Expert as defined by Storey Hooper et al. (1998).

configurations, incorporating precise and robust AI algorithms in the base stations, which allows for autonomous operations.

Hagos and Rawat (2022) stated that using AI involves advanced ML systems to achieve autonomy in civilian and military applications. These systems aim to exploit vulnerabilities in autonomous systems critical to real-time security with minimal human control. Tactical autonomy provides solutions for military and defence applications with limited human involvement, leveraging AI and ML technologies to develop reliable, robust and secure autonomous systems.

In the aerial part, Sun et al. (2021) say that artificial intelligence consists mainly of developing advanced combat aircraft that use Artificial Intelligence to improve their capabilities. The development of unmanned aircraft with the help of AI demonstrates greater agility and durability compared to aircraft piloted by humans. Integrating AI in air combat systems can streamline and capitalise on decision-making processes, introducing new levels of lethality in air combat scenarios.

Interviewee 2 added that artificial intelligence is currently enabling high data availability resulting from the availability of portable sensor networks, the expansion of the C4ISR-OTM system and the infrastructure for storage in the cloud and the periphery, noting that AI has had its application mainly in tactical decision making, logistics decision making, robotics and intelligent devices, cybersecurity, surveillance of military facilities, border surveillance, health monitoring of soldiers, risk models, crisis management, robotics and equipment control, natural language processing, target location and routing in complex terrains.

Interviewee 3 stated that AI affects Military Science and military decision-making in various fields, such as Cyber Security and Information warfare, C5ISR systems, IoT and the development of mobile devices, Big Data storage and analysis, cloud technologies and powerful computing systems.

SQ2: How can we use artificial intelligence to support making better decisions?

Regarding using AI to improve decision-making, Liao (2000) mentions that AI can effectively help if we incorporate knowledge-based decision support systems, such as CBDSS. These systems use case-based reasoning to provide commanders with historical cases, i.e., past cases that provide strategic and tactical planning knowledge, thus improving decision-making in dynamic environments.

Moffat and Medhurst (2009) stress the importance of using probabilistic models that capture human behaviour in decision-making. They also emphasise using statistical models, such as probit models, to represent and simulate decision-making in dynamic and uncertain environments, thus helping to understand how the individuals making the decision respond to variable circumstances and stress.

Hagos and Rawat (2022) add that artificial intelligence aids decision-making by rapidly evaluating data, providing a streamlined operational planning process and strategic support, which speeds up decision-making. This is in line with what Interviewee 1 says, as he mentions the large amount of information that exists, which can come from, for example, drones and sensors. This information is essential for decision-making; however, it is becoming increasingly difficult to assimilate all the information present to make that same decision, and this is where AI comes in and makes it possible, through automatic learning and reinforcement learning techniques, to simplify this information processing, making it easier for us to make decisions. Last but not least, Interviewee 1 mentions that even though AI has many positive sides, we can't discount the understanding of what algorithms are doing, ensuring we're not making blind decisions.

This is where the document of Li et al. (2020) comes in. He says that AI can help improve decisions through explainable AI since it can generate qualitative and quantitative modalities of trust, allowing human actors to understand the underlying reasoning of AI in various applications. In this way, and by providing how they "think" through explainable visual, textual, and symbolic results, XAI can improve the decision-making process as it gives a transparent rationale for AI steels.

Storey Hooper et al. (1998) say that AI can help decision-making through expert systems. It states that artificial intelligence improves decision-making by assisting critical decision-making processes. Its expert system, BOARDEX, designed mainly for human resource management, aims to help people make decisions by providing valuable recommendations based on predefined rules and their accumulated knowledge.

Sun et al. (2021) mention the development of algorithms and advanced decision-making strategies. This refers to the Multi-Agent Hierarchical Policy Gradient algorithm that allows the apprentice Autonoma adversary. AI can reduce ambiguity and help select optimal action sequences in complex military scenarios by adopting hierarchical decision networks to handle complex and hybrid steels.

Interviewee 2 mentions that AI helps decision-making by creating data digests with models trained for on-demand use. It also has a real-time tracking capability of data evolution, consequently, real-time situational awareness, and a wide range of applications, from strategic and tactical support to decision-making to control of low-level equipment.

Interviewee 3 added that using C5ISR systems that, through interoperability and cross-industry, receive critical data in real time, we can analyse a massive amount of that, and through various techniques like ML, NN and DL, we can speed the decision-making process and render near real-time the optimal solution to a problem.

SQ3: Which artificial intelligence applications serve us the most in the military?

In the military context, Liao (2000) says that military applications that focus on modelling human decision-making in conflict simulation models are precious. Combined with experimental games and statistical approaches, conflict simulation models enable researchers to understand and gain insight into how commanders make complex and rapidly changing decisions. This knowledge and conclusions can be used to develop decision-support systems and strategies that improve military operations' decision-making processes.

Storey Hooper et al. (1998) also agree, saying that in the military context, the AI applications with the most significant impact are specialised systems designed for military intelligence, command decision-making, instruction, database management and human resource management. The design of these systems aims to simplify processes, improve decision-making, and improve military operations.

Li et al. (2020) point out that, in the military context, artificial intelligence is most important in safety-critical tasks such as autonomous driving, remote surgery and production. He also mentions that AI algorithms with high-dimensional capabilities can improve performance in complex scenarios, such as the equalisation of non-linear channels in wireless communication and the dynamic management of radio resources in unmanned aerial vehicles' navigation, relay and communication.

Hagos and Rawat (2022) add that artificial intelligence has a more significant impact on the military world when associated with it. We include systems that can perform tasks independently, make intelligent decisions without explicit human intervention and manage operations autonomously. It also mentions that this type of system, powered by ML and DL, has the potential to revolutionise military operations and improve efficiency, effectiveness and decision-making processes in various defence applications.

Sun et al. (2021) point out that artificial intelligence applications that focus on improving decision-making, optimising strategies and improving combat capabilities are relevant in the military. He points out that AI allows the development of advanced combat systems, unmanned autonomous aircraft and decision-making algorithms that can devastate the battlefield. The use of AI in air combat tactics, defence, offensive and the emergence of new operational strategies, as demonstrated by the MAHPG[4] algorithm, shows AI's potential to improve military capabilities and overcome traditional methods in air combat scenarios.

Interviewee 1, when asked about this topic, said that the most promising area and area in which AI best served the military world was in the automation of small tasks, that is, repeated tasks over and over again, giving an example of an information system used to prepare a mission in which the system was able to automatically verify the content with techniques of natural language process, thus passing from an effective of three people to analyse the content, for something automatic, faster and easier.

Interviewee 3 added that AI's promising application in the military spectrum is solving problems, i.e., rendering a solution near real-time through decision systems linked to CS5ISR. He also mentioned that AI has promising applications in self-guided drones, real-time cyber-attack detection, and crisis management optimisation.

RQ1: What are the possibilities and applications of artificial intelligence in supporting military decision-making?

As showcased in SQ1, SQ2 and SQ3, Artificial Intelligence in the military spectrum has many applications, including data fusion, situational assessment and response monitoring in military command and control systems; the development of conflict simulation models incorporating human decision-making processes, such as the rapid planning process based on naturalistic decision-making; the use of case-based reasoning and knowledge-based decision support systems to provide commanders with historical cases and strategic planning knowledge of past scenarios; the application of probabilistic models, statistical and technical models of AI to represent and simulate human decision-making in uncertain and dynamic environments showing how individuals respond to various circumstances and stress; quickly assess data and provide simplified operational planning, accelerating the decision-making process; Use explainable AI to generate qualitative and quantitative modalities of confidence, allowing human authors to understand the reasoning underlying AI systems, thus improving transparency; developing specialized systems for critical decision-making processes, providing valuable recommendations based on predefined rules and accumulated knowledge; implementing advanced decision-making strategies and algorithms, such as MAHPG, to deal with complex military scenarios, reduce ambiguity and select the best action sequences;

[4] Multi-Agent Hierarchical Policy Gradient defined by (Sun et al., 2021).

create data digests with models trained for on-demand use, allowing real-time monitoring of data evolution and better knowledge of the situation for better decision making and integrate AI in C5ISR systems for real-time data analysis, using techniques such as automated Learning, neural networks, and deep learning are used to accelerate decision-making and provide optimal solutions to problems in near real time.

AI offers several possibilities to support military decision-making, including data analysis, simulation modelling, knowledge-based systems, advanced algorithms, and command and control systems integration. It aims to improve situation knowledge, strategy formulation, and decision-making efficiency in dynamic and complex military operations.

CONCLUSION AND RECOMMENDATIONS

In conclusion, evaluating military decision-making driven by AI revealed a scenario rich in potential and practical applications. This research aimed to analyse the possibilities and the application of artificial intelligence in supporting military decision-making, and the results highlighted the significant impact that AI has in improving military operations. The analysis performed in this study demonstrated that AI plays a crucial role in enabling a faster and smarter decision-making process in the military context. By leveraging advanced algorithms and data analysis capabilities, AI performs prominently in command and control systems optimisation, increasing situational awareness and ultimately improving operational efficiencies.

The results stress that the integration of AI in military decision-making processes showed current capabilities and highlighted the vast potential for future advances in this field, from data merging and situational assessment to detecting real-time cyber-attacks and crisis management; military applications continue to evolve and expand. This research provided valuable insights into how AI can revolutionise military decision-making by bridging the gap between theoretical frameworks and practical implementations. Evidence from systematic literature reviews and expert interviews reinforced the importance of transparency, ethical considerations, and the need for explainable AI to ensure the responsible deployment of AI technologies in military operations.

The SLR, combined with interviews, gave us valuable information about the capabilities and applications of AI in the military context. First, this SLR highlighted the increasing focus on integrating ethical frameworks in AI systems for high-risk decision-making in military operations, demonstrating a growing awareness of the ethical implications of AI in military contexts. This SLR also highlighted advances in automated learning models, as it indicated a positive trend towards adopting more complex automated learning models in military applications, suggesting potential improvements in decision-making in the military operations environment and taking advantage of the capabilities of advanced AI technologies.

On the other hand, this SLR highlighted a lack of research into ethical concerns related to artificial intelligence in military operations, presented challenges in solving ethical problems and ensuring a responsible use of AI in defence contexts. This SLR still addresses the growing challenges regarding transparency and accountability in military AI systems due to the need for an explanatory AI to interpret the decisions made by this, especially in legally regulated areas. Addressing these problems can take a lot of effort and resources.

Regarding the method of the interviews, the result shows the great potential of AI to improve decision-making processes in military operations. AI technologies such as data fusion and conflict simulation models have been identified as tools that can improve decision-making efficiency. The interviews also identify promising applications of AI in the military spectrum, such as the detection of cyber-attacks, the optimisation of crisis management and self-guided drones. These applications demonstrate AI's varied roles in improving military operations and decision-making processes.

In addition to these positive aspects, with the interviews, we were able to identify some negative aspects in the application of artificial intelligence, for example, corroborating the SLR, and limited research on ethical issues since one of the interviewees stressed the need for greater exposure of the implications and ethical considerations in the use of AI in military contexts. The interviewees also highlighted the challenges in decision-making processes that raise ethical concerns and stressed the importance of involving human operators in the final phase of decision-making in order to balance support for AI-based decision-making with human oversight.

For future research, I recommend delving deeper into the ethical frameworks, including exploring the implications of AI biases, transparency and accountability in decision-making, and exploring further XAI's significance in bridging the gap between opaque AI models and human interpretability. I also recommend exploring advanced AI algorithms as AI technologies continue to evolve, and future research could focus more on the integration of advanced AI algorithms such as deep learning, neural networks and reinforcement learning in military decision-making processes.

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APPENDIX

APPENDIX A – INTERVIEW GUIDE

ACADEMIA MILITAR

GUIÃO DE ENTREVISTA

AI-powered military decision-making: an assessment of the current capabilities and applications

Autor: Aspirante de Infantaria Luís Filipe dos Santos Ribeiro

Orientador: Professor Doutor José Borges

Coorientador: Major de Administração Militar Hélio Fernandes

Mestrado Integrado em Ciências Militares na Especialidade de Infantaria

Relatório Científico Final do Trabalho de Investigação Aplicada

Lisboa, maio de 2024

1. Information for the interviewee

a. Request to analyse the answers provided during the interview for use in the author's master thesis research.

b. Introduction by the interviewer to the interviewee, including an explanation of the objectives and criteria of the interview.

My name is Luis Filipe dos Santos Ribeiro, an Aspirant Student at the Military Academy, currently carrying out my final dissertation for the Integrated Master's Degree in Infantry on the subject of 'AI-powered military decision-making: an assessment of the current capabilities and applications'. I appreciate your willingness to participate in this interview, as your contribution will be fundamental to the success of this research. The objectives of this research include:

OE1: Perform a systematic review of artificial intelligence research evolution;

OE2: Understand how AI can leverage faster and smarter decisions;

OE3: Identify the role of artificial intelligence in military decision-making.

The interviewee has the right not to answer any question in the questionnaire.

2. Informed consent

The interviewee receives the declaration of consent and signs it if he chooses to take part in the interview.

3. Identification

Name:

Function/Rank:

Unit/School:

Date:

4. Questions

Question 1: What are the most significant advancements or developments in AI technology that have impacted military decision-making?

Question 2: Could you provide examples of specific AI applications currently used in military decision-making?

Question 3: How does AI contribute to making faster and smarter decisions in military operations?

Question 4: Are there specific areas within military decision-making where AI has shown particular promise or effectiveness?

Question 5: What are some significant challenges and obstacles in integrating AI into military decision-making frameworks?

Question 6: How do you address ethical concerns related to the use of AI in military operations and decision-making?

Question 7: Based on your experience, what recommendations would you offer for optimising the use of AI in military decision-making processes?

APPENDIX B – INFORMED CONSENT

INFORMED CONSENT

I hereby declare that I am aware that Aspirant Student Luis Filipe dos Santos Ribeiro is carrying out his final dissertation for the Integrated Master's Degree in Infantry on the subject of **"AI-powered military decision-making: an assessment of the current capabilities and applications"** under the supervision of Professor José Borges and the co-supervision of Major de Administração Militar Hélio Fernandes.

I understand that I will be interviewed by Aspirant Student Luis Filipe dos Santos Ribeiro and that the information provided during the interview will be analysed by him. I recognise that my participation in this interview is essential to the success of the research, although I will not receive any compensation for this. I authorise the audio recording of the interview. At the end of the study, I can access this Master's Thesis through the Military Academy Library Repository or request it directly from the author. I declare that I agree to take part in the research by answering the interview.

Interviewee Signature: ____

Interviewer's Signature: ____

Thank you very much for your readiness and participation in this research