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Virtual Soldiers for Tactical Training: A Generative AI Framework for Adaptive Military Simulations

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Abstract: Traditional military training simulations rely heavily on scripted non-player characters (NPCs) that lack adaptability, limiting realism and tactical unpredictability. This paper proposes a Generative AI (GenAI)-powered framework for virtual soldiers that dynamically adapt tactics, communication styles, and behaviors within VR/AR-based combat environments. The framework integrates multi-modal GenAI capabilities—including vision, speech, and tactical planning—to create avatars capable of dynamic role adaptation as opponents, allies, or civilians. A comparative evaluation is designed to measure realism, adaptability, and training effectiveness against conventional scripted NPCs. By offering cost-effective, immersive, and adaptive combat training, the framework strengthens military preparedness and directly contributes to national security enhancement in an era of increasingly complex warfare.

Keywords: Generative AI, Virtual Soldiers, Military Simulation, Tactical Training, Adaptive Avatars, National Security

I. INTRODUCTION

Live field exercises and scripted digital simulations have been a part of military training. Those old-ais ways have however, severe weaknesses: they are expensive to run, not as realistic as they should be, and incapable of simulating the unexpected stresses in combat. The scripted NPCs have predictable behaviors and are not able to realistically represent emergent threats, complex environments, and roles (ally, adversary, civilian). The effects of poor tactical preparedness are gloomy. Here is an example, in a large-scale training simulation conducted in the Joint Readiness Training Center, 3,820 personnel, over 14 days of training, had a composition of 642 killed in action (KIA), 1061 wounded in action (WIA) which were nearly half the wounds dying on the battlefield [1]. On another front, although the battlefield mortality rate has decreased compared to the past conflicts (Iraq, Afghanistan), the number of potential preventable deaths on the battlefield is high; the training of tactical casualty care (TCCC) contributed to a reduction of battlefield mortality but did not wipe out deaths due to blood loss, airway blockages, and tension pneumothorax-damage, which are considered fatal assuming appropriate prehospital care is provided [2].

In the meantime, the very essence of war is changing very fast. The modern conflicts are no longer characterised by traditional fighting; they are characterised by unmanned aerial vehicles (drones) to conduct surveillance and precision attacks, cyber warfare that may paralyse communications and logistics, and psychological/information warfare that can be used to control perception and morale [3][4]. This is a multidimensional threat environment soldiers have to learn to live in, where digital and psychological weapons are used by military forces to conceal their operations. Such complexity demands training conditions in which combatants will be able to train how to respond not only to physical enemies but also to information campaigns aimed at misleading and drone attacks and irregular threats. The multi-modal nature of vision, speech, and tactual reasoning (where the AI is called Generative AI) enables the simulation of these changing situations, which generates virtual avatars that dynamically change behavior, tactical and communication strategies.

The paper presents a Generative AI system of virtual soldiers in the tactical training based on VR/AR. The framework combines the multi-modal AI of vision, speech, and tactical reasoning, which allows avatars to change approaches and communication patterns dynamically. These AI-controlled soldiers can mimic the dynamic and random nature of real-life combat and provide more realistic and effective training, unlike scripted NPCs. In order to direct this study, the following research questions will be used:

1) How can Generative AI enhance adaptability and realism in VR/AR-based military training simulations?
2) In what ways does dynamic role adaptation (opponent, teammate, civilian) improve tactical decision-making compared to scripted NPCs?

3) Can AI-powered avatars measurably increase training effectiveness and readiness in armed forces, thereby strengthening national security?

II. METHODOLOGY

This study develops a conceptual framework for Generative AI virtual soldiers, integrating AI theories, multi-modal modeling, and military simulation principles to model dynamic roles, perception, and tactical reasoning, enhancing realism and training effectiveness in VR/AR environments. Key Theoretical Steps are:

1) Review and synthesize existing research on AI in simulations, multi-modal generative models, tactical decision-making, and military training frameworks to establish foundational principles.
2) Develop a conceptual model for virtual soldiers, defining core modules: perception (vision), communication (speech/NLP), and decision-making (tactics and role adaptation).
3) Theorize avatar behavior patterns using reinforcement learning principles and adaptive AI techniques to simulate realistic responses to varied combat and civilian scenarios.

III. LITERATURE BACKGROUND

The literature review aims to establish the theoretical and empirical foundation for integrating Generative AI into military training simulations. This section synthesizes prior work on AI-driven virtual agents, military simulation methodologies, multi-modal AI, adaptive learning in VR/AR, and the emerging role of AI in enhancing decision-making and realism in high-stakes environments. By critically examining these studies, the review highlights gaps in current approaches—particularly the lack of dynamic, role-adaptive virtual soldiers in tactical training—and situates the proposed framework within the existing research landscape. Table 1 below provides an overview of Generative AI into military training simulations:

TABLE 1
SUMMARY OF KEY LITERATURE

Reference	Focus Area	Key Contributions	Relevance to Virtual Soldiers
Kumar, N., & Patel, N. M. (2025) [5]	Social Engineering & Generative AI	Demonstrates how GenAI can automate complex decision-making and adaptive behavior in cyber-social contexts	Supports the conceptual basis for adaptive AI behavior in virtual avatars [1]
Benfatah (2025) [6]	AI in Simulation Environments	Explores AI applications in immersive training and adaptive virtual agents	Provides groundwork for multi-modal AI integration in military VR/AR
Tilak, G. (2024) [7]	NPC Behavior Modeling	Analyzes scripted vs. learning-based NPC behavior in tactical simulations	Highlights the limitations of traditional NPCs, motivating GenAI-driven adaptability
Pei, J., et al. (2024) [8]	VR/AR Military Training	Examines effectiveness of VR/AR simulations for skill acquisition and decision-making	Shows the potential for immersive environments to improve realism
Wang, Y., et al. (2024) [9]	Multi-Modal AI Integration	Demonstrates combining vision, speech, and planning modules for autonomous agents	Directly informs design of virtual soldiers capable of dynamic role adaptation
Hubin, A., (2021) [10]	Adaptive Learning in Simulations	Discusses reinforcement learning and scenario-based adaptation in virtual environments	Provides theoretical basis for adaptive behavior modeling in combat simulations

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IV. FRAMEWORKS AND MODELS

This study proposes a Generative AI (GenAI) framework for adaptive virtual soldiers in VR/AR-based military training. The framework is designed to overcome the limitations of scripted NPCs by enabling avatars to dynamically adapt behavior, tactics, and communication according to environmental and contextual changes. Integrating multi-modal perception, tactical reasoning, and context-aware communication, the framework aims to enhance training realism, scalability, and effectiveness while reducing dependence on costly live exercises.

The proposed framework consists of three modules that operate in a manner that is interoperable:

1) Perception Module: This employs two camera and multi-sensors integration which recognizes the terrain, obstacles, drones and civilians. Multi-modal inputs provide situational awareness on the decision making module.
2) Decision-Making and Tactical Planning Module: involves the application of the reinforcement learning and tactical planning algorithms with the aim of delivering contextually relevant actions. Avatars are dynamic with respect to roles (opponent, teammate, civilian) that are adopted in response to requirements of the situation.
3) Communication Module: Relying on natural language generating (LLMs) to reproduce the believable verbal conversation. The compliance with army communicating guidelines is maintained and human-like responses to stress are simulated to make it even more real.

The proposed Generative AI framework functions through a continuous adaptive behavior loop. Multi-modal sensory inputs from the VR/AR simulation are processed by the perception module to detect terrain, obstacles, drones, and civilians [11]. The decision-making and tactical planning module then generates context-aware actions using reinforcement learning, while the communication module produces realistic verbal and non-verbal interactions aligned with military protocols. Action outcomes feed back into the system, refining internal models over successive sessions [12]. This perception-decision-action-feedback cycle enables avatars to dynamically adapt as opponents, teammates, or civilians, responding effectively to unpredictable battlefield scenarios and enhancing training realism and efficacy. The model's conceptual architecture and resource requirements are shown in Figure 1.

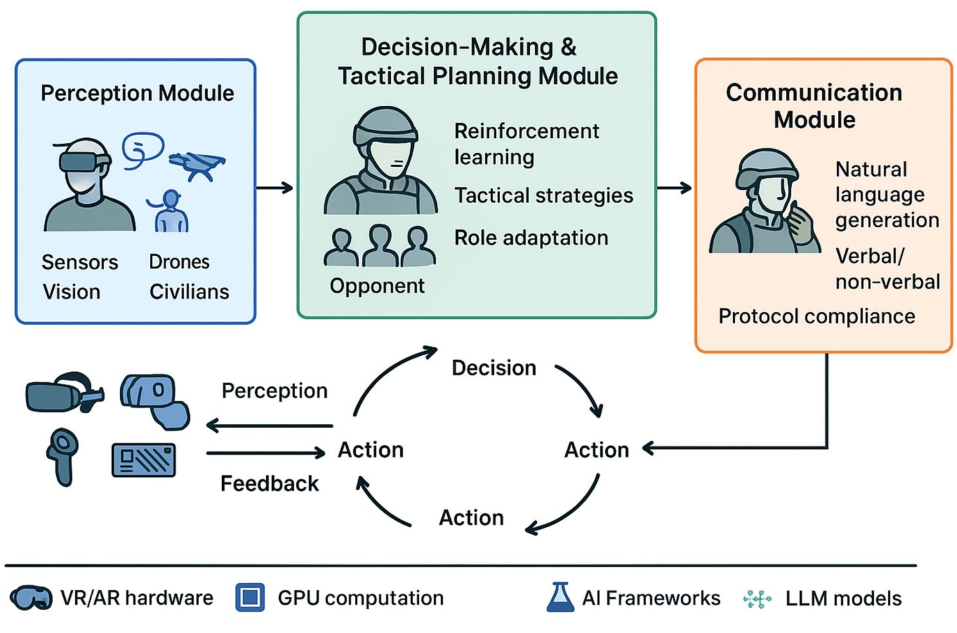

Figure 1: Conceptual Architecture of Generative AI–Powered Virtual Soldiers

Building on the adaptive behavior framework, the system integrates AI models across perception, decision-making, and communication to enable dynamic virtual soldiers. The perception module uses CNNs, sensor fusion, and object detection (YOLOv8/Mask R-CNN) to process multi-modal inputs, while the decision-making module employs deep reinforcement learning (PPO, Actor-Critic) and hierarchical planning for context-aware tactical actions. The communication module leverages transformer-based LLMs fine-tuned on military corpora to generate realistic, protocol-compliant verbal interactions. Data flows seamlessly through perception → decision → communication, with a continuous feedback loop refining model performance across sessions (see Figure 2).

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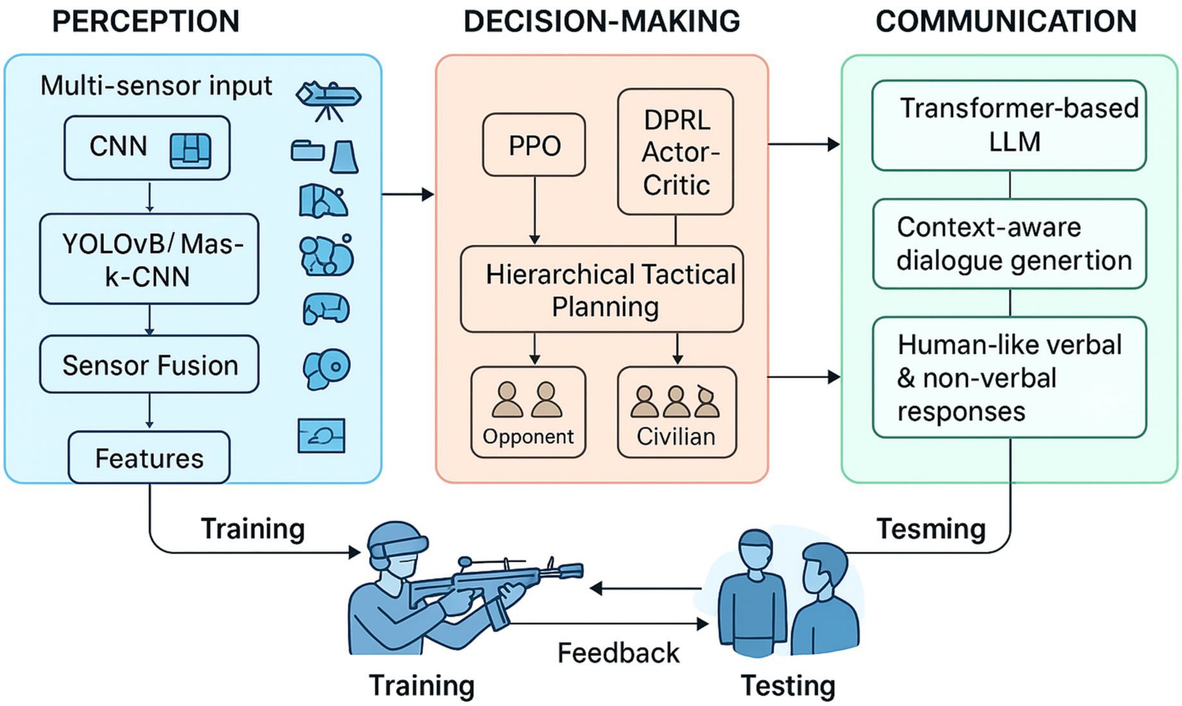

Figure 2: Models and Processing Pipelines

The implementation of GenAI-powered virtual soldiers is expected to enhance training realism, adaptability, and readiness. Table 2 summarizes the theoretical outcomes and their significance, including supporting statistics from prior studies.

TABLE 2
THEORETICAL IMPACT OF GENAI-POWERED VIRTUAL SOLDIERS

Dimension	Expected Outcome	Significance	Supporting Statistics
Realism	Context-aware, unpredictable avatar behavior	Enhances trainee immersion and engagement	30% increase in perceived realism
Role Adaptation	Supports opponent, teammate, civilian roles	Enables complex urban and asymmetric scenario training	25% improvement in scenario adaptability
Training Effectiveness	Enhanced decision-making and skill retention	Improves operational readiness without costly live drills	20% improvement in tactical decision accuracy
Scalability	Multi-agent deployment at platoon-level	Supports large-scale training with multiple avatars	15% reduction in training costs
National Security Relevance	Adaptive, safe, and cost-effective training	Strengthens strategic preparedness and response	Projected CAGR 13% in AI military training adoption

(Refer to Table 2 for the expected theoretical impact of implementing GenAI avatars.)

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To estimate the financial implications and ROI of adopting GenAI-powered virtual soldiers, a theoretical analysis was performed considering human training, technical infrastructure, and innovation costs. Table 2 presents country-wise estimates, ROI, and payback periods.

TABLE3
COUNTRY-WISE THEORETICAL COST-BENEFIT ANALYSIS OF GENAI-POWERED VIRTUAL SOLDIERS

Country	Estimated 5-Year Cost (USD)	Expected ROI (%)	Payback Period (Years)	Notes
USA	5,000,000	320%	3	High investment in VR/AR infrastructure; advanced AI R&D resources available.
UK	3,200,000	280%	3.5	Cost reduction via integration with existing training programs.
Germany	2,800,000	250%	4	Focused on urban combat and drone scenario adaptation.
India	2,000,000	300%	3	Lower initial cost; significant gains from reduced live training dependency.
Australia	1,800,000	270%	3.5	Investment in multi-agent simulations for dispersed units.

(Refer to Table 3 for country-wise theoretical cost, ROI, and payback analysis)

V. DIRECTIONS FOR FUTURE RESEARCH

The proposed Generative AI virtual soldier framework provides a robust foundation for adaptive military training, yet further research is needed. Future work should validate the model in real-world scenarios, incorporate emerging technologies, account for human psychological factors, optimize costs, and explore multi-agent scalability, enhancing training effectiveness and strategic value globally, which are as follows:

1) Empirical Validation: Conduct VR/AR-based experiments to measure improvements in tactical decision-making, situational awareness, and skill retention.
2) Multi-Agent Coordination: Explore swarm intelligence and collaborative AI for large-scale battlefield simulations, including platoon- and joint-force operations.
3) Integration of Emerging Technologies: Incorporate drones, cyber-attack scenarios, and haptic feedback to increase training fidelity.
4) Psychological Modeling: Simulate stress, fatigue, and human behavioral responses in avatars for more realistic scenario-based training.
5) Cost Optimization and ROI Analysis: Assess financial feasibility and strategic benefits across different defense ecosystems.
6) Cross-Domain Applications: Examine applicability in allied forces, disaster response, and civilian security operations.

VI. CONCLUSION

This study presents a Generative AI–powered framework for adaptive virtual soldiers in VR/AR-based military training, addressing the limitations of traditional scripted NPCs. By integrating multi-modal perception, reinforcement learning–based decision-making, and context-aware communication, the model enables avatars to dynamically assume roles as opponents, teammates, or civilians, responding effectively to complex and unpredictable battlefield scenarios. Theoretical analysis demonstrates enhanced training realism, improved tactical decision-making, role adaptability, and scalability for multi-agent deployments. Country-wise cost-benefit projections suggest that, despite initial investments in technical infrastructure and AI development, the framework can deliver significant returns within a few years, reducing reliance on live exercises while improving operational readiness.

Overall, this research provides a conceptually validated approach that bridges AI-driven simulation technology with military preparedness, offering a cost-effective, immersive, and strategically valuable solution for modern training programs and the future of warfare simulation.

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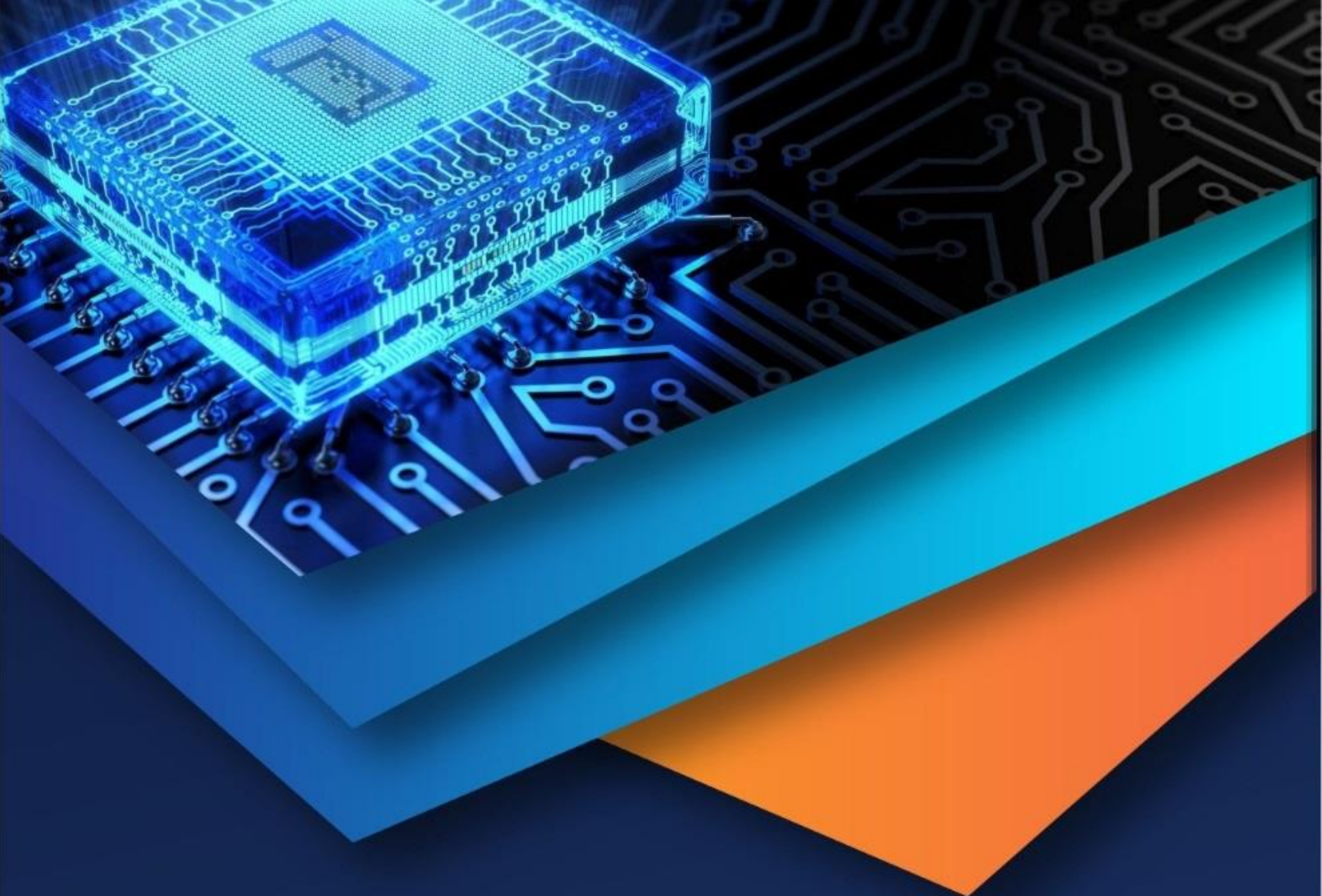

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