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VirtuAero: A CNN-LSTM and Random Forest- Driven Deep Learning Framework for Adaptive VR-Based Air Force Pilot Training

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Abstract.

Traditional simulation-based approaches have their limits, and field exercises are expensive and time-consuming, which creates major obstacles for air force pilot training. The complexity of real-world circumstances is difficult for current systems to simulate, and they also don't provide the kind of fast feedback that would be useful for improving one's skills. Our novel Virtual Reality (VR) training platform, VirtuAero, which incorporates cutting-edge technologies like AI and ML, is designed to remedy these issues.

We include features of pre-existing ML models that forecast pilot performance and categorize training challenges using deep learning methods into our solution. Utilizing adaptive features, VirtuAero customizes training situations to match the skills of each pilot, guaranteeing a learning experience that is uniquely suited to them. By incorporating Flight Maneuver Recognition (FMR), comprehensive evaluations of maneuver execution may be carried out using deep learning methods like CNN-LSTM and CNN, which greatly improve the accuracy of performance assessments. This all-encompassing method gives pilots access to lifelike training simulators that improve their situational awareness and decision-making while also providing the real-time feedback they need to hone their skills. The objective of VirtuAero is to improve operational preparedness by reshaping pilot training in the air force in a way that is more adaptable, efficient, and sensitive to the needs of current aerial operations.

Keywords: CNN-LSTM, 3D-Convolutional Neural Network, Flight Maneuver Recognition, Logistic Regression, Success rate prediction

1. INTRODUCTION

Training air force pilots effectively is critical for operational readiness and mission success in today's continuously changing military scenario. Conventional simulators and outdoor exercises, the backbone of traditional training techniques, may be a real pain. These methods overlook the intricacies of real-world situations, restrict training frequency, and may be prohibitively expensive. In addition, they usually don't have any kind of instant feedback system, which is crucial for this document and is highlighted in italics inside the sample for easy identification. Some parts, such multi-levelled equations, improve pilot ability and under-pressure decision-making.

In response to these limitations, VirtuAero presents a novel approach that makes use of VR, AI, and ML to solve the problem. To better prepare pilots for real-world operating situations, this state-of-the-art training platform incorporates lifelike flight simulators. Virtual aircraft training with VirtuAero eliminates the hazards and expenses of conventional training techniques by simulating real-world flight conditions in a safe and controlled environment.

Virtual reality (VR) systems not only include adaptive learning methods, but they also improve the training experience. Personalized teaching and real-time feedback are provided via situations that are dynamically adjusted depending on individual performance. The capacity to adjust means that every pilot can get training that's perfect for them, taking into account their own skills and weaknesses. Improving pilots' ability to make sound decisions is a by-product of analysing flight data with the use of machine learning algorithms, which also enhance training programs and allow for the simulation of various situations. The purpose of VirtuAero is to improve the way pilots are trained to handle the complicated air missions and defence operations of today by reimagining the way pilots fly planes. With its cutting-edge technology, this system is a game-changer for the air force's quest of operational excellence and improved capabilities.

2. VIRTUAERO COMPUTATIONAL FRAMEWORK AND REAL-TIME PROCESSING EFFICIENCY

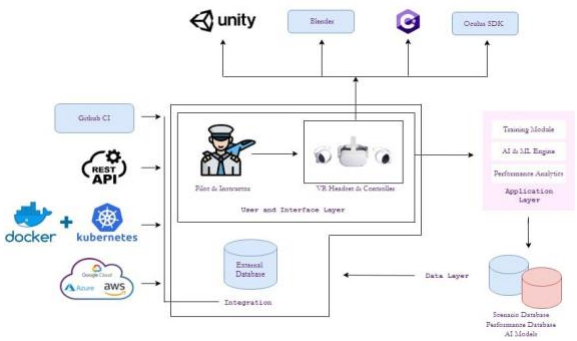

Figure 2.1. VIRTUAERO Architecture

Our plans call for VirtuAero to include a number of cutting-edge enhancements. By using the Multi-Modal Functional-Based Decision Support System (MFF_DSS), the system will be able to predict the success rates of individual pilots and identify the complexity of training. In this way, we can be confident that our instruction is both practical and sufficiently difficult. More than that, we'll include Flight Maneuver Recognition (FMR) methods using advanced deep learning models such as CNN-LSTM and RNN." These models will evaluate flying accuracy with great precision, enabling precise feedback and better execution of manoeuvres. Together, these state-of-the-art technologies will make training far more efficient, safer, and better prepared Air Force pilots for operation in the real world. We want to provide Air Force members with the self-assurance and flying abilities necessary to thrive in extreme conditions by raising the bar for pilot training with VirtuAero.

2.1. Block Diagram and Evaluation Layer

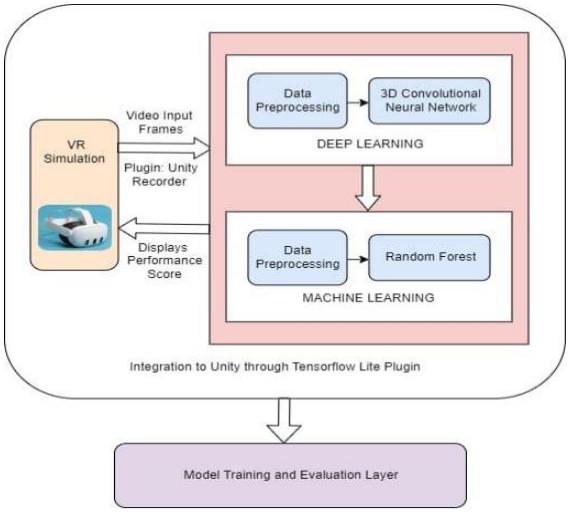

Figure 2.2. Block Diagram

The Model Training and Evaluation Layer is a crucial part of the VR simulator's development process, training and testing DL and ML models to ensure optimal performance. It handles data preparation, feature extraction, model training, hyperparameter tuning, and evaluation. Using historical pilot data, cross-validation, and grid search, the system identifies optimal model parameters, prevents overfitting, and improves generalization across flight conditions. Key metrics such as precision, recall, F1-score, and accuracy provide detailed performance insights. Structured databases store pilot performance measurements, 3D CNN-extracted video features, and Random Forest predictions for efficient querying, retrieval, and long-term storage, enabling continuous improvement of the AI-driven training system.

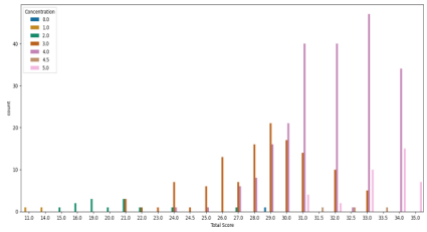

Figure 2.3 Analysis of Dataset

The VirtuAero system demonstrates high classification accuracy with CNN (~87%) and CNN-LSTM (~93%) models, capturing spatial and temporal dependencies for Flight Maneuver Recognition. Adaptive training scenarios adjust difficulty based on pilot skill, improving efficiency by 25-30%, while real-time feedback enhances situational awareness and decision-making. By integrating 3D CNNs, Random Forest algorithms, and Unity-based VR simulations, the system delivers personalized, immersive training that boosts learning outcomes, engagement, and operational readiness while reducing training costs.

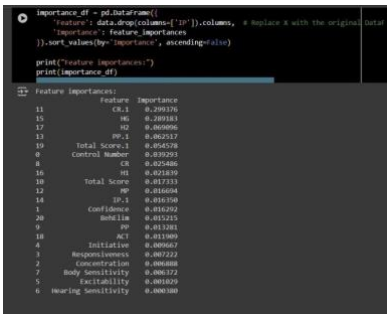

Figure 2.4 Hyper Parameter Tuning

Figure 2.5 VR Interface

Figure 2.6 Cockpit Setup

3. REFERENCES

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Biographies

 **Jegan Amarnath** is an Associate Professor in the Department of Computer Science and Engineering at Sri Sai Ram Engineering College, Chennai, with over 19 years of teaching experience. His expertise includes Data Structures, Software Engineering, Distributed Systems, Cyber Forensics, and academic leadership, and he is a Life Member of ISTE, IACSIT, and IAENG.

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